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Effect of Processing Methods on the Quality of Biscuit Supplemented with Pigeon Pea Seed Flour

P. I. Akubor[1*]

[1]*Department of Food Science and Technology, Federal University, Wukari, Taraba State, Nigeria.*

Author's contribution

The sole author designed, analyzed and interpreted and prepared the manuscript.

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ABSTRACT

Aim: To determine the effect of toasting, boiling, germination and fermentation of pigeon pea seeds on the quality of biscuit supplemented with pigeon pea flour.
Design of Study: The experiment was carried out in 3 replications and the data were analyzed by analysis of variance in completely randomized design.
Place and Duration of Study: The study was carried out in 2016 at The Federal Polytechnic, Idah, Kogi State, Nigeria.
Methodology: Flours were prepared from raw, toasted, boiled, germinated and fermented pigeon pea seeds. The flours were analyzed for the proximate composition. Each of the flours was used to substitute 10% wheat flour. Biscuits were prepared from the various blends and evaluated for the physical, chemical and sensory properties.
Results: There were no significant differences (P >0.05) among the pigeon pea flour based biscuits in height, diameter and density. The biscuit containing germinated pigeon pea flour was heavier (5.0 g) and occupied more volume (69 cm^3) than the other biscuits containing pigeon pea flour where weight and volume ranged from 4.0-4.6 g and 41-50 cm^3, respectively. All the pigeon pea flour based biscuits had comparable values with the 100% wheat flour biscuit for the physical attributes. There were no significant differences(p>0.05) among the biscuits containing pigeon pea flours in all the sensory attributes except for color where the biscuit containing germinated pigeon

**Corresponding author: E-mail: akuborpeter@gmail.com;*

pea flour was rated lower. The pigeon pea flour based biscuits were not significantly different (P>0.05) from the 100% wheat flour biscuit except for color where the 100% wheat flour biscuit was less preferred. The fat contents of the biscuits containing pigeon pea flours (14.0 - 15.9%) were lower than 17% for the biscuit containing raw pigeon pea flour. All the biscuits containing treated pigeon pea flour except that containing boiled pigeon pea flour had higher amounts of protein, crude fiber and carbohydrate than the biscuit containing raw pigeon pea flour. The Mg, Ca, Fe and Zn contents were higher in the biscuits containing raw pigeon pea flour than in the treated pigeon pea flour biscuit.

Conclusion: Boiling, toasting, germination and fermentation of pigeon seeds had no adverse effects on the physical, chemical and sensory properties of biscuits prepared from pigeon pea flour and wheat flour blends.

Keywords: Pigeon pea; boiling; toasting; germination; fermentation; biscuit.

1. INTRODUCTION

Biscuit is one of the major staple wheat based food products that has gained wide acceptance among consumers worldwide for many years. Biscuit is prepared from a mixture of flour, salt, sugar, yeast and water. However, wheat which is the predominant ingredient for making biscuit is rich in carbohydrates but low in protein, essential phytochemicals and minerals [1]. Thus, various efforts have been made in enriching biscuits with legumes, fruits, roots etc to increase the levels of these nutrients [2,3,4,5]. The biscuit making potential of millet/pigeon pea flour was also studied by Eneche [6]. Edema et al. [7] suggested the addition of not than 10% protein supplements in order to produce nutritionally balanced acceptable baked products.

Pigeon Pea (*Cajanus cajan*) ranks fifth in importance among edible legumes in the world [8]. Although, India remains the major producer of pigeon pea, the interest in pigeon pea in other parts of the world is ascribed to its nutritional, medicinal, economical and agronomic usefulness [9]. In Nigeria, the plant is reported as one of the underutilized legumes with broad potentials [10]. Presently, different varieties of pigeon pea are grown in Nigeria. Reports showed that pigeon peas contain 17.9-24.3% protein, 58.7% carbohydrate, 1.2-8.10% crude fiber and 0.6-3.8% fat [8,9]. Pigeon pea is also a good source of calcium, phosphorus, magnesium, iron, sulphur etc [9]. Clinical studies showed the potential of pigeon pea seed based meal in the dietary management of diabetes mellitus and cardiovascular diseases [1]. The pigeon oil was also reported to contain anti-sickling agent [1]. This claim was further supported by the work of Amaefule and Nwagbara [10] in which the extract of *Cajanus cajan* reversed sickling of the erythrocytes.

