Physico-chemical and sensory attributes of bread produced from wheat, cabbage and caterpillar insect flours

Abstract:

This study assessed the need of alternative flours in 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 cm^3, 10.16 to 2.94 cm, and 2.85 to 1.17 cm^3 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 cabbage and caterpillar insect flour. This implies that despite the high nutrient content of cabbage and caterpillar insect flour, it is not a good substitute for wheat in bread production due to its physical characteristics and sensory attributes.

Keywords: Physico-chemical attributes , Sensory attributes, Caterpillar insect flours, Cabbage, Wheat flour

1 Introduction

“Bread is generally made by baking dough which has wheat flour, water, yeast and salt as its main ingredient” (Okoye and Ezeugwu, 2019). “Other ingredients which may be added include flours of other cereals, fat, malt flour, soy flour, emulsifiers, milk, sugar, fruits, among others. It is consumed and enjoyed by both children and adults from different socio-economic status in Nigeria, therefore leading to its high daily demand” (Inyang and Asuquo, 2016). “It contains a rich source of energy, protein, vitamins especially the B vitamins, minerals and dietary fibre, making it highly nutritive. Recent developments for over 20 years have focused on healthy eating, enhancing the utilization of indigenous produce such as whole wheat, local cereals and legumes in baking industries. Though wheat is the main flour component used in bread making, composite flour technology has also introduced other flour-like materials from grains, fruits and leafy vegetables due to their nutritional advantages” (Sengev *et al*., 2021). “Wheat (*Triticum aestivum* L.) is the most widely produced cereal and one of the most important staple food crops in the world” (Saeid *et al.*, 2015). “Wheat is a rich source of carbohydrate. It also contains protein, fat, ash, fiber, and vitamins as well as mineral such as sodium, potassium, calcium, magnesium, iron, phosphorus, copper, zinc and manganese” (Kumar *et al*., 2011). “Demand for health-oriented products, which have high fibre and natural antioxidant and low-calorie contents and are sugar-free, is increasing because of their beneficial effects to overcome health problems such as some types of cancer, cardiovascular diseases, hypertension, diabetes, gastrointestinal disorders and weight gain” (Nomura, *et al.*, 2007).

Ayoade *et al*. (2020) defined “composite flours as blends of various cereals, legumes and tuber flours, rich in starch, protein and other nutrients integrated with or without wheat flour. The replacement or incorporation of wheat flour with indigenous raw materials is ever increasing as a result of the high demand for baked products and pastries”. “The use of composite flour in developing countries has been in use at different levels of substitutions which had achieved varying levels of success. Composite flour as an innovative flour that has attracted much attention in research as well as food product development" (Hasmadi *et al.,* 2014), it is a mixture of flours obtained from tubers which is rich in starch such as cassava, yam, potato, legumes which is rich in protein such as soybean and protein-rich flour and cereals, with or without wheat flour that created to satisfy specific functional characteristics and nutrient composition.

