PHYSICO-CHEMICAL AND SENSORY ATTRIBUTES OF BREAD PRODUCED FROM WHEAT, CABBAGE AND CATERPILLAR INSECT FLOURS

Abstract:

This study assessed the quality of bread made with wheat flour mixed with cabbage and caterpillar (Cirina forda) flour blends. Bread samples were prepared using different ratios of wheat flour supplemented with cabbage flour (0%, 20%, 20%, 20%, 20%) and caterpillar insect flour (0%, 5%, 10%, 15%, 20%). The bread samples were analysed for proximate composition, vitamin composition, essential amino acid composition, antioxidant composition and sensory attributes. Cabbage flour and caterpillar insect flour addition significantly ($p < 0.05$) increased the fibre (4.93% to 22.27%), ash (3.10% to 6.65%), protein (11.73% to 23.38%), and fat (6.94% to 10.55%), while decreasing moisture content (23.23% to 15.50%) and carbohydrate content (68.90% to 34.15%). Cabbage and caterpillar insect flour supplementation also significantly ($p < 0.05$) decreased the loaf volume, loaf height and specific loaf volume from 1102.68 to 322.86 cm3, 10.16 to 2.94 cm, and 2.85 to 1.17 cm3 respectively, while the loaf weight increased from 218.66 to 235.92 g. There was a significant ($p < 0.05$) increase in water absorption capacity, oil absorption capacity, bulk density, gelatinization temperature from 128.28 to 194.33%, 144.50 to 191.70%, 0.67 to 2.26 g/ml and 58.86 to $79.60^{O}C$ respectively, while swelling capacity decreased from 19.47 to 11.74. Sensory evaluation showed that although there was significant ($p < 0.05$) improvement in nutritional composition, the acceptability of all bread samples decreased with increasing level of Moringa supplementation. This implies that despite the high nutrient content of Moringa oleifera powder, it is not a good substitute for wheat in bread production due to its physical characteristics and sensory attributes.

1.0 Introduction

Bread is typically produced by baking dough made from wheat flour, water, yeast, and salt as its primary ingredients (Okoye and Ezeugwu, 2019). Additional components that may be incorporated include flours from other grains, fat, malt flour, soy flour, emulsifiers, milk, sugar, fruits, and more. It is enjoyed by children and adults across various socio-economic backgrounds in Nigeria, resulting in a high daily demand (Inyang and Asuquo, 2016). It is a rich source of energy, protein, vitamins (particularly B vitamins), minerals, and dietary fiber, making it highly nutritious.

For more than 20 years, recent trends have emphasized healthy eating, promoting the use of indigenous ingredients like whole wheat, local cereals, and legumes in the baking industry. Although wheat is the primary flour used in bread production, composite flour technology has also incorporated other flour-like substances from grains, fruits, and leafy vegetables because of their nutritional benefits (Sengev *et al.*, 2021).

Wheat (*Triticum aestivum* L.) is the most extensively cultivated cereal and a crucial staple food globally (Tama's *et al*., 2009). It is a rich source of carbohydrates and also provides protein, fat, ash, fiber, and various vitamins and minerals, including sodium, potassium, calcium, magnesium, iron, phosphorus, copper, zinc, and manganese (Kumar *et al*., 2011). The demand for health-oriented products is on the rise due to their beneficial properties, including high fiber, natural antioxidants, low calories, and sugar-free ingredients. These products are sought after for their potentials to help manage and prevent health issues like certain cancers, cardiovascular diseases, hypertension, diabetes, gastrointestinal disorders, and weight gain (Adams and Engstrom, 2000).

According to Ayoade et al. (2020), composite flours are mixtures of different cereal, legume, and tuber flours, which are high in starch, protein, and other nutrients, and may or may not include wheat flour. The growing demand for baked goods and pastries is leading to an increase in the substitution or blending of wheat flour with local raw materials. In developing countries, composite flour has been utilized at various substitution levels, resulting in differing degrees of success. Composite flour, an innovative type of flour, has garnered significant interest in both research and food product development (Hasmadi *et al.*, 2014). This flour is a blend of starch-rich tuber flours like cassava, yam, and potato, along with protein-rich legumes such as soybeans, and cereals. It may or may not include wheat flour and is designed to meet particular functional and nutritional requirements.

Vegetables offer valuable natural antioxidants and fiber. White cabbage, in particular, is renowned for its abundance in antioxidants, polyphenols, fiber, minerals, and low-calorie properties, making it a staple in human diets. Overall, vegetables provide essential nutrients and are crucial for maintaining good health, according to Hülya et al. (2013).

