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Quality Evaluation of Sourdough Bread Produced Using Wheat (*Triticum aestivum*), Orange-Fleshed Sweet Potato (*Ipomoea batata* L.) and Soybean (*Glycine max* L.) Composite Flour

DEEBOM, Maureen Dumlebabari[1], Barber, L.I[1], Obinna-Echem P C[1], Emelike, N.J.T[1]
[1]Department of Food Science and Technology, Rivers State University,
Nkpolu-Oroworokwo, Port Harcourt, Rivers State, Nigeria
*Correspondence author: maurlessy@gmail.com
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Abstract
Sourdough bread fermented with *Lactobacillus plantarum, Lactobacillus brevis* and *Saccharomyces cerevisiae* was produced from a combination of three flours (wheat, orange flesh potato and soybean). The flour used in the investigation was assessed for functional and proximate composition while the sourdough bread produced was evaluated for nutritional composition, physical properties and glycemic index. Bread leavened with commercial yeast (*Saccharomyces cerevisiae*) served as control. The flour samples possessed good functional and proximate properties. Bulk density, water/oil absorption capacity and swelling index ranged from 0.54 – 0.77 g/cm3, 2.42-3.79%, 1.32-1.42% and 1.36-2.44%, respectively, for wheat, orange flesh potato and soybean. Moisture content varied from 4.48 – 12.22%, protein (6.56 – 38.83%), fat (1.45- 20.16%), Ash (1.57-3.03%), fiber (2.00-3.55%) and carbohydrate (25.95-82.56%). Lactobacillaceae significantly ($p < 0.05$) improved the nutritional indices of the sourdough bread samples with increase in protein (14.46%), fat (8.96%), fiber (5.03%) and Ash (1.71%) against 8.45, 4.16, 1.88 and 1.07%, respectively, for protein, fat, fiber and ash content recorded for the control (bread leavened with yeast). The benefits of sourdough-fermented bread on glycemic index showed estimated glycemic value of 58.04% against 76.93% recorded for control sample. Shelf life improved to 9 days while control sample remained at 5 days. Sourdough fermentation is a valuable natural alteration for increasing the quality of bread. Combination of wheat, orange flesh potato and soybean in sourdough bread production will be of great importance in the preparation of bread that does not require high gluten and glycemic content.
Keyword: Functional, nutritional, glycemic, sourdough bread, Lactobacillus, yeast

1. Introduction

Bread is a food produced by baking leavened dough mixed with yeast and other ingredients. Commercial baker's yeast (s*accharomyces cerevisae*) has been used in bread making with the objective to improve the sensorial characteristics of bread (Lahue et al., 2020). Commercial bread is made from wheat flour which often contains additives to improve flavor, texture, color, shelf life, nutrition, and simplicity of production. Wheat flour is a powdered product made from wheat kernel and mainly used for manufacturing various bakery and pasta products (Amith, Chattopadhyay & Majundar, 2012). Wheat flour provides numerous nutrients, such as carbohydrates, protein, and minerals, the flour is unique in that, when mixed with water, its protein components (gliadin and glutenin) collectively known as gluten form an elastic network capable of holding gas and developing a firm spongy structure during baking, suitability of flour for baking is determined by its gluten content. The foremost quality characteristics of leavened wheat breads are high volume, soft and elastic crumb structure, good shelf life, and microbiological safety (Chavan and Chavan 2011). Essentially, all flours and grain products contribute complex carbohydrates (starch), vitamins, minerals, and protein. However, wheat protein is low in essential amino acids like lysine, methionine and threonine content which are desired by diabetics and gastro-intestinal patients. Wheat consumption triggers allergies, intolerance and celiac disease in some people (Li, Hou and Chen, 2013), celiac disease is a countless of health conditions derived from the body immune response to gluten.

Sourdough bread is bread made by the fermentation of dough using lactobacillaceae and yeast, lactic acid from fermentation imparts a sour taste and improves keeping qualities (Gänzle, & Michael, 2014). At the same time, the action of lactobacillaceae and yeast determines the sourdough bread characteristics in terms of acid production, aroma and leavening, resulting in an improvement of the bread volume, texture, flavour, nutritional value and shelf life of bread. Sourdough (SD) fermented bread is a natural, with no additive and "generally regarded as safe" (Magnusson et al., 2003). SD has demonstrated a higher potential to break down complex molecules into simpler forms during long fermentation. On the impact of sourdough fermentation on blood glucose some research suggests that LAB ferments free maltose and monosaccharides to lactic acid and/or acetic acid which inhibit the enzymes that metabolize starches, causing the starches to be more slowly digested when consumed. This prevents blood glucose and insulin levels from rising quickly and further aid secondary proteolysis of oligopeptides (optimal pH 6.0–8.0) by the intracellular peptidases to accumulation amino acids in the sourdough matrix. These amino acids not only enrich sourdoughs nutritionally but also improve flavour, rheology aroma and taste development of the bread (Ganzle & Gobbetti, 2013). The acidic medium preserves the dough acts as natural dough conditioner, improves flavour and gas retention resulting in good product texture, massive bread volume; during baking of the fermented sourdough, as the temperature increases, it causes the yeast to produce carbon dioxide and alcohol that cause sudden volume rise (oven spring) Gänzle, 2014). The acid medium activates phytases, proteases and pentosanases thereby contribute to dough biochemical changes. Bioactive compounds are also produced during fermentation. Besides, during fermentation, fatty acids of the flour are catalysed by lipoxygenase and hydroperoxide-lyase to produce volatile aldehyde that contributes to bread flavour. Also, sourdough fermentation improved the shelf life of baked goods resulting in reduced staling (Petel et al., 2017).