"Vegetables are good sources of natural antioxidants and dietary fiber. Among vegetables, white cabbage has been used for years in human nutrition due to its high antioxidant, polyphenol, dietary fiber and mineral and low-calorie content. Vegetables as a whole are considered natural sources of nutrients gifted by nature to human beings. Vegetables are important sources of food and are highly beneficial for health" (Hülya *et al*., 2013). "Vegetables consumption is encouraged in many countries to prevent various diseases such as cancer and cardiovascular disorders. Vegetables occupy an important place among the food crops as they provide adequate amount of many vitamins and minerals for humans. They are rich source of carotene, ascorbic acid, riboflavin, folic acid and minerals like calcium, iron, and phosphorus" (Allah Bux *et al.*, 2015). "Cabbage (*Brassica oleracea*) is a leafy green or purple biennial plant having a globose head consisting of a short stem and tightly over lapping green to purplish leaves. Nutritionally, cabbage contains vitamins such as A, B, C and E. It also contains some minerals such as irons, manganese, folate, thiamine (vitamin B_1), riboflavin (vitamin B_2), calcium, magnesium, potassium, zinc etc. Moreover, cabbage is an important source of dietary fiber, antioxidant and various anti carcinogenic compounds" (Adeniji *et al*., 2010). "The main constituents of cabbage are carbohydrates (90 % of the dry weight), where approximately one third is dietary fiber and two third are low-molecular-weight carbohydrates (LMWC). Cabbage is low in calories, high in vitamin C, a good source of folic acid and fiber. The main component of the cabbage is water and it is a low-calorie food because it has a low content of carbohydrates, proteins and fats. However, it is considered a good source of dietary fiber, vitamin B_6, folic acid, Vitamin B_5, and small amounts of other B group vitamins (like B_1, B_2 and B_3) and minerals especially potassium and phosphorus" (Baloch *et al*., 2015). "Cabbage contains important phytochemicals with its bioactive compounds, glucosinolates, and indole-3-carbinol. Cabbage shows great promise in providing substantial protection against cardiovascular disease, cancer, diabetes" (Baloch *et al*., 2015). "Insects are widely spread all over the world; many of them are well known and appreciated for their characteristics. Entomophagy (the habit of eating insects as food) is a well-established custom in many parts of the world, and many edible insects have become a food resource that is being tapped by various communities. In Europe, Asia, Australia and Africa, people feed on different stages of various insects. Early records showed that the ancient Greek Parthians and Nasamines ate locust and grasshoppers as food" (Yohanna *et al.*, 2014). "The caterpillar of the pallid emperor moth (*Cirina forda*) is of the order, Lepidoptera and family, Saturniidae. It is an insect pest of *Butyrospermun paradoxum*, the shear butter tree and is widely accepted as a food source and is also an important item of commerce in many Nigerian States such as Oyo, Kwara, Kogi, Niger, Kaduna and Benue" (Yohanna *et al*., 2014). "The larvae of this insect are processed into the dried form and consumed as a delicacy served as snacks or as an essential ingredient in vegetable soups along with carbohydrate food in Southern Nigeria and many homes in Africa" (Odeyemi, and Fasoranti, 2000, and Omotoso, 2006). They have been found to contain protein and abundant fat calories. The larvae of this insect are processed into the dried form which is widely marketed and consumed as an essential ingredient in vegetable soups (Osasona and Olaofe, 2010). 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 (*cirina forda*), 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 leaves were 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 and sieved using 0.05mm sieve mesh. 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, sieved 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.

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^{0}C 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 bread were determined using AOAC 2012.

FUNCTIONAL PROPERTY DETERMINATIONS

The Water Absorption Capacity were observed by following the method of Abbey and Ibeh's (1988).

The bulk density and swelling index were observed by following the method of Onwuka, 2005.

PHYSICAL PROPERTIES OF LOAF

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

The Loaf height was measured using a meter rule.

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

SENSORY EVALUATION

Sensory evaluation of the bread samples was carried out according to the method described by Sengev *et al.* (2013). A panel of twenty (20) members consisting of students and members of staff from Food Science and Technology Department, Joseph Sarwuan Tarka University, Makurdi, Nigeria was chosen based on their familiarity and experience with wheat-based breads for sensory evaluation. Breads produced from each flour blend, along with the reference sample were presented in coded form and were randomly presented to the panelists. The panelists were provided with portable water to rinse their mouth between evaluations. However, a questionnaire describing the quality attributes (crumb appearance, crust appearance, taste, aroma, and overall acceptability) of the bread samples were given to each panelist. Each sensory attribute was rated on a 9-point Hedonic scale (1 = dislike extremely and 9 = like extremely). Bread produced from wheat flour (100 %) was regarded as control.

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 2.