In spite of its high nutritional qualities, pigeon is not a popular in the Western and Northern states of Nigeria. It has no industrial use as at now. Like most tropical legumes, pigeon peas contain antinutritonal substance, such as trypsin inhibitors and tannins which affect their utilization, especially the raw seeds [1]. They also contain flatulence causing oligosaccharides such as starchyose, raffinose and verbacose [1]. Similarly, the characteristic problem of hard-to-cook phenomenon also hinders the extensive use of pigeon peas as food. The dried seeds are hard and by the traditional processing methods, it takes 24 hours to prepare a meal of pigeon pea [11]. Various methods have been used to improve the food value of pigeon pea by improving its processing, storage, preservation and utilization. Such methods included germination [12,13], fermentation [11], toasting [14], boiling [14], irradiation [8] etc. The processing methods employed in the preparation of pigeon pea may affect the physicochemical properties of the seeds hence, their potential food application. Moderate heat treatment has been reported to improve the digestibility of plant proteins without developing toxic derivatives and to inactivate several enzymes such as proteases, lipases, lipoxygenases, amylases and other oxidative and hydrolytic enzymes. Roasting is the most significant step in processing of different seeds, that causes important physical, chemical, structural and sensorial changes [15]. The roasting process could promote more flavor, desired color, increased the palatability and improved efficiency of subsequent treatment [14]. One of the main desired outcomes of roasting process is the increase in antioxidant activity that occurs mainly due to the formation of Maillard reaction products [15]. Boiling helped to destroy protease inhibitors and cyanogens in pigeon peas [11]. Toasting and boiling have been reported to enhance taste and flavor of foods [15]. Fermentation gives the food longer keeping quality, develops flavor and decreases anti-nutritional factors in foods [15]. The study therefore, determined the effect of toasting, germination and fermentation of pigeon pea seeds on the quality of biscuit supplemented with the pigeon pea flour.

2. MATERIALS AND METHODS

2.1 Source of Materials

The pigeon pea seeds were purchased from Oja-Oba market in Ijare town, Ondo State. The seeds were cleaned of extraneous materials and stored in jute bags prior to use. Wheat flour was purchased from a local market in Idah Township, Kogi State, Nigeria. The wheat hour was screened through a 60 mesh sieve (0.01 mm) (British standard) and stored in high density polyethylene (HDPE) bags (0.77 mm thick) prior to use.

2.2 Preparation of Raw Pigeon Pea Flour

The pigeon pea seeds were hydrated in cold water (30±2°C) for 60 min, dehulled manually, oven dried (60°C, 3 h) and milled in attrition mill. The powder was screened through a 60 mesh sieve, packed in HDPF bags and kept on a laboratory bench (30±2°C) until used.

2.3 Preparation of Toasted Pigeon Pea Flour

The cleaned pigeon pea seeds were toasted on trays (120°C, 30 min) in an air convection oven with intermittent mixing. The toasted seeds were dehulled manually, the kernels were milled in attrition mill and screened though a 60 mesh sieve.

2.4 Preparation of Boiled Pigeon Pea Flour

The pigeon pea seeds were boiled in hot water (100°C) for 60 min, cooled, dehulled manually, oven dried (60°C, 3 h), milled in attrition mill and sieved through a 60 mesh sieve.

2.5 Preparation of Germinated Pigeon Pea Flour

The pigeon pea seeds were surface sterilized with 1.5% sodium hypochorite solution followed by soaking in 70% ethanol for 20 min. The seeds were rinsed thoroughly with tap water and soaked for 6 h in tap water. The hydrated seeds were spread evenly on layers of wet jute bags in large petrish dishes (in 3 replicates) and germinated for 5 days in the dark. The jute bags were moistened at regular intervals. The ungerminated seeds were discarded. The sprouted seeds were rinsed with tap water and then oven dried (60°C, 3 h). The kernels were milled in attrition mill and screened through a 60 mesh sieve.