Cabbage, scientifically known as *Brassica oleracea,* is a biennial plant with either green or purple leaves forming a round head. It is rich in essential vitamins like A, B, C, and E, as well as minerals including iron, manganese, folate, thiamine (B1), riboflavin (B2), calcium, magnesium, potassium, and zinc. Additionally, cabbage serves as a significant provider of dietary fiber, antioxidants, and several anti-carcinogenic substances (Adeniji *et al*., 2010). Insects are abundant worldwide, with numerous species celebrated for their unique traits. Entomophagy, the practice of consuming insects as food, is widespread across many cultures, with various communities embracing edible insects as a valuable food source. Throughout history, people in regions such as Europe, Asia, Australia, and Africa have incorporated different insect stages into their diets. The caterpillar of the pallid emperor moth (Cirina forda) belongs to the Lepidoptera order and Saturniidae family. The aim of this study is to produce bread with high protein and fibre content from wheat, cabbage and caterpillar insect flour to be able to manage and alleviate diseases. This research work is aimed at evaluating the physico-chemical and sensory qualities of composite bread with high density nutrients from wheat, cabbage and caterpillar insect flours.

2.0 Materials and Methods

2.1 **Materials**

Wheat flour, cabbage leaves and caterpillar insects, wheat flour and other ingredients for baking such as sugar, salt, yeast and margarine were purchased from Wurukum Market, Benue State.

2.2 Sample preparation

Fresh cabbage was washed and the outer layers removed. The rest was sliced into smaller pieces which was weighed and dried in an oven at 70°C for 18hrs. The dried particles were ground into flour using a laboratory grinder. Dry larvae of *C. forda* were screened for bad ones and impurities and further cleaned, dried at 70°C for 15hrs after which it was milled into flour and packaged in polythene bag for further analysis. The blends adopted for formulation of six samples (A, B, C, D, E, and F) is given in Table 1.

NB: No blanching treatment done to the cabbage as part of pre-preparation process?

Table 1: Blend Formulation for Bread Produced from Wheat Supplemented with Cabbage and Caterpillar Flours

Sample code	Wheat	Cabbage flour	*Cirina forda*
A	100	0	0
B	80	20	0
C	75	20	5
D	70	20	10
E	65	20	15
F	60	20	20

Keys:

A = 100% Wheat Flour
B = 80% Wheat Flour: 20% Cabbage Flour
C = 75% Wheat Flour: 20% Cabbage Flour: 5% Caterpillar Insect Flour
D = 70% Wheat Flour: 20% Cabbage Flour: 10% Caterpillar Insect Flour
E = 65% Wheat Flour: 20% Cabbage Flour: 15% Caterpillar Insect Flour
F = 60% Wheat Flour: 20% Cabbage Flour: 20% Caterpillar Insect Flour

Caterpillar *(Cirina forda)*

↓

Oven drying (70^{0}C for 18hrs)

↓

Milling

↓

Sieving (0.05mm mesh sieve)

↓

Cirina forda flour

Figure 1: Flow chart for the processing of *Cirina forda* flour

Source: (Modified Oyegoke *et al*., 2014)

Cabbage

↓

Cleaning

↓

Washing

↓

Cutting (dimension 20mm × 20mm)

↓

Oven drying (70^{o}C for 18hrs)

↓

Milling

↓

Sieving (0.05 mm mesh sieve)

↓

Cabbage flour

Figure 2: Flow chart for the processing of Cabbage flour

Source: (Modified, Haque *et al.*, 2016)

Wheat flour + cabbage flour + caterpillar insect flour

↓

Mixing

↓

Kneading

↓

Cutting

↓

Proofing (30mins)

↓

Baking (250^0C at 30mins)

↓

Cooling

↓

Bread

Figure 3: Flow chart for the processing of Bread

Source: (Modified, Sengev *et al*., 2013)

2.3 Bread Making Process

The dough made from the flour blends were baked using the straight dough method as described by Sengev et al. (2013). The baking formula included 500g of flour blend, 10g of compressed baker's yeast, 5g of salt (NaCl), 80g of sugar, 30g of margarine, and around 280 mL of water. All the ingredients were mixed for 3.5 minutes using a Kenwood mixer (Model A 907 D, Finland). The dough was then proofed for 90 minutes at 30^0C and baked at 250^0C for 30 minutes.

PROXIMATE ANALYSIS OF THE BREAD

The ash, moisture, crude fat, crude protein, crude fibre and carbohydrate content of the composite flour were determined using AOAC 2012.

FUNCTIONAL PROPERTY DETERMINATIONS

Determination of water absorption capacity by Abbey and Ibeh's (1988)

Determination of bulk density and swelling index by Onwuka 2005

PHYSICAL PROPERTIES OF LOAF

Determination of loaf volume and specific volume was determined using Giami et al., 2004

Determination of loaf height

Loaf height will be measured using a meter rule.