The moisture content of foods is usually used as an indicator of food quality. Moisture content of food material is an index of storage ability of such food products (Cagiltay *et al*., 2014). The lower moisture observed in this study is an indication of longer shelf life of the blends and this agreed with the findings of Olitino *et al.* (2007). The values obtained for the moisture contents in this study were higher than 5.70 to 7.57 % reported for cookies made with wheat, soy flour and carrot powder (Ukeyima *et al*., 2019). Conversely, with the increase in the substitution level of caterpillar insect flour, there was a significant decrease in moisture content as caterpillar insect flour has less moisture content. This justifies its suitability for long-term storage without deterioration. Similar to this study, Daramola *et al*. (2022) also reported decreased moisture content values in their study on quality evaluation of composite flour produced from wheat flour, edible caterpillar and lemon peel. The authors further stressed that moisture content estimates directly the water content and indirectly the dry matter of the samples. The values of protein obtained in this study are higher than 9.05 to 15.69 % reported by Ojinnaka *et al*. (2015). The higher protein content of sample T_6 compared to sample T_1 and T_2 may be due to the addition of caterpillar insect powder. The increased protein content with increasing levels of caterpillar insect powder were expected because edible caterpillar has been reported to have relatively high protein content (Igwe *et al*., 2011). Similar to the increased protein values reported in this present study, da Rosa Machado and Thys (2019) reported a magnitude increases of 28.8 and 62.8 % in the protein content of enriched bread compared to their control non-enriched counterpart involving bread enrichment with 10 and 20 % cricket (*Gryllus assimilis*) powder substitution. Protein is the basis of all organism activity and constitutes many important materials such as enzymes, hormones and haemoglobin. Studies done by Osimani *et al*. (2018) and Burt *et al*. (2019) proved that the utilization of cricket powder in bakery products had remarkably increased their protein content as compared to the control. This finding is also in agreement with that by Ayensu *et al*. (2019) on the nutritional composition of biscuits fortified with orange-fleshed potato and palm weevil larvae (*Rhynchophorus phoenicis*). According to the Guide to Nutrition Labelling and Claims, a food product can be claimed as high protein if its protein content is double the Nutrient Reference Value (NRV) which is 5 g (Ministry of Health, 2010). Fat is important in the human diet since it makes food more palatable (Igbabul *et al*. 2014). Despite increase in crude fat content of wheat bread enriched with caterpillar insect powder with increase in substitution levels, the crude fat contents of the wheat bread were generally high. This observation might be ascribed to margarine used as an ingredient in the formulation of wheat bread. A similar observation of increasing fat contents with increase in substitution level was made by Ayensu *et al*. (2019) in his research on biscuits fortified with *R. phoenicis* larvae four and orange-fleshed sweet potato. The values obtained for the fat contents in this study were lower than 44.82 %, 46.59 %, 47.03 % and 47.31 % reported for four edible winged termites (Kinyuru *et al*., 2013) and also lower that fat content (9.14 to 12.7 %) of cookies enriched with edible termite meal (Ojinnaka *et al*., 2015). The difference in values may be attributed to the type of insect used in this study.