2.6 Fermented Pigeon Pea Flour

A portion of the raw pigeon pea flour was mixed with water at 3.2 (water: flour) ratio in a covered plastic bowl as described by Ariahu et al. [16]. The paste was fermented for 5 days, oven dried (60°C, 3 h), milled in attrition and screened through a 60 mesh sieve. All the flour samples were stored in the HDPE (0.77 mm thick) bag prior to use.

2.7 Preparation of Biscuits

The wheat flour (90%) was blended with 10% raw treated pigeon pea flour in a Kenwood food processor operated at full speed (120 rpm) for 5 min. The choice of this level was based on the report of Gayle et al. [17] and Edema et al. [18] that the maximum level of wheat flour substitution that would produce acceptable bread was 10%. The wheat flour/pigeon pea flour biscuits were prepared using the recipe described by Ceserani [19]. The basic formulation used was 49.5% flour, 20% margarine, 10% beaten whole egg, 25% sucrose, 9% water and 0.5% baking powder. The ingredients were weighed and used to prepare biscuits by the straight dough method [19]. All the ingredients were mixed together in a mixing bowl until dough was obtained. The dough was kneaded on a clear flat stainless metal table for 5 min. The dough was rolled thinly on a sheeting board to uniform thickness and cut out using a round scorn cutter to a diameter of 4 cm. The cut out dough pieces were baked on greased pans at 160°C for 15min in air oven (F1 Foem, model 4BF: APV – Schroder, Germany), cooled at room temperature (30±2°C) and packed in HDPE bags. Ten cookies were baked for each treatment.

2.8 Physical Evaluation of Biscuits

The weight of the biscuit samples was determined with electronic weighing balance. The height, length and width were measured using vernier caliper. The biscuit volume was determined by seed displacement method [20]. Biscuit density was calculated as weight/volume.

The spread ratio was calculated as height/ diameter [21].

2.9 Sensory Evaluation of Biscuits

The biscuit samples including 100% wheat biscuit were evaluated for color, flavor, texture taste and overall acceptability by a panel of 20 trained panelists on 5-point hedonic scale (1 = dislike extremely and 5 = like extremely) [1]. The panelists consisted of members of staff of the Department of Food science and Technology, Federal Polytechnic Idah, Kogi State. The sensory evaluation was carried out in the mid morning (10 am) in a sensory evaluation laboratory under controlled conditions of lighting and ventilation. The samples were presented to the panelists in three-digit coded white plastic plates. The order of presentation of the samples to the panelist was randomized. Tap water was provided for the panelists to rinse their months in between evaluations.

2.10 Chemical Evaluation of Biscuits

Moisture content was determined by hot air oven drying at 105%C to constant weight [22]. The ash, protein (N x6.25), crude fiber and fat (solvent extraction) contents were determined by the AOAC [22] methods. Carbohydrate content was calculated by difference as 100-(% Protein + % Fat + % Crude fiber + %Ash + % Moisture). The Mg, Ca, Fe and Zn contents were determined using atomic absorption spectrophotometer as described by the AOAC [22] methods.

2.11 Statistical Analysis

The data were analyzed by analysis of variance using Statistical Package for Social Sciences (SPSS) soft ware version 18. The least significant difference (Lsd) test was used to separate significantly different means Significance was accepted at $P < 0.05$.

3. RESULTS

3.1 Physical Properties of Biscuits

The physical properties of biscuits prepared from blends of raw/treated pigeon pea flour and wheat flour are present in Table 1.

The weights of biscuits supplemented with the raw pigeon pea flour and the 100% wheat flour (control) were 5.0 g and 4.0 g, respectively. The weights of the biscuits supplemented with the treated pigeon pea flours ranged between 4.0 and 5.0 g. All the treatments given to the pigeon pea seeds except germination reduced the weight of the biscuit. All the biscuits except that containing toasted pigeon pea flour had higher diameter than the 100% wheat flour biscuits. Only boiling and germination of the seeds increased the diameter of the biscuits. However, all the biscuits including the 100% wheat flour had similar diameter and density. Only germination of pigeon seeds caused the increase in the spread ratio of the biscuits containing treated pigeon pea flours.