Sourdough fermentation also reduces levels of certain FODMAPs (Fermentable oligosaccharides, disaccharides, monosaccharides, and polyols), which are a type of carbohydrate that causes bowel irritation in some people; it is a class of carbohydrates poorly digested that can be classified as a prebiotic. The low levels of this type of carbohydrate in sourdough make it much more digestible for certain consumers (Menezes et al., 2019). Sourdough has also been shown to produce less gas and bloating overall, and this may also be due to its low-FODMAP profile (Rizello et al., 2019).

Minerals in some flour such as calcium, sodium, zinc, and magnesium can be isolated in a molecule known as the phytate complex, which must be broken down in order for humans to absorb. While baker's yeast is unable to break down the phytate complex, research has shown that these minerals may be present in a more available form in sourdough fermented bread. Organisms in sourdough

can break down the complex very effectively; this could increase minerals availability for absorption in the human gut (Leenhardt et al., 2005; Nionelli & Rizzello, 2016).
Soybean is an economically important crop, which is a source of energy and good-quality protein for animals and humans, as it presents a high content of protein (36-48%), lipids (18-21%) and carbohydrates (33.5%), besides the amount of crude fibre and unsaturated lipids (Badger et al., 2005). They are rich in micro and macro nutrients such as sodium, zinc, copper, potassium, iron, phosphorous, magnesium and manganese. Soybean contains health promoting phytochemicals including isoflavones, phytosterols, inositol hexaphosphate, saponins, protease inhibitors, and bioactive peptides which have been linked to the reduction of some human diseases, such as cardiovascular diseases, diabetes, obesity, hypertension, (Badger et al., 2005). Soy protein has many functional properties that is widely used in different products.
Orange-Fleshed Sweet potato (OFSP) is an improved breed of sweet potato (Ipomea batatas [L.] Lam) cultivated in tropical and semi-tropical regions (Mitra, 2012). Orange flesh sweet potato has been reported to increase children's levels of vitamin A and serum retinol concentration (Ajanaku et al., 2013) and has been used to fight global vitamin A deficiency (Degras, 2003). In Nigeria, sweet potato is eaten mostly as a snack, fried, cooked, used in pounded yam, and as a sweetener in beverage production.
In vitro starch digestibility is an enzymatic analysis to measure starch hydrolysis rate for the prediction of glycaemic index (GI). The glycemic index (GI) characterizes the carbohydrates consumed in different types of foods on the basis of postprandial level of blood glucose. Long-term intake of low GI foods was reported to associate with the reduced incidence and prevalence of heart disease, diabetes, and also some forms of cancer (Buddrick *et al*., 2015). The concept of a glycemic index was developed to provide a series classification of carbohydrate foods on the assumption that such data would be useful in situation where the patient is suffering from diabetes (Giuberti, Gallo, 2018). Highly glycemic index of wheat bread causes rapid increase of blood glucose level which is harmful for people with chronic diseases such as type II diabetes and obesity. Awareness regarding nutrition and health in simple traditional food processes, such as sourdough bread, has increased over the past years. Sourdough bread fermentation is claimed to promote various health benefits, such as better digestibility and enhanced nutritional content, improvement in nutrient bioaccessibility and reduction in the GI of bread by sourdough fermentation have already highlighted (Dimidi, Rossi and Whelan, 2019).
Commercial bread made from wheat flour is low in essential amino acids and contains gluten with short shelf life, however, sourdough bread is linked with longer shelf life, low glycemic index, higher sensorial quality and better nutritional value, hence, this study focused at Quality evaluation of sourdough bread produced using wheat (*triticum aestivum*), orange-fleshed sweet potato (*ipomoea batata* l.) and soybean (*glycine max* l.) composite flour.

2. Materials and methods

2.1.Materials

Wheat flour, orange flesh potato tubers and soybean, granulated cane sugar, iodized salt, eggs, bakery fat and baker's compressed yeast (*Saccharomyces cerevisiae*) were purchased from Mil 3 Market, Port Harcourt, Rivers State, Nigeria.

2.1.2. Starter cultures for the sourdough bread making

Pure cultures of *Lactobacillus plantarum and Lactobacillus brevis* were also purchased from Mil 3 Market, Port Harcourt, Rivers State, Nigeria.

2.1.3. Chemicals and reagents

Chemicals used in this study are of analytical grade procured from Unique scientific, Ogbumnabali, Port Harcourt, Nigeria.

2.2. Methods

2.2.1. Starter culture preparation

Starter culture was prepared using the method described by De, Sena, Bhowmik, Maity, Bhowmik, (2016) with some modifications.

2.2.2. Preparation of De Man-Rogosa –Sharpe Agar (MRS) Medium

The medium was prepared by weighing 68 g of MRS agar into 1000 ml distilled water in conical flask. This was brought to boiling to dissolve completely by heating it over Bunsen burner flame for 30 min. The medium was sterilized at 121^{o}C for 15 min using the autoclave at 15 psi. The medium was allowed to cooling to 45^{o}C and 15 mL of the medium was poured into sterile petri dishes. The plates were allowed to set and dried in an oven before used (De et al. 2016).

2.2.3. Preparation Sub-culturing of pure culture

Pure cultures *(Lactobacillus plantarum* and *Lactobacillus brevis*) were sub-cultured on slants prepared from MRS media in laminar flow. This was incubated at 37℃ for 24 h.