The ash content of a product is an indication of the mineral concentration of the particular product (Chen *et al*. 2021). The ash content of the bread increased with increase in the cabbage and caterpillar insect powder. Ash is a non-organic compound containing mineral content of food and nutritionally aid in the metabolism of other organic compounds such as fat and carbohydrate (William, 2007). A significant increase in the ash content of wheat supplemented with cabbage and caterpillar insect powder with increase in substitution level was observed. Thus, the trend indicated that supplementing wheat bread with cabbage and caterpillar insect flour could improve the mineral concentration of the bread. The values obtained for the ash content of the bread samples in this study were however lower than 4.71 to 6.38 % reported by Ojinnaka *et al*. (2015) but higher than 0.70 to 1.23 % reported by Ukeyima *et al*. (2019). Previous research studies on biscuit and bread making (Ayensu *et al*. 2019; de Oliveira *et al*. 2017; Osimani *et al*. 2018) have also shown similar findings of linear correlation between ash content and the substitution level of wheat flour with insect flours. Crude fibre content of the bread samples increased as a result of cabbage and caterpillar insect powder inclusion. Similar to this observation, Bawa *et al*. (2020) also reported an enriched bread with 10 % freeze-dried cricket powder and reported a magnitude increase of almost 81.8 % for fibre content for the enriched bread when compared to its non-enriched counterparts. The significantly increased and higher fibre content reported for the enriched bread could be due to the presence of chitin in the exoskeleton of the edible caterpillar insect and its powder (Bresciani *et al*., 2022). Fibre aids in bowel movement and plays a role in maintaining the health of the digestive system (Nantanga and Amakali 2020). An increase in the fibre content of bread has some beneficial effect on the muscles of the large and small intestines. Consumption of high fiber food products has been linked to reduction in hemorrhoids, diabetes, high blood pressure, and obesity (Chukwu *et al*., 2013). Dietary fiber is an important constituent in *Brassica oleracae* var. capitata L. and other vegetables of the Brassica family, helping to reduce serum cholesterol level, risk of coronary heart disease, and contributing to prevent colon and breast cancers and hypertension. Fiber has useful role in providing roughage that aids digestion, soften stools and lower plasma cholesterol level in the body (Ajala *et al*., 2014). Also, increase in fibre content of wheat bread with corresponding increase in substitution levels of cabbage and caterpillar insect powders might be ascribed to the high crude fibre content of the cabbage powder. This finding is in agreement with those by Ayensu *et al*. (2019) and Osimani *et al*. (2018) in their research on biscuits fortified with *R. phoenicis* larvae flour and bread enriched with cricket powder (*Acheta domesticus*), respectively. The European food safety authority (EFSA) suggests that for a food product to be considered as a high fibre food, it should provide 3 mg/100 g of dietary fbre (EFSA 2010; Osimani *et al*. 2018). The quantities of carbohydrate in food material are a function of other proximate constituents of the food samples. Therefore, the low carbohydrate content in the sample made with 20 % cabbage and 20 % caterpillar insect flour may be attributed to the high protein, fat and fibre content present while the highest carbohydrate content in the 100% wheat bread (sample A) may also be attributed to the low protein, fat and fiber content observed. The decrease in carbohydrate content is related to the increase in protein, fat and ash content of F_2 CP baked chips (Pauter *et al*., 2018). This finding corroborates the finding of Ayensu *et al*. (2019) who reported a decrease in the carbohydrate content of biscuits fortified with orange-fleshed potato and *R. phoenicis* larve powder. Similarly, de Oliveira *et al*. (2017) also reported a decreasing trend in the carbohydrate content of bread enriched with cockroach (*Nauphoeta cinerea*) powder with increase in substitution levels. The caloric content of the formulated samples decreased with a reduction in wheat flour and an increase in caterpillar insect powder and cabbage powder. This finding is consistent with the report by Alaunyte *et al*. (2012), which observed similar trends in the caloric content of bread made with a combination of enzyme in straight dough and sourdough methods. The decrease in carbohydrate content and caloric value in the samples with higher proportions of cabbage and caterpillar insect flour can be attributed to the higher protein, fiber, and fat content of these powders, which displace some of the carbohydrate content present in wheat flour (Alaunyte *et al*., 2012).

Functional properties of Wheat Bread Supplemented with Cabbage and Caterpillar Insect Flour

The values of water absorption capacity (WAC) were significantly ($p < 0.05$) different between samples. Water absorption capacity is referring to the ability of the flour or starch to hold water against gravity that can comprise of bound water, hydrodynamic water, capillary water and physically entrapped water (Moure *et al*., 2016). Chavan *et al*. (2011) reported that WAC is an indicator of the sample's ability to interact with water, retain the water and be stable in food systems which is dependent on several factors, including size, shape and conformational characteristics of the proteins. Wu and Ding (2022) also showed that WAC depends on the presence of hydrophobic/hydrophilic amino acids within the food material. The values obtained in this study were higher than 2.50 and 2.47 g/g reported for chicken and fish protein meals, respectively (Ganie *et al*., 2016). The WAC of sample B, C and D obtained here was similar to the value (295 %) reported for alcalase hydrolyzed fish protein (Cai *et al*., 2017). The differences in the WAC of the flour samples could be attributed to differences in the amounts of hydrophobic amino acids residues such as alanine, valine, leucine, etc., present in the samples, structural variation and processing methods used, as earlier reported to affect functional properties (Chavan *et al*., 2011).