Determination of loaf weight

The loaf weight of the bread samples will be determined according Giami *et al*. (2004) which will by simple weighing using an electronic balance.

SENSORY EVALUATION

Twenty-four hours post-baking, sensory assessment was conducted utilizing a 9-point hedonic scale to assess the crust appearance, crumb appearance, crumb texture, flavor, and overall acceptability of the bread samples, following the methodology outlined by Sengev et al. (2013).

3.0 Results and Discussion

Proximate Composition of Wheat Bread Supplemented with Cabbage and Caterpillar Insect Flour

The results of the proximate composition of wheat bread supplemented with cabbage and caterpillar insect flour is presented in Table 1.

The moisture content of the samples ranged between 15.50 to 23.23% and the values were significantly ($p<0.05$) different from one another. Sample A had the highest moisture content with sample F being the least. Moisture content in foods is typically used as a measure of food quality and an indicator of storage stability (Cagiltay *et al.*, 2014). The lower moisture content observed in this study suggests a longer shelf life for the samples, consistent with Olitino et al.'s (2007) findings. The moisture content values in this study were higher than the 5.70 to 7.57% reported for cookies made with wheat, soy flour, and carrot powder (Ukeyima *et al.*, 2019). Additionally, as the level of caterpillar insect flour substitution increased, there was a notable decrease in moisture content, supporting its suitability for long-term storage due to its lower moisture content. This observation aligns with Olaoye et al.'s (2006) report of reduced moisture content in wheat, plantain, and soybean composite bread.

The protein content of the bread samples ranged between 11.73 to 23.38%, with bread sample supplemented with 20% cabbage and 20% caterpillar insect flour having the highest protein content of 26.38% while the one with the least protein contents is the 80% wheat and 20% cabbage flour bread (11.73%). The bread samples showed significant differences ($p<0.05$) from each other. The protein values found in this study exceed the range of 9.05 to 15.69% reported by Ojinnaka et al. (2015). The increased protein content in sample F, compared to samples A and B, might be attributed to the inclusion of caterpillar insect flour and the release of amino acids from the breakdown of peptide bonds in the native protein during hydrolysis by pepsin-pancreatin enzymes (Selvakumari *et al*., 2018). The rise in protein content with increasing amounts of caterpillar insect flour is anticipated, as edible termites are known to have high protein levels (Igwe *et al*., 2011). Protein is essential for all biological functions, forming crucial components like enzymes, hormones, and hemoglobin. Research by Osimani et al. (2018) and Burt et al. (2019) also demonstrated that incorporating cricket powder into bakery products significantly boosted their protein levels compared to those made solely with all-purpose flour.

The fat contents ranged between 6.94 to 10.55%, with sample F having the highest (10.55%) while the bread made with 80% wheat and 20% cabbage had the lowest fat content (6.94%). These values were significantly ($p<0.05$) different from one another. Caterpillar insect flour had higher fat content than wheat flour. Caterpillar insect flour contains more fat compared to wheat flour. Fat plays a crucial role in the human diet by enhancing the taste of food (Igbabul *et al*. 2014). Even though the crude fat content in wheat bread increased with higher levels of caterpillar insect flour substitution, the fat content in the bread remained generally high. This could be due to the margarine used in the bread's formulation. Ayensu et al. (2019) also noted increased fat content in biscuits fortified with *R. phoenicis* larvae flour and orange-fleshed sweet potato at higher substitution levels. The fat content values observed in this study were lower than the 44.82%, 46.59%, 47.03%, and 47.31% reported for four types of edible winged termites (Kinyuru et al., 2013), and also lower than the 9.14% to 12.7% fat content of cookies enriched with edible termite meal (Ojinnaka *et al*., 2015). These differences may result from variations in termite species, climate, and processing conditions.

The ash content of wheat bread enhanced with cabbage and caterpillar insect flour varied from 3.10% to 6.65%. The lowest ash content was found in the 100% wheat flour bread (3.10%), while the highest was in the bread supplemented with 20% cabbage and 20% caterpillar insect flour (6.65%). These differences were statistically significant ($p<0.05$). Ash content reflects the mineral concentration in a product (Chen *et al*. 2021). The ash content increased as the proportion of cabbage and caterpillar insect flour in the bread rose. Ash is an inorganic compound that includes the mineral content of food, which helps in metabolizing other organic compounds like fat and carbohydrates (William, 2007).