3.2 Sensory Properties of Biscuits

The sensory properties of the biscuits are presented in Table 2. All the biscuits containing pigeon pea flour received significantly higher ($P<0.05$) scores for color than the 100% wheat flour biscuit. Only fermentation and germination decreased the score for color of biscuits containing pigeon pea flour. Significant differences ($P>0.05$) were not detected by the panelists in the flavor, taste, texture and overall acceptability of the biscuits containing raw, variously treated pigeon pea seed flours and the 100% wheat flour. However, the biscuit containing boiled pigeon pea seed flour was rated higher than the other biscuits for the sensory attributes of flavor and taste. Indeed, the biscuit containing boiled pigeon pea flour had higher score for overall acceptability than the 100% wheat flour biscuit.

3.3 Chemical Composition of Biscuits

The effects of the various treatments on the chemical composition of the biscuits are shown in Table 3. The raw pigeon flour contained 10.5% moisture, 23% crude proten, 2.0% ash, 5.3% fat, 1.5% crude fiber and 57.7% carbohydrate (Data not shown in the Table). All the treatments except toasting increased the moisture contents of the biscuits. The crude protein contents of the biscuits containing treated pigeon pea flours ranged between 25.2% in the biscuit containing boiled pigeon flour and 28.8% in the biscuit containing germinated flour. These values were higher than that of 11.0% for wheat flour biscuit. Only toasting and germination of the pigeon seeds increased the crude fiber contents of the biscuits. Similarly, the crude fiber content of wheat flour biscuit was lower than those of the biscuits containing pigeon pea flour. On the other hand, toasting concentrated the crude fiber content of the seed by loss of moisture. The carbohydrate contents of the biscuits containing treated pigeon pea flour varied from 57.6-68.8% while that of the biscuit containing raw pigeon pea flour was 60.2%.

3.4 Mineral Composition

The effects of the processing treatments on mineral composition of breads supplemented with pigeon flour are shown in Table 4. The raw pigeon flour contained 146 mg/100g Mg, 110 mg/100 g Ca, 5.0 mg/100 g Fe and 3.0 mg/199 g Zn. The mineral contents of the biscuits were significantly ($p<0.05$) affected by the processing treatments. The mineral contents of all the biscuits except that containing toasted pigeon pea flour were lower than those of the raw pigeon pea flour. However, all the pigeon pea based biscuits contained higher amounts of minerals than the wheat flour biscuit.

4. DISCUSSION

The raw and germinated pigeon flours might have retained more water and oil than the other flours during the biscuit baking. This probably explains why the biscuits had higher weight than the other biscuits. Similarly, the higher volume and height of the biscuits supplemented with the germinated pea flour over others biscuits containing pigeon pea flour may be due to structural modification of the starch and protein constituents of the pigeon pea flour during germination. The modified constituents probably enhanced gas retention by the dough [23].

Table 1. Physical properties of biscuits prepared from pigeon pea seed flour and wheat flour blends

Biscuits	Weight (g)	Volume (cm^3)	Height (cm)	Diameter (cm)	Density (g/cm^3)	Spread ratio
Raw	5.0^a	46^c	0.5^a	5.0^a	0.125^a	0.1^a
Boiled	4.6^{ab}	50^b	0.4^a	5.6^a	0.092^a	0.08^b
Toasted	4.0^b	41^d	0.3^a	4.7^a	0.097^a	0.06^b
Germinated	5.0^a	69^a	0.7^a	5.4^a	0.556^a	0.13^a
Fermented	4.0^b	45^c	0.4^a	5.0^a	0.089^a	0.08^b
Wheat	4.0^b	49^b	0.4^a	4.7^a	0.082^a	0.08^b
$Lsd_{0.05}$	0.94	0.82	0.85	1.01	0.52	0.08

Means within a column with the same superscript were not significantly different (P>0.05). Lsd, least significant difference

Table 2. Sensory properties of biscuits prepared from pigeon pea flour and wheat flour blends