Rehman *et al*. (2017) studied the effect of partial substitution of wheat flour (*Triticum aestivum*) with vetch flour (*Lathyrus sativus* L) at the levels of 5, 10, 15 and 20 g/100 g on the physicochemical, rheological, nutritional and sensory characteristics of composite flour doughnuts. They found that the water absorption capacity of wheat flour was 58.6 g/100 g, which significantly increased on increasing the amount of vetch flour. Increase in the water absorption of composite flours might be due to the increase in protein level. The flour's water absorption increases with an increase in protein content of composite flours because vetch contains more protein (26 %) than wheat.

The results of the bulk density analysis showed that the addition of caterpillar insect powder to the bread resulted in improved bulk density values, thereby increasing the heaviness of the samples. Previous reports indicated values of 0.65 mg/ml for cricket flour and 0.85 mg/ml for mushroom flour (Ayo *et al*., 2018). Bulk density of composite flour increased with an increase in the incorporation of different flours with wheat flour. The high bulk density of flour suggests their suitability for use in food preparations (liquids, semisolids or solids). The bulk density of flour depends on combined effects of factors such as intensity of attractive inter-particle forces, geometry, particle size and method of preparation. Bulk density (BD) is a reflection of the load the samples can carry if allowed to rest directly on one another (Onabanjo and Ighere, 2014). Bulk density is useful in determining the packaging requirement, application in wet processing and material handlings of flours (Adebowale *et al*., 2008). The low bulk density of any food materials could be an advantage in the formulation of baby foods where high nutrients density to low bulk is desired. However, high bulk density is important for physical properties of the flours (Aremu *et al*., 2009).

The swelling properties of food material is regarded as an index of starch based flour during heating and depended on several factors, which include particle size, types and the variety of processing methods applied and or the units operation involved during the production of the food material or flour mix (Nzelibe *et al*., 2000). Swelling capacity of flour refers to its ability to absorb water and increase in volume. Wheat flour generally has good swelling capacity due to its gluten formation. Swelling power is influenced by amylose and amylopectin characteristics, the interaction between the water molecules and the flour starch chains in the amorphous and crystalline areas (Chan *et al*., 2019). The lowest value of swelling index observed in sample T_6 may be due to the high percentage of caterpillar insect flour used in the production of the bread, as it has been reported that swelling properties of food material is regarded as an index of starch-based flour (Ukeyima *et al*., 2019). The results from this study clearly showed that the swelling index of the samples are affected by the addition of caterpillar insect powder. Swelling capacity is regarded as a quality criterion in some good formulations as bakery products. It is evidence of non-covalent bonding between molecules within starch granules and also a factor of the ratio of α-amylose and amylopectin ratios.

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

The physical properties of wheat bread supplemented with cabbage and caterpillar insect flour exhibit notable changes compared to standard wheat bread, as presented in Table 4. Specifically, loaf volume, loaf height, and specific volume all decreased with increasing levels of cabbage and caterpillar insect flour, while loaf weight showed an increase.

In this present study, loaf volume decreased significantly ($p < 0.05$) as the level of cabbage and caterpillar insect flour increased. This trend aligns with several studies that report a reduction in loaf volume when insect powders are incorporated into bread. For example, González *et al*. (2019) found that incorporating cricket powder into bread resulted in a decreased loaf volume due to the disruption of gluten network formation, which is essential for gas retention and expansion during baking. Similarly, Chauhan *et al*. (2017) observed a reduction in loaf volume when mealworm powder was added, attributing it to the dilution of gluten proteins and the increased density of the dough.