2.2.4. Preparation of orange flesh potato flour

The method described by Amith, Chattopadhyay & Majundar, (2012) with some alterations was used as shown in Fig 1. Five hundred grams of orange flesh potato tubers were peeled, washed, sliced, soaked (for 24 h), oven-dried, and milled into powder using a milling machine. The milled powder was sieved using 0.25 mm mesh and packaged until required for use.

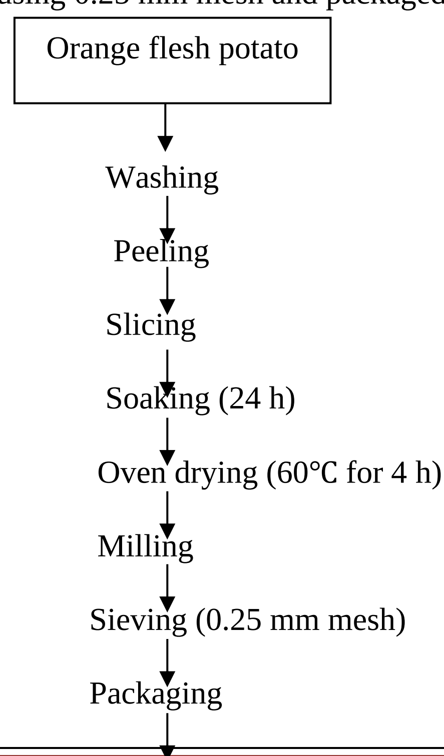

Fig. 1: Production of Orange flesh potato flour
Source: (Amith, Chattopadhyay & Majundar, 2012)

2.2.5. Preparation of soybean flour

Soybean flour was produced according to the method described by (Barber, Osuji, Onuegbu & Ogueke, 2020) with some modifications (Figure 2). Soybeans (300 g) were steeped for 24 h. The rehydrated beans were rubbed in-between the hand to remove the hull and washed with clean water. The bean seeds was drained and boiled for 30 min at 100˚C and dried in the oven at 60˚C for 8 h. It was then milled into flour and packaged for further use.

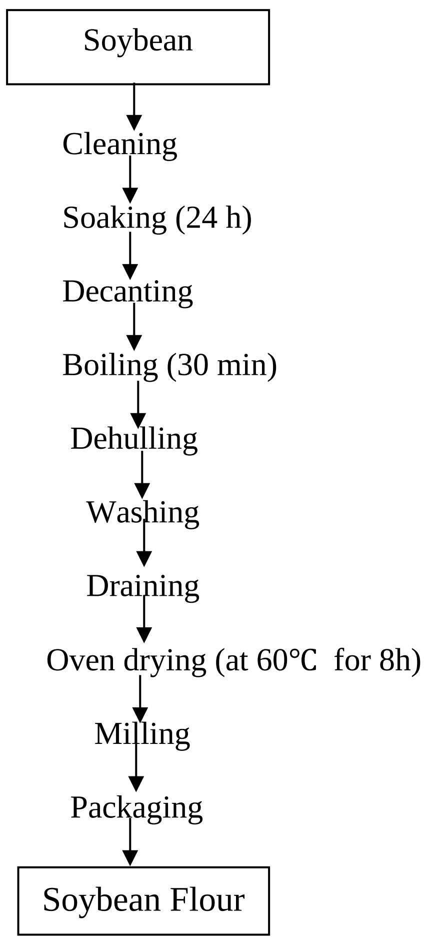

Fig. 2: Production of soybean flour
Source: Barber *et al.* (2020)

2.2.6. Preparation of sourdough bread

The production of sourdough bread was carried out in the Department of Food Science and Technology microbiology laboratory using *Lactobacillus brevis, Lactobacillus plantarum* and *Saccharomyces cerevisiae* with some modifications in the method described by Ogunsakin, Banwo, Ogunremi & Sanni, (2015). The recipe used for preparation of the sourdough bread is mentioned below in Table 1. The dough was prepared and inoculated with organisms from fermented dough in sterile distilled water. Likewise, dough was prepared using (1 %) of baker's yeast; this served as the control sample. The dough with the baker's yeast (control) was allowed standing for 45 min, while the dough inoculated with organisms from fermented leavened dough was allowed standing for 6 h; however, both samples were baked at 180–200 ºC for 45–60 min.

Table 1 Recipe for sourdough bread preparation

S/N	**Ingredients**	**Weight (g)**
1	Flour (60% wheat flour, 20% potato and 20% soybean)	100.0
2	Water	60.0
3	Sugar	2.0
4	Salt	1.5
5	Bakery fat	2.0
6	Baker's yeast (*Saccharomyces cerevisae*)	1.0

Source: Settanni et al. (2013).

3.0. Analytical Methods

3.1. Functional properties of the flours used in sourdough bread production

Each composite flour sample was analyzed using standard methods described by AOAC, (2019).