A notable increase in the ash content was observed in wheat bread supplemented with cabbage and caterpillar insect flour as the substitution level increased. This trend suggests that adding cabbage and caterpillar insect flour to wheat bread can enhance its mineral concentration. The ash content values found in this study were lower than the 4.71 to 6.38% reported by Ojinnaka et al. (2015), but higher than the 0.70 to 1.23% reported by Ukeyima et al. (2019). Specifically, the bread sample with 20% cabbage and 20% caterpillar insect flour had the highest mineral content among the samples tested. Previous studies on biscuit and bread making (Ayensu *et al*. 2019; de Osimani *et al*. 2018) have also demonstrated a similar linear relationship between ash content and the level of wheat flour substitution with insect flours.

The fiber content in the samples ranged from 4.93% in sample A to 22.27% in sample F. The addition of cabbage and caterpillar insect flour resulted in an increase in the crude fiber content of the bread samples. This inclusion likely influenced the properties of the flour, leading to higher water absorption compared to samples without added fiber (Elleuch *et al*., 2011). Fiber facilitates bowel movement and contributes to the overall health of the digestive system (Nantanga and Amakali, 2020). An increase in fiber content in bread positively impacts the muscles of both the large and small intestines. High-fiber foods are associated with a decreased risk of hemorrhoids, diabetes, high blood pressure, and obesity (Chukwu *et al*., 2013).

Dietary fiber is a crucial component in Brassica oleracea var. capitata L. and other Brassica vegetables, aiding in the reduction of serum cholesterol levels and the risk of coronary heart disease. It also helps prevent colon and breast cancers, as well as hypertension. Fiber provides essential roughage that supports digestion, softens stools, and lowers plasma cholesterol levels (Ajala *et al*., 2014). The high crude fiber content in G. zambesina caterpillar flour is likely due to the presence of chitin, which is a part of the exoskeleton of certain insects (Dauda *et al*., 2014). The increase in fiber content of wheat bread with higher substitution levels of cabbage and caterpillar insect flour can be attributed to the high crude fiber content of the cabbage flour. This aligns with findings by Ayensu et al. (2019) and Osimani et al. (2018) in their studies on biscuits fortified with *R. phoenicis* larvae flour and bread enriched with cricket powder (Acheta domesticus), respectively. The European Food Safety Authority (EFSA) recommends that for a food product to be considered high in fiber, it should contain 3 mg/100 g of dietary fiber (EFSA 2010; Osimani *et al*., 2018).

The carbohydrate content of the samples varied from 34.15% to 68.90%, with sample A having the highest and sample F the lowest. The carbohydrate levels in food depend on the amounts of other components present. Thus, the lower carbohydrate content in the sample containing 20% cabbage and 20% caterpillar insect flour can be attributed to its higher protein, fat, and fiber levels. Conversely, the high carbohydrate content in the 100% wheat bread (sample A) can be linked to its lower protein, fat, and fiber levels. A decrease in carbohydrate content corresponds with an increase in protein, fat, and ash content in F2 CP baked chips, as noted by Pauter et al. (2018). This observation aligns with findings by Ayensu et al. (2019), who noted reduced carbohydrate levels in biscuits fortified with orange-fleshed potato and *R. phoenicis* larva flour. Similarly, de Oliveira et al. (2017) reported a decrease in carbohydrate content in bread enriched with cockroach (Nauphoeta cinerea) flour as the substitution levels increased.

The calorific value of the samples ranged from 407.42% to 337.04%, with Sample A having the highest energy value of 407.42% and Sample F the lowest at 337.04%. The calorific content decreased as the amount of wheat flour decreased and the amounts of caterpillar insect flour and 20% cabbage flour increased. This is consistent with Alaunyte et al. (2012), who reported similar findings in their study on the combination of enzymes in straight dough and sourdough bread making. The decrease in carbohydrate content and calorific value in the formulated samples can be attributed to the higher protein, fiber, and fat content in the blends of cabbage and caterpillar insect flour.

Functional Properties of Wheat Bread Supplemented with Carrot and Caterpillar Insect Flour

The results of the functional properties of bread from wheat, cabbage and caterpillar insect flour are shown in Table 2. The water absorption capacities (WAC) varied from 128.28 to 194.33%. Bread samples with 20% carrot and 20% caterpillar insect flour had the highest WAC, while sample A (100% Wheat Bread) had the lowest. These values significantly differed from each other ($p<0.05$). According to Chavan et al. (2001), WAC reflects a sample's ability to interact with and retain water in food systems, influenced by factors such as protein size, shape, and conformational characteristics. Wu and Ding (2002) also noted that WAC relies on the presence of hydrophobic/hydrophilic amino acids in the food material. Compared to values for chicken and fish protein meals reported by Ganie et al. (2016), the WAC in this study was higher. Sample B, C, and D had WAC values similar to alcalase hydrolyzed fish protein. Differences in WAC among flour samples may stem from variations in hydrophobic amino acid residues, structural differences, and processing methods, as previously reported (Chavan et al., 2001).