Loaf height in this study decreased significantly ($p < 0.05$) with higher levels of caterpillar insect powder and at constant cabbage proportion. This reduction is consistent with findings from other studies. For instance, Nyangena *et al*. (2020) noted that bread supplemented with termite powder exhibited reduced loaf height, which they associated with the altered viscoelastic properties of the dough and the compromised ability to trap carbon dioxide during fermentation. The reduced height is typically due to the interference of non-gluten proteins from insect flour, which affects the dough's rising capability.

The specific volume, an important quality indicator for bread, also decreased significantly ($p < 0.05$) in this study. This is in agreement with other research that shows a decline in specific volume with the addition of insect powders. Osimani *et al*. (2018) reported a similar decrease when bread was supplemented with silkworm powder, citing the heavier dough and reduced gas retention as contributing factors. The presence of insect powder increases the dough density and decreases its elasticity, resulting in lower specific volumes.

However, loaf weight in this study showed a significant ($p < 0.05$) increase with the addition of cabbage and caterpillar insect powders. This contrasts with some studies, such as those by Roncolini *et al*. (2020), which found that the incorporation of insect flour did not significantly affect the loaf weight. However, the increase in weight observed here could be due to the higher moisture retention properties of the combined cabbage and insect flour, leading to denser and heavier loaves.

The physical properties of wheat bread supplemented with cabbage and caterpillar insect powder, as observed in this study, are consistent with findings from other literature that explore the use of insect powders in bread formulations. The decrease in loaf volume, height, and specific volume, coupled with the increase in loaf weight, highlights the impact of these non-traditional ingredients on the bread-making process (Bojnanska *et al.*, 2024). These changes are primarily due to the alteration of the dough's gluten network, increased dough density, and modified gas retention capabilities.

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

Sensory properties are critical aspects of food products that determine their acceptability and preference among consumers. These properties include attributes such as aroma, appearance (both crumb and crust for baked goods), taste, texture, and overall acceptability. Sensory evaluation involves a structured process where trained panelists or consumers assess these attributes using various scales and methodologies. The sensory attributes of wheat bread supplemented with cabbage and caterpillar insect flours, as shown in Table 5, reveal a general significant ($p < 0.05$) decrease in aroma, crumb appearance, crust appearance, taste, and overall acceptability with increasing levels of the supplementary flours. This trend is common in studies exploring the addition of unconventional ingredients, such as insect flours, to traditional food products.

Aroma is the smell of the food, which can significantly influence the initial perception and appeal. It is often the first attribute noticed by consumers and can set expectations for taste and overall quality. The aroma of the bread samples decreased significantly with the addition of cabbage and caterpillar insect flours. This decline aligns with findings from other studies, where the incorporation of insect flours, such as cricket or mealworm powder, often introduces distinct and sometimes unfamiliar odours that may not be well-received by consumers. According to Mertens *et al.* (2019), the strong characteristic smell of certain insect powders can significantly impact the sensory profile of baked goods, often resulting in lower aroma scores.

For bread and other baked goods, the crumb appearance refers to the internal structure, including the size and distribution of air cells, color, and uniformity. A desirable crumb appearance is typically even and well-aerated**.** Crumb appearance scores in this study showed a moderate decrease with higher levels of supplementary flours. This is consistent with previous research by Niaba *et al*. (2020), which found that the addition of insect powder can alter the internal structure of bread, making it denser and less visually appealing. The presence of insect particles can also affect the uniformity and color of the crumb, contributing to lower sensory scores.

The crust appearance involves the outer layer of the bread, including its color, texture, and thickness. A well-baked crust is usually golden brown and evenly textured, contributing to the product's visual appeal and eating experience. The crust appearance of bread from blends of wheat flour, cabbage and caterpillar powders showed a decline. This reduction can be attributed to the changes in the dough properties and baking performance caused by the addition of cabbage and caterpillar insect powders. Similar findings were reported by Azzollini *et al*. (2018), who noted that bread with insect powder had a different crust color and texture, which affected its visual appeal.