3.1.1 Bulk density (loose and pack)

This was determined by the procedure. For loose bulk density, an empty and dried 50 mL measuring cylinder was weighed and flour sample allowed falling freely into it up to the mark, without tapping. The flask was weighed again along with the sample and value obtained recorded. For packed bulk density, the same sample was tapped by gently tapping the cylinder 10 times on the bench top from a height of 5 cm, and more of the sample added up to the mark before weighing. The volume and weight of the sample was recorded.

$$\text{Bulk density } (g/cm^3) = \frac{Weight\ of\ sample}{Volume\ of\ sample} \quad \text{Eq. (1)}$$

3.1.2 Water Absorption Capacity

To 1 g of the flour samples, 15 mL of distilled water was added in a 25 mL centrifuge tube and agitated on a vortex mixer for 2 min. It was then centrifuged at 4000 rpm (revolutions per min) for 20 min. The supernatant was decanted and discarded. The adhering drops of water were removed and the tube re-weighed as described by AOAC, (2019).

$$WAC = \frac{Weight\ of\ tube + sediment - weight\ of\ empty\ tube}{Weight\ of\ sample} \quad \text{Eq. (2)}$$

3.1.3 Oil Absorption Capacity

The method by Onwuka, (2018) was used. One (1 g) gram of the flour sample was mixed with 10 mL refined corn oil in a centrifuge tube and allowed to stand at room temperature (30 ± 2°C) for 1 h. It was centrifuged at 1600 rpm for 20 min. The volume of free oil was recorded and decanted. Fat absorption capacity was expressed as mL of oil bound by 100 g dried flour**.**

3.1.4 *Swelling Power*

One gram (1g) of the sample was weighed into 50 mL plastic centrifuge tube and 50 mL of distilled water was added and mixed gently. The resultant slurry was heated in a water bath at 60ºC for 10 min. The solution was gently shaken during heating to prevent clumping of the starch and the solution was centrifuged at 3000 rpm for 10 min. Then the supernatant was decanted and dried to determine the amount of soluble solid and dissolved and was used to calculate the solubility. The weight of the sediment was recorded and moisture content of the sediment gel would be determined according to the method described by AOAC, (2019).

$$\text{Swelling power} = \frac{\text{Weight of the wet mass of seed}}{\text{Weight of dry matter in the gel}} \quad \text{Eq. (3)}$$

3.2. Proximate Analysis

The standard procedure of AOAC, (2019) was applied for proximate analysis including moisture, crude protein, crude fat, and crude fibre and ash contents of the formulated sourdough bread. Total carbohydrates were calculated difference from the sum of moisture, crude protein, crude fat, ash and crude fibre, and subtracting from 100%.

3.3. In-vitro starch digestibility and estimated glycemic index (eGI) of sourdough bread

The in vitro starch digestibility (g/100g) and glycaemic index (GI) was determined based on Goñi *et al*. (2018). The glucose content was analysed using GOPOD K-GLUC (AACC, 2000). Starch digestion rate was expressed as the percentage of total hydrolysed starch at different time intervals (30, 60, 90, 120, 150 and 180 min). The percentage of hydrolysed starch was calculated by multiplying the glucose content by 0.9. Rapidly digestible starch (RDS) and slowly digestible starch (SDS) contents were calculated as in Equation below:

RDS (%) = (G20 – FG) × 0.9

SDS (%) = (G120 – G20) × 0.9

Where; G20 = quantity of free glucose measured after 20 min incubation with the enzyme,
G120 = quantity of free glucose measured after 120 min incubation with the enzyme and
FG = Free glucose content

The free glucose (FG) content was carried out using a D-Glucose GOPOD assay Kit (Megazyme International K-GLUC, Ireland) (AACC, 2000). Total starch hydrolysis (%) values of samples were plotted against time (min) and the area under the curve (AUC) was calculated using Microsoft Excel. The hydrolysis index (HI) was obtained by dividing the AUC of the sample by the AUC of the standard reference. Glucose was used as the standard reference (HI=100). The GI value was calculated: GI = (0.594 × HI) + 39.71.

Determination of shelf life of bread samples

The bread loaves were wrapped in sterile plastic bags and stored at room temperature (28±2℃) on the shelf to determine the storage time (in days) until mould growth became visible (Settanni, Ventimiglia, Alfonzo, Corona, Miceli, Moschetti, 2013).

4.0. Results

The proximate composition and functional properties of the flour samples are shown in Table 2, while the proximate composition and physical features of sourdough bread samples are presented in Table 3.

5.0. Discussions

Functional characteristics of the flour samples

The functional property of a food is characterized by the structure, quality, texture, nutritional value, acceptability, and (or) appearance of the food product (Singh, 2006; Siddiq et al., 2009). The functional properties of foods and flours are influenced by the components of the food material, especially the carbohydrates, proteins, fats and oils, moisture, fibre, ash, and other ingredients added to the food (flour), such as sugar alcohols as well as the structures of these components (Awuchi, 2017; Awuchi and Echeta, 2019). Functional characteristics are necessary to evaluate and predict how novel proteins, fat, fibre and carbohydrates may perform in specific systems and show whether they can be used to inspire or replace conventional component (Siddiq et al., 2009).

The bulk density (g/cm^3) (Table 2) of the flour samples varied between 0.77, 0.62 and 0.54 g/cm^3, respectively, for wheat, orange flesh potato and soybean flour. Suresh, Samsher & Durvesh, (2015) reported bulk densities of flours that ranged from 0.76 to 0.82 g/cc in their study on the evaluation of functional properties of composite flours and sensorial attributes of composite flour biscuits. Bulk density is the mass of many particles of flour material divided by the total volume they occupy (Suresh et al., 2015). It reflects the relative volume of the required packaging material, the higher the bulk density of the flour, the denser the packaging material required for packaging. Bulk density is used to assess flour heaviness, storage, and transport properties; with a lower bulk density, a lower amount may be packaged within a constant volume (Iwe *et al*., 2016). Studies suggest that bulk density of flours may be influenced by the initial moisture content, particle size, fibre and starch of flours. High bulk density of flours suggests their suitability for application in food preparations while low bulk density would be useful in the formulation of complementary foods (Montemurro et al. 2019).