Water absorption capacity refers to how well flour or starch retains water, including bound, hydrodynamic, capillary, and physically entrapped water (Moure et al., 2006). Rehman et al. (2007) examined the impact of substituting wheat flour with vetch flour in doughnuts. They observed that as the amount of vetch flour increased (at 5, 10, 15, and 20 g/100 g levels), the water absorption capacity of the composite flour increased significantly from the initial 58.6 g/100 g of wheat flour. This rise in water absorption is attributed to the higher protein content in vetch (26% compared to wheat), which enhances the flour's ability to absorb water.

The bulk density of bread samples varied from 0.67 to 2.26 g/ml in this study, with significant differences between them ($P<0.05$). The sample with 100% wheat flour (Sample A) had the lowest bulk density (0.67 mg/ml), indicating it's the lightest due to the fine nature of wheat flour. Conversely, the sample with 20% cabbage and 20% caterpillar flour (Sample F) had the highest bulk density (2.26 g/ml), making it the heaviest among the samples tested. This suggests that the addition of caterpillar flour enhanced the bulk density of the bread. Previous research reported bulk density values of 0.75 mg/ml for acha flour and 0.85 mg/ml for mushroom flour (Ayo et al., 2018). The study also found that incorporating different flours with wheat flour increased the bulk density of the composite flour, indicating their suitability for various food preparations. The low bulk density of food materials can be beneficial in making baby foods, as it allows for a high nutrient content with a low volume. On the other hand, a high bulk density is crucial for the physical characteristics of flours (Aremu et al., 2009).

The swelling properties of food materials are considered an indicator of starch-based flour during heating and are influenced by several factors, including particle size, types, and the variety of processing methods or unit operations involved in the production of the food material or flour mix (Nzelibe et al., 2000). The swelling capacity of flour refers to its ability to absorb water and expand in volume. Wheat flour typically exhibits good swelling capacity due to gluten formation. The values ranged between 11.74 and 15.20, with significant differences ($p<0.05$) among them. Sample A, composed entirely of wheat flour, had the highest swelling index (15.20), while sample F, which contained 20% cabbage and 20% caterpillar insect flours, had the lowest (11.74). Swelling power is influenced by the characteristics of amylose and amylopectin and the interaction between water molecules and the flour starch chains in both amorphous and crystalline regions (Chan et al., 2009).

The lowest swelling index observed in sample F might be attributed to the high percentage of caterpillar insect flour used in the bread production. According to Ukeyima et al. (2019), the swelling properties of food materials are typically considered an indicator of starch-based flour. This study's results clearly demonstrated that the swelling index of the samples is influenced by the addition of caterpillar insect flour. Swelling capacity is considered a quality criterion in some bakery formulations. It indicates non-covalent bonding between molecules within starch granules and is influenced by the ratio of α-amylose to amylopectin.

Physical Properties of Wheat Bread Supplemented with Cabbage and Caterpillar Insect Flour

The loaf volume decreased in proportion to the increase in cabbage and caterpillar insect additions. The loaf volume values varied significantly (P<0.05) from 1102.68% to 322.86%, with sample A (100% wheat flour bread) having the highest value at 1102.68%, and sample F (supplemented with 20% cabbage and 20% caterpillar insect flour) having the lowest value at 322.86%. Loaf volume is a crucial indicator for identifying bread characteristics as it offers a quantitative measurement of baking performance.

Gomez et al. (2003) noted that incorporating dietary fiber into baked goods primarily leads to a significant decrease in loaf volume and alters the bread's texture. Generally, adding dietary fiber notably affects dough properties, resulting in increased water absorption, enhanced mixing tolerance and tenacity, and reduced extensibility compared to doughs without fiber (Gomez et al., 2003). Consequently, at higher levels of whole wheat flour substitution, the gas cells in the dough cannot expand properly due to reduced gas retention.

The specific volume values ranged from 1.17% to 2.85%, showing significant differences (P<0.05) among them. Sample A (100% wheat flour bread) had the highest specific volume of 2.85%, while sample F (containing 20% cabbage and 20% caterpillar insect flour) had the lowest at 1.17%. This aligns with Ndife et al. (2011), who found that adding soy flour to wheat flour reduced bread volume and dough expansion. Similarly, Mohensen et al. (2006) reported that increasing the supplementation of wheat flour with defatted or non-defatted soy flour significantly decreased loaf and specific volumes. In this study, the specific volume of NB bread was 2.7 times higher than that reported for barley bread by del Carmen Robles-Ramirez et al. (2020).

Cardone et al., (2020) found that germination significantly reduces the specific volume of bread, likely due to a weakened gluten network. Similarly, Wirkijowska et al. (2020) observed a reduction in loaf volume when high fiber ingredients were added to wheat bread, attributed to decreased gluten content from the supplementation. Other studies have also indicated that partially substituting wheat flour with non-glutinous flour leads to lower bread volumes.