Biscuits	Color	Flavor	Taste	Texture	Overall acceptability
Raw	4.10^a	3.60^a	4.20^a	4.20^a	4.20^a
Boiled	4.30^a	4.20^a	4.20^a	4.20^a	4.40^a
Toasted	4.30^a	3.90^a	3.60^a	4.20^a	4.20^a
Germinated	3.70^b	3.80^a	3.90^a	4.20^a	4.20^a
Fermented	3.80^{ab}	3.50^a	4.10^a	3.60^a	4.20^a
Wheat	3.40^b	4.00^a	4.40^a	4.20^a	4.20^a
$Lsd_{0.05}$	0.53	1.63	1.58	1.04	0.87

Means (n=20) within a column with the same superscript were not significantly different (P>0.05). Biscuits were evaluated on a 5-point Hedonic scale (1 = disliked extremely and 5 = liked extremely)

Table 3. Effect of processing methods on the proximate composition of biscuits supplemented with pigeon pea seed flours

Composition (%)	Raw	Toasted	Boiled	Germinated	Fermented	Wheat biscuit
Moisture	9.0^a	7.0^b	9.5^a	6.5c	9.7^a	5.5d
Fat	17.0a	15.9b	14.7d	4.0d	15.0c	5.8e
Crude protein	26.4^b	27.7^a	25.2^c	28.8^b	27.5^b	11.0
Ash	4.0^a	5.0^b	3.6^a	4.6^a	4.0^b	2.0c
Crude fiber	2.6c	3.09b	2.0d	3.5a	2.4cd	1.2e
Carbohydrate	60.2^e	$61.49.3^d$	57.6^f	69.6^b	68.8^c	74.5a

Means within a row with the same superscript were not significantly different (p>0.05)

Table 4. Effect of processing methods on the mineral composition of biscuits supplemented with pigeon pea flours

Mineral (mg/100 g)	Raw PPF	Toasted PPF	Boiled PPF	Germinated PPF	Fermented PPF	Wheat biscuit
Mg	147^b	150.9^a	143^d	138^f	146^c	142^e
Ca	112^b	115.7^a	108^d	99^d	109^c	28^e
Fe	6.3^b	7.6^a	5.3^e	5.8^c	5.9^c	4.0^f
Zn	4.8^b	6.1^a	3.3^d	3.9^c	4.8^b	3.4^d

Values are means ± SD of 3 replications. Means within a row with the same superscript were not significantly different (p>0.05).PPF, Pigeon pea flour

Similar observation was documented for biscuits prepared from other germinated legume flours [24]. Volume of biscuit is of great importance in determining quality because it is generally influenced by the quality of the ingredients used in the formulation of the biscuits. The volume of some of the biscuits decreased relative to wheat flour biscuit with the addition of pigeon pea flour in the biscuits due to dilution of gluten protein. During dough development, gluten, which confers gas retention properties to wheat flour dough, becomes extensive and strong. This allows the dough to rise and also prevents easy escape of the gas during baking [1]. This improves biscuit qualities [1]. This property was probably reduced in the composite flour biscuits. This probably explained the higher height for the 100% WF biscuit. Glutenin and gliadin fractions of wheat gluten protein have unique effects on dough quality. The gliadin fraction is a heterogeneous protein fraction responsible for the viscous properties of dough during mixing [15]. On the other hand, the glutenin fraction is polymeric protein which exhibits a high degree of intermolecular bonding, reduces dough extensibility. This is the protein fraction responsible for strength. The increase in the spread ratio of the biscuit due to germination was probably due to the low water absorption capacity of germinated pigeon pea flour. Ingredients which absorb water during mixing and increase the dough viscosity would decrease the spread ratio of biscuits [25]. Akubor [25] reported that germination decreased the water absorption capacity of germinated cowpea flour. The addition of germinated pigeon pea flour caused increase in the height and diameter which resulted in the higher spread ratio over other flours.