Water absorption capacity ranged from 2.42 – 3.79 g/g with the highest value found in orange flesh potatoes while the lowest was observed in the wheat flour. Water absorption capacity is the amount of water (moisture) taken up by food/flour to achieve the desirable consistency and create quality food product. It is the optimum amount of water required to be added to dough before it becomes excessively sticky to process (Tenagashaw *et al*., 2015). Water absorption can influence bread parameters and baking: Proofing, fracture stress of bread crumb, Loaf volume, bread yield, final products attributes, machinability and shelf life (Iwe *et al*., 2016). The highest WAC of potato flour (3.79%) could be attributed to the presence of higher amount of carbohydrates (starch) and fibre.

The highest value of OAC was observed in soybean flour (1.42%), followed by wheat flour (1.34 %) and orange flesh potato flour (1.32%). The water and oil binding capacity of food protein depend upon the intrinsic factors like amino acid composition, protein conformation and surface polarity or hydrophobicity (Suresh and Samsher, 2013). Oil absorption capacity is the binding of fat by the non-polar side chain of proteins. The Oil absorption capacity is an essential functional property that contributes to enhancing mouth feel while retaining the food products' flavor (Iwe *et al*., 2016). The rate of oil absorption is very high in foods with high protein content. Soybean flour having highest OAC could therefore be a better flavor retainer than wheat and orange flesh potato flour. The ability of the proteins of these flours to bind with oil makes it useful in food system where optimum oil absorption is desired. This makes flour to have potential functional uses in foods such as sausage production.

Swelling capacity was significantly ($p<0.05$) lowest in wheat flour (1.36 g/g) and highest in orange flesh potato (2.44%). The swelling capacity is the measure of the starch ability to absorb water and swell, and also reflects the extent of associative forces in the starch granules. It is an indication of the non-covalent bonding between the molecules of starch granules and also one of the factors of the α-amylose and amylopectin ratios (Iwe et al., 2016). The swelling capacities (index) of flours are influenced by the particle size, species variety and method of processing or unit operations (Eke-Ejiofor, Wordu, and Bivan, 2018).

Proximate composition of the flour samples

From Table 2 the obtained flour from wheat flour, orange flesh potato and soybean was found to contain, respectively, 12.22, 5.77 and 4.48% of moisture. The lower moisture content of flours samples makes it appropriate for long term storage without deterioration (Peter and James, 2000). The low moisture observed for the flours was a good indicator of their potential to have longer shelf life. It is believed that materials such as flour and starch containing more than 12% moisture have less storage stability than those with lower moisture content. For this reason, a water content of 10% is generally specified for flours and other related products (Awuchi, 2019).

The lowest protein content (6.56%) was recorded for orange flesh potato whereas the highest value (38.83%) was obtained in soybean flour. The higher protein content is important for strong elastic dough which will provide high water absorption capacity with excellent gas holding properties and will yield bread with good volume, grain and texture (Ma, Wang, Guo, Wang, Huang, Sun, Wang, 2021).

Values obtained for crude fat and ash content ranged from 1.45- 20.16% and from 1.57-3.03% respectively, for wheat, orange flesh and soybean flour (Table 2). Fat has the unique ability to absorb and preserve flavors. Fats and oils can alter a food's appearance by creating a glossy or moist visual texture. On the other hand, ash content indicates the presence of minerals in the flour. The results obtained in the present study are in line with previous findings.

Crude fibre and carbohydrate varied from 2.0 - 4.55% and 57.65 - 82.56% in wheat flour, orange flesh potato and soybean flour, respectively. The values of fiber were higher than values 0.29%-0.59% reported by Beghin *et al.* (2022); Cappelli & Bettaccini, (2020). Carbohydrate was highest (82.56%) in the orange flesh potatoes flour while soybean flour recorded the lowest (25.95%) carbohydrate content.

Proximate composition and physical features of sourdough bread

The proximate composition and physical features of the sourdough bread samples are presented in Table 3. From the table it can be seen that sourdough fermentation significantly ($p<0.05$) increased the protein (14.46%) and fibre contents (5.03%) of the sourdough bread sample when compared with yeast fermentation with protein (8.45%) and fibre (1.88%). This indicate that the composite flour blend leavened with starter cultures is a good source of protein and fibre, and can be used in the production of functional food products. Intake of food with high fibre content has been linked to the reduction of diabetes, obesity, and haemorrhoids (Ohizua et al., 2017). SD fermentation boosts the activity of enzymes, such as cellulases and hemicellulases, which break down cell walls and improve the accessibility and extraction efficiency of dietary fiber. According to Akamine,