Increasing yeast amounts and extending fermentation/proofing times may help enhance these physical properties.

The loaf height decreased in proportion to the increase in cabbage and caterpillar insect additions. The loaf height values varied significantly ($P<0.05$) from 10.16 to 2.94 cm, with sample A (100% wheat flour bread) having the highest value at 10.16cm and sample F supplemented with 20% cabbage and 20% caterpillar insect flour) having the lowest value at 2.94cm. It is understandable that loaves with reduced volume will also have short height. It is reported by (Elleuch, et al., 2011) that more fiber can decrease bread expansion and thus reduced bread size.

The decrease in wheat flour decreases in gluten strength with increase in cabbage and caterpillar insect flour, as gluten is known to form the network within dough that result in rising (height). This result is in line with (Taha et al., 2006) who also reported decrease in chickpea-bread bean soy protein flour blend.

The loaf weights ranged from 235.92 to 218.66 grams, with significant differences ($P<0.05$) between them. Sample C (comprising 75% wheat flour, 20% cabbage flour, and 5% caterpillar insect flour) had the highest weight of 235.92 grams, while sample E (comprising 65% wheat flour, 20% cabbage flour, and 15% caterpillar insect flour) had the lowest weight of 218.66 grams. According to Keetels et al. (2020), weight loss during bread making is a natural occurrence, as carbon dioxide (CO2) gets trapped in small air pockets during dough fermentation.

While baking, the CO2 trapped in the dough expands the air pockets, and as the starch gelatinizes, the dough turns into a flexible bread crumb. This process causes the bread to lose weight. For communities favoring dense bread, these samples would meet their physical expectations. This could be due to a gel network forming during baking, which reinforces the dough cells, enhancing gas retention and bread volume (Keetels *et al*., 2020)

Sensory Evaluation of Wheat Bread Supplemented with Cabbage and Caterpillar Insect Flour

The ratings for crust appearance were similar among samples B, C, D, and F ($p \geq 0.05$), but there was a notable difference between samples A and E. Bread containing 65% wheat flour, 20% cabbage flour, and 15% caterpillar insect flour received the lowest score for crust color, indicating unattractive appearance at that supplementation level. This refers to the outer layer of the bread, ideally smooth and golden brown, as noted by Sanful (2011) in their study on Taro and Whole Wheat Flour Composite Bread.

The crumb appearance was similar for samples B, C, D, and E ($p \geq 0.05$), but there was a notable difference for samples A (100% wheat flour bread) and F (bread with 60% wheat flour, 20% cabbage flour, and 20% caterpillar insect flour). Factors like baking conditions, bread components, and water absorption during dough mixing all influence the final texture. Adding cabbage and caterpillar insect flour resulted in a coarser structure and larger crumb pores. The number of cells in a bread slice reflects the gas bubbles captured during proofing, with a preference for a large number of small cells for quality bread. Incorporating wheat bran into white flour led to a coarser bread structure, as observed by Banu et al. (2012).

The flavor varied noticeably among the samples, except for samples E and F, which exhibited similarity ($p \geq 0.05$). The taste of bread pertains to the sweet sensation experienced in the mouth upon contact with the bread, influenced by the sweetening agent. These taste attributes play a crucial role in determining the overall acceptability of the bread. As the substitution level of whole wheat flour increased, there was a notable decrease in aroma and taste. This result is similar with the 8.2% reported by (Bansal and Kapoor, 2015). As the concentration of cabbage and caterpillar insect flour increases, its aroma and flavor in the bread get more pronounced. However, there was no significant difference in taste between the control and bread samples containing 10 and 20% whole wheat flour ($p \leq 0.05$). This variance could be attributed to the higher levels of water chestnut flour, which introduced an undesirable chestnut flavor at elevated levels, consequently reducing taste and aroma values significantly.

The overall acceptability score dropped notably with higher levels of whole wheat flour substitution. It reflects how consumers or panelists generally perceive the product. The control scored highest for overall acceptability, followed by samples B through F. Whole wheat flour's baking properties and taste may suffer due to reduced gluten content, as noted by Dewettinck et al. (2008) and Jideani and Onwubali (2009).

Different blends of synthetic and natural enhancers like malt flour, vital wheat gluten, and ascorbic acid can be incorporated into dough recipes to enhance the baking and sensory characteristics of the final product (Rodriguez et al., 2006). The decline in overall satisfaction as the proportion of caterpillar insect flour increases suggests that panelists were not receptive to bread enriched with caterpillar insect flour. Overall acceptability indicates how consumers or panelists perceive the product, taking into account all other sensory evaluation criteria.