Taste is a primary determinant of food acceptability and includes the basic tastes (sweet, sour, salty, bitter, and umami) as well as the overall flavor profile. Taste is often the most critical attribute in sensory evaluation as it directly affects consumer preference and satisfaction. Taste scores exhibited the most significant drop. This sharp decline is often due to the strong and distinct flavours of insect powder, which may not be palatable to all consumers. According to Lammers *et al*. (2019), the earthy and nutty flavors of insect powders can be quite pronounced and may overpower the traditional taste of wheat bread, leading to lower taste scores.

Overall acceptability scores decreased significantly ($p < 0.05$) reflecting the cumulative effect of the decreased scores in other sensory attributes. This overall decrease is common in studies involving unconventional ingredients. Halloran *et al*. (2016) reported similar trends, where the inclusion of insect flour in food products led to lower overall acceptability due to the combined impact on aroma, appearance, and taste.

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

SAMPLES	MOISTURE (%)	ASH (%)	PROTEIN (%)	FAT (%)	FIBRE (%)	CHO (%)	ENERGY VALUE (J)
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 (mL)
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	$1102.68^{a} \pm 1.36$	$231.92^{b} \pm 0.02$	$10.16^{a} \pm 0.04$	$2.85^{a} \pm 0.02$
B	$511.03^{b} \pm 0.18$	$229.15^{e} \pm 0.03$	$4.52^{b} \pm 0.01$	$2.04^{b} \pm 0.02$
C	$470.29^{c} \pm 0.45$	$235.92^{a} \pm 0.01$	$4.34^{c} \pm 0.02$	$1.71^{c} \pm 0.02$
D	$400.54^{d} \pm 0.17$	$231.84^{c} \pm 0.03$	$4.05^{d} \pm 0.02$	$1.52^{d} \pm 0.01$
E	$357.29^{e} \pm 0.02$	$218.66^{f} \pm 0.03$	$3.56^{e} \pm 0.02$	$1.32^{e} \pm 0.02$
F	$322.86^{f} \pm 0.09$	$229.54^{d} \pm 0.04$	$2.94^{f} \pm 0.02$	$1.17^{f} \pm 0.01$

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 quality evaluation of bread from wheat supplemented with cabbage and caterpillar (*Cirina forda*) flour blends was investigated and the following conclusions were drawn. There was an increase in the protein, fibre, fat and ash contents as a result of addition of the cabbage and caterpillar insect powders to the wheat bread but decreased in the moisture and carbohydrate content. There was an increase trend significantly ($P<0.05$) in the amino acid, minerals, vitamins, antioxidants and functional properties (except for swelling capacity) which shows a decreasing trend) as a result of increase addition of caterpillar insect flour at a constant level of cabbage flour to the wheat bread. The loaf volume, loaf height and the specific volume of the bread samples showed a decreased trend but a fluctuating trend of the loaf weight at an increased addition of caterpillar insect powder and at constant level of cabbage powder to the wheat bread. Sensory attributes of this study showed a decreasing trend in all the attributes of the wheat bread with the addition of the cabbage and caterpillar insect powders. Though the bread made from 100 % wheat was the most preferred. It is therefore recommended, given the increase in protein, fiber, fat, ash content, amino acids, minerals, vitamins, and antioxidants, incorporating cabbage and caterpillar flours can be beneficial for enhancing the nutritional profile of bread. However, careful formulation and optimization are needed to balance nutritional benefits with sensory acceptability. The decrease in loaf volume, height, and specific volume suggests a need for improvement in the bread's physical characteristics. Techniques such as the addition of dough improvers, emulsifiers, or gluten enhancers could help mitigate the negative impacts on the bread's structure and volume.

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Details of the AI usage are given below:

1.

2.

3.

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