Toasting influences physical, chemical and functional properties of foods [15]. Toasting is accompanied with caramelization of sugar polysaccharides and Maillard reactions of reducing and proteins of food materials [1]. These reactions generate flavor and color which probably enhanced the acceptance of the biscuits containing toasted pigeon pea flour [1]. The germinated pigeon pea flour was bitter which affected the score for taste of the biscuit containing germinated pigeon pea flour. Complex carbohydrates are broken down to organic acids and simpler substances during fermentation which affect sensory properties of foods [24].This explains why the biscuits containing fermented pigeon pea flour had the lowest scores for flavor and texture relative to the other biscuits.

The moisture contents of the biscuits were below 10% which suggest reduced chances of spoilage by microorganisms and consequently increased shelf life [15]. The decrease in fat content of the biscuits containing fermented flour might be attributed to the increased activities of the lipolytic enzymes during fermentation of the pea seeds which hydrolyzed fat components into fatty acid and glycerol [25]. Decrease in fat content due to sprouting was due to the activities of lipases which were activated during sprouting [13,26]. Synthesis of new protein was reported to occur during seed fermentation [25]. Activities of proteolytic bacteria during fermentation were reported to improve the digestibility and availability of proteins due to the breakdown of protein-tannin and protein-phytate complexes [15]. High proteolytic activity in germinating millet grains was reported by Hamad and Fields [27]. Germination of the pea seeds may have increased the amino acids content of the pigeon pea seed storage protein in this study.

Hamad and Fields [27] reported significant improvement in the protein content of sorghum and other grains during malting. The increase in the crude fiber content of the biscuit containing germinated pigeon pea flour could be attributed to the synthesis of more of the cell wall material during germination to support the roots and rootlets [14]. Decrease in certain diseases such as diverticulosis and colonic has been associated with increased fiber consumption [28]. Dietary fiber acts as bulking agent and thus, increases intestinal motility and wet faecal mass of feaces [28]. These effects help in reducing diseases of the colon [28]. Some reports showed that some plant fibers can lower serum cholesterol [29]. The carbohydrate contents of the breads containing treated pigeon pea flour were higher than that of the bread containing raw pigeon pea flour probably due to leaching of soluble solids during the boiling of the seeds. Carbohydrates in the biscuits would provide readily available glucose for energy production to meet the high activity level of children and adolescents. As many children go to school most times without breakfast, biscuits prepared from treated pigeon pea flours would be of immense help in furnishing these children with glucose and other nutrients to enhance brain work and sustenance for academic activities.

The US RDA for iron is 10-15 mg per day [30]. The levels of iron lend the pigeon pea based biscuits good sources of iron. Iron is very important in blood building. Deficiency of iron is the most common nutritional disorder in the world, causing anaemia that affects more than 3.5 million people in the developing world [30]. Magnesium is an essential constituent of all cells necessary for the functioning of enzymes involved in energy utilization and it is present in the bone [30]. Deficiency of Mg is rare and results from excessive losses in diarrhea rather than from low intakes. Zinc is needed by over 300 enzymes, some of which are involved with metabolism of blood sugars [31]. Zinc is so important that lack of it causes Types 1 and Type ll diabetes [31]. Meals rich in zinc protect the body from inflammatory signals that damage beta cells [31]. The RDA for zinc for all groups is 15mg, thus, consuming 200g of pigeon pea flour based biscuits would provide the RDA for zinc [30].

5. CONCLUSION

Boiling, toasting, germination and fermentation of the pigeon seeds had no adverse effects on the physical, chemical and sensory properties of biscuits prepared from pigeon pea flour and wheat flour blends. The pigeon pea based biscuit had similar physical properties with the 100% wheat flour biscuit. There were no significant differences in the sensory properties of the biscuits containing raw and treated pigeon pea flours. The biscuits containing pigeon pea flours were not significantly different from that of wheat flour biscuit in the sensory attributes. However boiling of pigeon pea seeds improved the sensory attributes of the biscuits containing boiled pigeon pea flour over those of the other treatments. This study has opened a new food of application for pigeon pea seeds. This is of interest in non – wheat producing counties like Nigeria. It is also of interest in child feeding programmes.

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COMPETING INTERESTS

Author has declared that no competing interests exist.

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