Mansoldo, Vermelho, (2023), promoting a healthy colon environment and providing chemopreventive benefits, Increasing the activity of protease while reducing the activity of amylase in SD makes the fiber more soluble. The carbohydrate of the starter culture leavened bread samples is low (44.63%) when compared with 63.16% recorded for the bread leavened with yeast which makes the bread samples suitable choice of food for the elderly.
In the In-vitro starch digestibility and estimated glycemic index of bread Samples, the total starch (TS,) rapidly digestible starch (RDS), and slowly digestible starch (SDS) values of the sourdough and control bread samples are presented in Table 4. Sourdough bread had the lowest TS and RDS (36.36 and 8.32 %) and highest (39.76 and16.14%) in the control sample, On the other hand, SDS and HI were lowest (11.77 and 28.76%) in sourdough bread and significantly ($p<0.05$) highest (20.58 and 67.82 %) in the control sample. Estimated glycemic index (eGI) were, respectively, 58.04 and 76.73% in sourdough bread and the control sample. From studies, because the rapid digestion of starch (RDS) causes an increased glycemic response, products with low RDS are preferred by diabetic patients (Buddrick, Jones, Hughes, Kong, Small, 2015). According to Buddrick, Jones, Hughes, Kong, Small, (2015) in vitro starch digestion and in vivo blood glucose levels in healthy individuals both decreased significantly after consumption of sourdough bread compared with bread leavened with yeast. When comparing the bread samples it was observed that the addition of LAB decreased the eGI values more effectively than control sample. The glycemic index (GI) is a ranking criterion for foods containing carbohydrates based on their effect on glucose levels in the blood (glycaemia) during the two hours of ingestion. It allows comparison of the glycemic power of each food directly measured during digestion. Increased awareness in health issues has led to increased development of functional foods with specific health benefits; sourdough's impact on Glycemic Index of Bakery Products is well documented (Fardet, 2015).
Bread shelf-life can be greatly improved by fermentation, Shadi et al. (2010), in their study, used lactic acid fermentation to improve the shelf life of baguette and observed that the bread with highest percentage of sourdough had the lowest staling index. Again, in the study of Edema and Sanni, (2008), mould growth was inhibited in the sour maize breads for up to seven days. Lactic acid bacteria (LAB) strains are able to improve the shelf life of several food products (Ma, Wang, Guo, Wang, Huang, Sun, Wang, 2021) since the acids formed during fermentation process, lower the pH thus inhibiting the growth of spoilage organisms (Gänzle, 2014).)

6.0. Conclusion

LAB culture was used successfully in preparation of sourdough bread from three flours (wheat, orange flesh potato and soybean). Physicochemical properties of orange flesh potato and soybean flours used in this study have been found to be similar to those of wheat flour and are likely to have the potential to replace it Sourdough fermentation of wheat, orange flesh potato and soybean dough substantially improved the nutritional composition of the sourdough bread, it resulted in longer shelf life and low glycemic index of the bread produced. The results obtained can be explained by high degree of acidity in the samples of bread with sourdough fermentation Soybean and orange flash sweet potato addition to sourdough bread can be a sustainable healthy food for people suffering from celiac disease. Also, soybean and orange flash sweet potato and other tuber crops can be substitutes for the major raw materials in bread making because of the abundance of these crops in some parts of Nigeria.

Tables

Table 2 Proximate content and functional characteristics of the flour samples (%/g/cm^3)

Sample	Moisture	Crude protein	Fat	Ash content	Crude fibre	Carbohydrate	BD	WAC	OAC	SC
WF	12.22^a±0.01	8.18^b±0.01	9.16^b±0.00	1.57^c±0.00	2.03^b±0.07	66.84^b±0.01	0.77^a±0.00	2.42^c±0.00	1.34^b±0.01	1.36^c±0.00
OFSP	5.77^b±0.01	6.56^c±0.07	1.45^c±0.07	1.75^b±0.01	2.00^c±0.00	82.56^a ±0.01	0.62^b±0.00	3.79^a±0.00	1.32^b±0.00	2.44^a±0.01
SB	4.48^c±0.01	38.83^a±0.00	20.16^a±0.01	3.03^a±0.01	3.55^a±0.00	25.95^c±0.07	0.54^c±0.00	3.64^b±0.01	1.42^a±0.00	2.12^b±0.01

Values are means ± standard deviation of duplicate determination, Means that do not share a letter are significantly different (P<0.05). Key: WF = wheat flour, OFSP = orange flesh potatoes flour, SB = soybean flour, BD = bulk density, WAC = water absorption capacity, OAC = oil absorption capacity, SC = swelling capacity

Table 3 Proximate composition and Shelf life stability of sourdough bread samples

Sample	Moisture (%)	Protein (%)	Crude fat (%)	Crude fibre (%)	Ash (%)	Carbohydrate (%)	Shelf life
SD	25.21^a±0.00	14.46^a±0.16	8.96^a±0.01	5.03^a±0.14	1.71^a±0.01	44.63^b±0.02	9
BYS	21.28^b±0.04	8.45^b±0.15	4.16^b±0.12	1.88^b±0.11	1.07^b±0.07	63.16^a±0.03	5

Values are means ± standard deviation of duplicate determination, Means that do not share a letter are significantly different (P<0.05).

Key: SD = sourdough bread, BYS= sample leavened with baker's yeast

Table 4: In-vitro starch digestibility (g/100g) and estimated glycemic index (eGI) of sourdough and control bread

Sample	TS	RS	RDS	SDS	HI	eGI
Sourdough bread	36.36^b ± 0.02	16.93^a ± 0.71	8.32^b ± 0.10	11.77^b ± 0.11	28.76^b ± 0.11	58.047±0.31
Control	39.76^a ± 0.14	2.86^b ± 0.65	16.14^a ± 0.12	20.58^a ± 0.07	67.82^a ±0.04	76.93 ±0.16

Values are presented as mean ± SD. Values with different superscripts within the same column are significantly different ($p<0.05$).
Key: TS = Total starch, RS = resistant starch, RDS = rapidly digestible starch, SDS = slowly digestible starch, HI = hydrolysis index
eGI = estimated glycemic index