Table 2: Proximate Composition of Wheat Bread Supplemented with Cabbage and Caterpillar Composite Flours

SAMPLES	MOISTURE (%)	ASH (%)	PROTEIN (%)	FAT (%)	FIBRE (%)	CHO (%)	ENERGY VALUE
A	23.23^{a} ±0.41	3.10^{f} ±0.09	15.17^{e} ±0.03	7.91^{e} ±0.09	4.93^{f} ±0.08	68.90^{a} ±0.13	407.42^{a} ±0.34
B	20.14^{b} ±0.03	3.97^{e} ±0.06	11.73^{f} ±0.05	6.94^{f} ±0.06	12.71^{e} ±0.09	64.57^{b} ±0.19	367.69^{b} ±0.50
C	18.18^{bc} ±0.02	5.19^{d} ±0.04	13.09^{d} ±0.06	8.09^{d} ±0.07	14.99^{d} ±0.05	55.56^{c} ±0.10	359.39^{c} ± 1.15
D	17.08^{cd} ±0.04	5.75^{c} ±0.07	16.10^{c} ±0.07	9.14^{c} ±0.11	18.97^{c} ±0.03	46.03^{d} ±0.13	346.80^{d} ±0.64
E	15.39^{d} ±0.14	6.02^{b} ±0.08	20.94^{b} ±0.30	9.84^{b} ±0.12	20.57^{b} ±0.07	40.62^{e} ±0.40	342.86^{e} ±0.62
F	15.50^{d} ±3.24	6.65^{a} ±0.03	23.38^{a} ±0.04	10.55^{a}±0.07	22.27^{a} ±0.02	34.15^{f} ±0.10	337.04^{f} ±0.38

Values are means ± std of triplicate determinations. Means values with different letters across rows are significantly different at ($p<0.05$).

A = 100% WHEAT FLOUR
B =80%WHEAT FLOUR:20%CABBAGE FLOUR
C = 75% WHEAT FLOUR:20%CABBAGE FLOUR:5%CATERPILLAR INSECT FLOUR
D = 70% WHEAT FLOUR:20%CABBAGE FLOUR:10%CATERPILLAR INSECT FLOUR
E = 65% WHEAT FLOUR:20%CABBAGE FLOUR:15%CATERPILLAR INSECT FLOUR
F =60% WHEAT FLOUR:20%CABBAGE FLOUR:20%CATERPILLAR INSECT FLOUR

Table 3: Functional Properties of Wheat Flour Supplemented with Cabbage and Caterpillar Composite Flours

SAMPLES	WATER ABSORPTION CAPACITY (%)	BULK DENSITY (g/ml)	SWELLING INDEX
A	128.28^{f} ±0.27	0.67^{f} ± 0.02	15.20^{b} ±0.31
B	135.35^{e} ±0.48	0.81^{e} ±0.02	19.47^{a} ±0.09
C	151.02^{c} ±0.06	1.25^{d} ±0.02	14.12^{c} ±0.07
D	163.68^{d} ±0.18	1.62^{c} ±0.02	13.05^{d} ±0.04
E	177.07^{b} ±0.21	1.95^{b}±0.03	12.42^{e} ±0.03
F	194.33^{a} ±0.39	2.26^{a} ±0.02	11.74^{f} ±0.03

Values are means ± std of triplicate determinations. Means values with different letters across rows are significantly different at ($p<0.05$).

A = 100% WHEAT FLOUR
B =80%WHEAT FLOUR:20%CABBAGE FLOUR
C = 75% WHEAT FLOUR:20%CABBAGE FLOUR:5%CATERPILLAR INSECT FLOUR
D = 70% WHEAT FLOUR:20%CABBAGE FLOUR:10%CATERPILLAR INSECT FLOUR
E = 65% WHEAT FLOUR:20%CABBAGE FLOUR:15%CATERPILLAR INSECT FLOUR
F =60% WHEAT FLOUR:20%CABBAGE FLOUR:20%CATERPILLAR INSECT FLOUR

Table 4. Physical Properties of Wheat Bread Supplemented with Cabbage and Caterpillar Composite Flours

SAMPLES	LOAF VOLUME (cm^3)	LOAF WEIGHT (g)	LOAF HEIGHT (cm)	SPECIFIC VOLUME (cm^3)
A	1102.68^{a} ± 1.36	231.92^{b} ±0.02	10.16^{a} ±0.04	2.85^{a} ±0.02
B	511.03^{b} ±0.18	229.15^{e} ±0.03	4.52^{b} ±0.01	2.04^{b} ±0.02
C	470.29^{c} ±0.45	235.92^{a} ±0.01	4.34^{c} ±0.02	1.71^{c} ±0.02
D	400.54^{d} ±0.17	231.84^{c} ±0.03	4.05^{d} ±0.02	1.52^{d} ±0.01
E	357.29^{e} ±0.02	218.66^{f} ±0.03	3.56^{e} ±0.02	1.32^{e} ±0.02
F	322.86^{f} ±0.09	229.54^{d} ±0.04	2.94^{f} ±0.02	1.17^{f} ±0.01

Values are means ± std of triplicate determinations. Means values with different letters across rows are significantly different at ($p<0.05$).