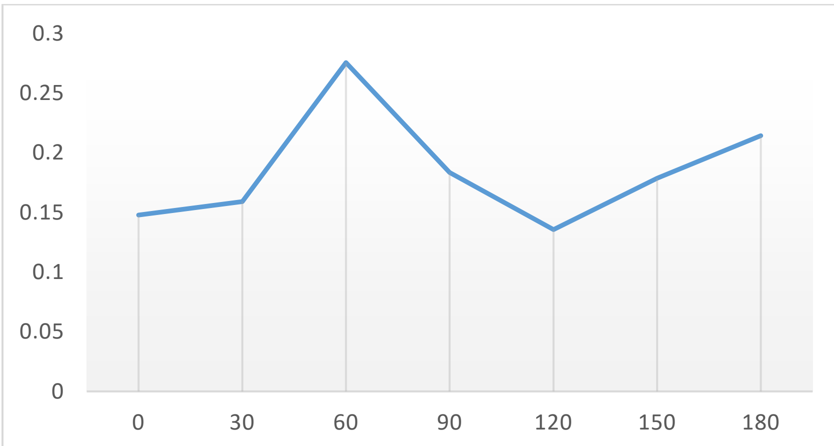

Figure 1: The hydrolysis curve for the sourdough bread

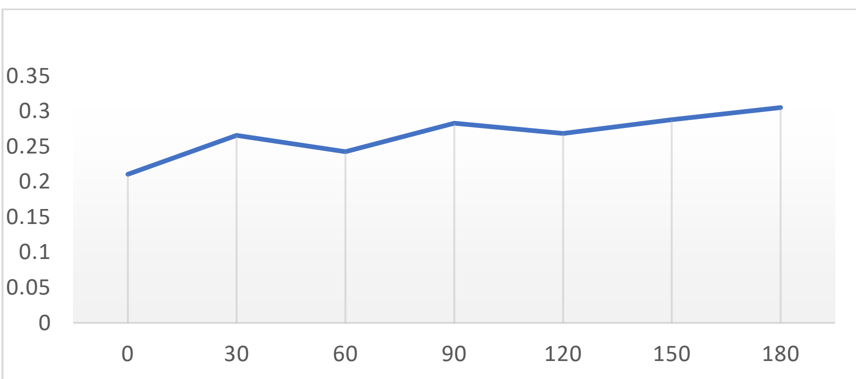

Figure 2: The hydrolysis curve for the control bread sample

References

Akamine, I.T.; Mansoldo, F.R.P.; Vermelho, A.B, (2023). Probiotics in the Sourdough Bread Fermentation: Current Status. Fermentation 2023, 9, 90.Fermentation: Current Status. Fermentation, 9, 90.

Amith, N., Chattopadhyay, P.K. & Majundar, G.C. (2012). Operation of HTST process pararmeters for production of ready-to-eat potao-soy snack. *Journal of Food Science and Technology*- Mysore-49(4): 427-38.

Arora, K., Ameur, H., Polo, A., Di Cagno, R., Rizzello, C. G., & Gobbetti, M. (2021). Thirty years of knowledge on sourdough fermentation: A systematic review. Trends in Food Science & Technology, 108, 71–83

Awuchi, C. G. (2019). Proximate Composition and Functional Properties of Different Grain Flour Composites for Industrial Applications. *International Journal of Food Sciences*, 2(1):43- 64,

Badger, T.; Ronis, M.; Simmen, R. & Simmen, F. (2005). Soy protein isolate and protection against cancer, In: J Am Coll Nutr, 24, 2, 146S–149S

Barber, L.I.; Osuji, C.M.; Onuegbu, N.C. & Ogueke, C.C. (2020). 'Quality characteristics of probiotic soy yoghurt with enzyme hydrolysed breadfruit and rice additives'. *American Journal of Food Science and Technology*. 8, no. 6: 233-241.

Beghin, A. S., Ooms, N., Kristof Brijs, |, Pareyt, B., & Delcour, J. A. (2022). Release of 14C-labeled carbon dioxide from ascorbic acid during straight dough wheat bread making. Wiley Online Library, 99(4), 731–736.

Buddrick, O.; Jones, O.A.H.; Hughes, J.G.; Kong, I. & Small, D.M, (2015). The effect of fermentation and addition of vegetable oil on resistant starch formation in wholegrain breads. Food Chemistry, 180, 181–185

Cappelli, A., & Bettaccini, L. (2020). The kneading process: A systematic review of the effects on dough rheology and resulting bread characteristics, including improvement strategies. Elsevier. https://www.sciencedirect.com/science/article/pii/S0924224420305665

Chavan R. S. and Chavan S. R. (2011). Sourdough Technology—A Traditional Way for Wholesome Foods: A Review. Comprehensive Reviews in Food Science and Food Safety.10: 169–182.

De, S., Sena, S., Bhowmik, I., Maity, S. & Bhowmik, S. (2016). Isolation, Characterisation and Identification of Lactobacilli spp. And study of its pharmacological activity in-vitro. *International Journal of Recent Science Research*; 7(11):14296-14298

Dimidi, E. Cox, S.R. Rossi, M. Whelan, K, (2019). Fermented foods: definitions and characteristics, impact on the gut microbiota and effects on gastrointestinal health and disease, Nutrients 11 (8) (2019) 1806.

Edema, M.O. & Sannni, A.I. (2008): Functional properties of selected starter cultures for sour maize bread. Food Microbiol., 25, 616–625

Eke-Ejiofor J., Wordu G.O., and Bivan S.K. (2018). Functional and pasting properties of acha, deffated soybean and groundnut flour blends.A*merican Journal of Food Science and Technology*, 6(5); 215-218.

Fardet, A., (2015). Complex foods versus functional foods, nutraceuticals and dietary supplements: differential health impact (Part 1). Agro Food Ind. Hi Tech. 26, 20e24.

Fernández-Peláez, J.; Paesani, C.; Gómez, M, (2020). Sourdough Technology as a Tool for the Development of Healthier Grain-Based Products: An Update. Agronomy 2020, 10

Gänzle, Michael G. (2014). "Enzymatic and bacterial conversions during sourdough fermentation" . Food Microbiology. V International Symposium on Sourdough - Cereal Fermentation for Future Foods, Helsinki 10–12

Gobbetti, Marco; De Angelis, Maria; Di Cagno, Raffaella; Calasso, Maria; Archetti, Gabriele; Rizzello, Carlo Giuseppe (2019). "Novel insights on the functional/nutritional features of the sourdough fermentation" . International Journal of Food Microbiology. 302: 103–113

Lahue C., Madden A., Dunn R. and Smukowski C., (2020). History and domestication of saccharomyces cerevisiae in bread baking. Front. Genet. 11: 584718.

Leenhardt, F., Levrat-Verny, M. A., Chanliaud, E., & Rémésy, C. (2005). Moderate decrease of pH by sourdough fermentation is sufficient to reduce phytate content of whole wheat flour through endogenous phytase activity. Journal of Agricultural and Food Chemistry, 53(1), 98–102

Li J., Hou G. and Chen Z., (2013). Whole grain slatine crackers: formulation, processing, and quality improvements. Cereal Foods World. 58: 180–185

Liu, Z. S., & Chang, S. K. (2013). Nutritional profile and physicochemical properties of commercial soymilk. Journal of Food Processing and Preservation, 37(5), 651–661.

Ma, S.; Wang, Z.; Guo, X.; Wang, F.; Huang, J.; Sun, B.; Wang, X, (2021). Sourdough improves the quality of whole-wheat flour products: Mechanisms and challenges—A review. Food Chemistry 360, 130038.

Menezes, L. A., Molognoni, L., de Sá Ploêncio, L. A., Costa, F. B. M. M., Daguer, H., & Dea Lindner, J. De. (2019). Use of sourdough fermentation to reducing FODMAPs in breads. European Food Research and Technology, 245(6), 1183– 1195

Montemurro M et al. (2019): Investigation of the nutritional, functional and technological effects of the sourdough fermentation of sprouted flours. *International Journal of Food Microbiology*, 302:47-58.

Murugkar, D. A. (2014). Effect of sprouting of soybean on the chemical composition and quality of soymilk and tofu. Journal of Food Science and Technology, 51(5), 915–921.

Nionelli, L., & Rizzello, C. G. (2016). Sourdough-based biotechnologies for the production of gluten-free foods. Foods, 5(3), 1–14.

Oyeyinka, S. A., Singh, S., Adebola, P. O., Gerrano, A. S., & Amonsou, E. O. (2015). Physicochemical properties of starches with variable amylose contents extracted from bambara groundnut genotypes. Carbohydrate Polymers, 133, 171–178.

Ohizua, E. R., Adeola, A.A, Idowu M.A., Sobukola, O.P, Afolabi, T A…………….Falomo, A., (2017) Nutrient composition, functional, and pasting properties of unripe cooking banana, pigeon pea, and sweetpotato flour blends. Food Science and Nutrition., 7, 1–13.

Ogunsakin, A.O., Banwo, K., Ogunremi, O.R. & Sanni A.I. (2015): Microbiological and physico-chemical properties of sourdough bread from sorghum flour. *International Food Research Jouranl*, 22(6), 2610–2618

Paucar-Menacho, L. M., Berhow, M. A., Mandarino, J. M. G., De Mejia, E. G., & Chang, Y. K. (2010). Optimisation of germination time and temperature on the concentration of bioactive compounds in Brazilian soybean cultivar BRS 133 using response surface methodology. Food Chemistry, 119(2), 636–642.

Peter C.M. and James H.B. (2000).Cereal biotechnology (Edits) Woodhead Publishing Limited. 2:132

Poliseli-Scopel, F. H., Hernández-Herrero, M., Guamis, B., & Ferragut, V. (2012). Comparison of ultra high pressure homogenization and conventional thermal treatments on the microbiological, physical and chemical quality of soymilk. LWT-Food Science and Technology, 46(1), 42–48

Rizello, C. G., Portincasa, P., Montemurro, M., di Palo, D. M., Lorusso, M. P., de Angelis, M., … Gobbetti, M. (2019). Sourdough fermented breads are more digestible than those started with baker's yeast alone: An in vivo challenge dissecting distinct gastrointestinal responses. Nutrients, 11(12), 2954.

Settanni, L., Ventimiglia, G., Alfonzo, A., Corona, O., Miceli, A., Moschetti, G. (2013). An integrated technological approach to the selection of lactic acid bacteria of flour origin for sourdough production. Food Res Int, 12;54(2):1569-78.

Siddiq M, Nasir M, Ravi R, Dolan KD, Butt MS (2009). Effect of defatted maize germ addition on the functional and textural properties of wheat flour. *International Journal of Food Properties.* 12:860-870.

Singh U (2001). Functional properties of grain legume flours. *Journal Food Science Technology* 38:191-199.

Tenagashaw, M. W., Kenji, G. M., Melaku, E. T., Huyskens-Keil, S. and Kinyuru, J. N. (2015). Proximate composition & selected functional properties of complementary foods from teff fortified with soybean and orange-fleshed sweet potato. RUFORUM Working Document Series (ISSN 1607-9345) No. 14 (1): 953-965.