A = 100% WHEAT FLOUR
B =80%WHEAT FLOUR:20%CABBAGE FLOUR
C = 75% WHEAT FLOUR:20%CABBAGE FLOUR:5%CATERPILLAR INSECT FLOUR
D = 70% WHEAT FLOUR:20%CABBAGE FLOUR:10%CATERPILLAR INSECT FLOUR
E = 65% WHEAT FLOUR:20%CABBAGE FLOUR:15%CATERPILLAR INSECT FLOUR
F =60% WHEAT FLOUR:20%CABBAGE FLOUR:20%CATERPILLAR INSECT FLOUR

Table 5: Sensory Properties of Wheat Bread Supplemented with Cabbage and Caterpillar Composite Flours

SAMPLES	AROMA	CRUMB APPEARANCE	CRUST APPEARANCE	TASTE	OVERALL ACCEPTABILITY
A	$7.45^{a}\pm1.10$	$7.70^{a}\pm0.92$	$7.55^{a}\pm1.15$	$7.80^{a}\pm0.89$	$7.85^{a}\pm0.59$
B	$6.50^{ab}\pm1.28$	$6.90^{ab}\pm1.55$	$6.90^{ab}\pm1.45$	$5.70^{b}\pm1.56$	$6.45^{b}\pm1.50$
C	$6.10^{b}\pm1.59$	$6.85^{ab}\pm1.90$	$6.95^{ab}\pm1.73$	$5.25^{bc}\pm1.33$	$5.90^{bc}\pm1.52$
D	$6.00^{b}\pm1.62$	$7.30^{ab}\pm1.38$	$6.85^{ab}\pm1.57$	$4.50^{cd}\pm1.40$	$5.40^{cd}\pm1.47$
E	$5.40^{bc}\pm2.09$	$6.75^{ab}\pm1.68$	$5.90^{b}\pm2.20$	$4.20^{d}\pm1.74$	$4.70^{d}\pm1.78$
F	$4.85^{c}\pm2.01$	$6.40^{b}\pm2.35$	$6.40^{ab}\pm2.35$	$4.10^{d}\pm1.80$	$4.75^{d}\pm1.89$

Values are means of triplicate determinations. Means values with different letters across rows are significantly different at ($p<0.05$).

A = 100% WHEAT FLOUR
B =80%WHEAT FLOUR:20%CABBAGE FLOUR
C = 75% WHEAT FLOUR:20%CABBAGE FLOUR:5%CATERPILLAR INSECT FLOUR
D = 70% WHEAT FLOUR:20%CABBAGE FLOUR:10%CATERPILLAR INSECT FLOUR
E = 65% WHEAT FLOUR:20%CABBAGE FLOUR:15%CATERPILLAR INSECT FLOUR
F =60% WHEAT FLOUR:20%CABBAGE FLOUR:20%CATERPILLAR INSECT FLOUR

4.0 Conclusion

The assessment of bread quality made from wheat mixed with cabbage and caterpillar (Cirina forda) flour blends was examined, leading to the following findings. Incorporating cabbage and caterpillar insect flour into wheat bread resulted in heightened levels of protein (11.73-26.38%), fiber (4.93-22.27%) fat (6.94-10.55%), and ash (3.10-6.65%), while moisture (15.50-23.23%) and carbohydrate (34.15-68.90%) content decreased. Notably, there was a significant increase (P<0.05) in the functional properties, except for swelling capacity (15.20-11.74), which exhibited a declining trend, with an increase in the addition of caterpillar insect flour alongside a constant level of cabbage flour in the wheat bread. The volume of the loaf (from 1102.68 to 322.68cm3), its height (from 10.16 to 2.94cm), and the specific volume (from 2.85 to 1.17 cm3) of the bread samples declined with increasing addition of caterpillar insect flour, while the loaf weight (from 235.92 to 218.66g) showed fluctuation. Meanwhile, sensory evaluations indicated a decreasing trend in all attributes of wheat bread with the inclusion of cabbage and caterpillar insect flours, although bread made solely from wheat remains the most favored option. More research is needed to enhance the taste and overall appeal of whole wheat flour enriched bread. Educating the public about the nutritional advantages of these functional foods could enhance their taste perception

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