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Oraka, Cecilia Ogechukwu and Okoye, Joseph Ikechukwu

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EFFECT OF HEAT PROCESSING TREATMENTS ON THE CHEMICAL COMPOSITION AND FUNCTIONAL PROPERTIES OF LIMA BEAN (*Phaseolus lunatus*) FLOUR

1*Oraka, Cecilia Ogechukwu
Department of Food Science and Technology, Enugu State University of Science and Technology

Corresponding Author Email: ogececilia@yahoo.com

1* Okoye, Joseph Ikechukwu
Department of Food Science and Technology, Enugu State University of Science and Technology

ABSTRACT

Purpose: The effect of heat treatment methods on the nutrient composition and functional properties of lima bean (*Phaseolus lunatus*) flour were investigated.

Methodology: The lima bean seeds were sorted, cleaned and processed into boiled, roasted and autoclaved lima bean flours. The flours obtained were analyzed for proximate composition, mineral content and functional properties using standard methods.

Results: The proximate composition of the samples revealed that the flours had a range of moisture, 8.25±0.01 - 10.21±0.06%, crude protein, and 18.24 ±0.02 - 22.72±0.00%, ash, 3.94±0.13 - 4.82±0.02%, fat, 1.47±0.03 - 1.68±0.00%, crude fiber, 3.62±0.00 - 4.27±0.02%, carbohydrate, 57.31±0.13 - 62.89±0.01%, and energy 334.11±0.30 - 339.91±0.18kJ/100g, respectively. The mineral composition showed that the flours contained 176.89±0.002 - 234.72±0.17mg/100g calcium, 2.38±0.03 - 3.24±0.00mg/100g iron, 68.36±0.00 - 73.62±0.26mg/100g sodium, 163.73±0.11 - 195.33±0.01mg/100g magnesium, and 125.86±0.00 - 136.76±0.06mg/100g potassium, and 158.78±0.03 - 184.29±0.01mg/100g phosphorus, respectively. The result of the functional properties of the flours equally revealed that the water absorption, solubility index, foam capacity, oil absorption and swelling capacities and bulk density of the samples were significantly ($p<0.05$) increased by roasting than the boiling and autoclaving treatments. However, the nutrient composition and the functional properties of the flours observed suggested that the processed flours have the potentials to be used as nutritional supplements and functional ingredients in the preparation of a wide range of food products than the raw sample.

Key words: *Lima beans, boiling, roasting, autoclaving, proximate, mineral, physical quality*.

1.0 INTRODUCTION

Lima bean (Phaseolus lunatus) is a legume that originated from Peru. Lima bean is the second most economically important species of Phaseolus and is one of the twelve primary grain legumes known in the world (Fofana et al., 1999). The Lima bean is an annual or short-lived perennial species, with a mixed mating system that is predominantly autogamous but without crossing levels up to 48% (Baudoin et al., 1998). The grain of Lima bean has high protein content and can be used for human alimentation thereby decreasing over dependence on common bean (Vieira, 1992). According to Oliveira et al. (2004), the Lima bean is actually an alternative food source for human alimentation in the Northeast region of Brazil. It is an important source of plant protein and is rich in antioxidants, vitamins, minerals, and plant sterols. Lima beans are a very rich source of B-complex vitamins, especially vitamin B6 (pyridoxine), thiamine (vitamin B1), pantothenic acid, riboflavin and niacin. Most of these vitamins function as co-enzymes in carbohydrate, protein, and fat metabolism in the body. Lima bean is also one of the excellent sources of minerals like molybdenum, iron, copper, manganese, calcium, magnesium. They are relatively rich in potassium(1724mg) compared to the red kidney beans (1359mg), broad beans (1062mg) and black beans (1483mg). Potassium is important electrolyte of cell and body fluids. It helps to counter the pressing effects of sodium on heart and blood pressure. Like other grain legumes, lima beans are relatively rich in protein. They contain about 25% protein in the dietetic management (DM), a value that is comparable to that of peas and cowpeas (Vigna unguiculata), but its variability is remarkably high (from 19 to 28% DM). The starch content of the legume is also high and is about 40% dietetic management, which is lower than the starch content of peas and cowpeas. Lima beans are low in cell wall constituents (about 5% crude fibre) and low in fat (less than 1.5% DM)(Vieira, 1992). The main limitation of lima beans in human and animal nutrition is the presence of naturally occurring anti-nutritional factors such as alkaloids, saponins, tannins, phytates, and oxalates and these anti-nutrients can be drastically reduced or eliminated by the use of simple processing techniques such as boiling, roasting, fermentation, autoclaving, blanching, dehulling and germination (Sandberg, 2002). The objective of this study is to investigate the effects of boiling, roasting and autoclaving on the nutrient composition and functional properties of lima bean flours.

2.0 MATERIALS AND METHODS

Mature dried lima bean *Phaseolus lunatus* seeds used for the study were purchased from Afor Nmaku Market, Enugu State, Nigeria. The seeds were sorted, cleaned and divided into four equal portions of 500g each. Three portions were subjected to different processing treatments (boiling, roasting and autoclaving) while the fourth batch was processed raw.

2.1 Preparation of Raw Lima Bean Flour

The raw lima bean flour was prepared according to the method of Ugwu and Oranye (2006). During preparation, five hundred grams (500g) of Lima bean seeds which were free from dirt and other extraneous materials were weighed, cleaned and soaked in 2 litres of potable water at room temperature (30±2^{0}C) for 12 h. The soaked seeds were drained and dehulled manually by rubbing in between palms to remove the hulls. The dehulled seeds were rinsed, spread on the trays and dried in a hot air oven (Model DHG 9101 ISA) at 60^{0}C for 6 h with occasional stirring of the seeds at intervals of 30min to ensure uniform drying. The dried seeds were milled into flour using the locally fabricated attrition mill and sieved through a 500 micron mesh sieve. The flour produced was packaged in an airtight plastic container and kept in a freezer until needed for analysis.

2.2 Preparation of Boiled Lima Bean Flour

The boiled lima bean seed flour was prepared according to the method of Ugwu and Oranye (2006). During preparation, five hundred grams (500g) of lima bean seeds which were free from dirt and other extraneous materials were weighed, cleaned and soaked in 2 litres of potable water at room temperature (30±2^{0}C) for 12 h. The soaked seeds were drained, rinsed and dehulled manually by rubbing in between palms to remove the hulls. The dehulled seeds were boiled with 2 litres of potable water in a hot plate at 100^{0}C for 30 min. The boiled seeds were drained, spread on the trays and dried in a hot air oven (Model DHG 9101 ISA) at 60^{0}C for 6 h with occasional stirring of the seeds at intervals of 30 min to ensure uniform drying. The dried seeds were milled into flour using the locally fabricated attrition mill and sieved through a 500-micron mesh sieve. The flour produced was packaged in an airtight plastic container and kept in a freezer until needed for analysis.

2.3 Preparation of Roasted Lima Bean Flour

The roasted lima bean flour was prepared according to the method of Ugwu and Oranye (2006). During preparation, five hundred grams (500g) of lima bean seeds that were free from dirt and other extraneous materials were weighed, cleaned and soaked in 2 litres of potable water at room temperature (30±2^{0}C) for 12 h. The soaked seeds were drained, rinsed and dehulled manually by rubbing in between palms to remove the hulls. The dehulled seeds were rinsed, spread on the trays and roasted in a hot air oven (Model DHG 9101 ISA) at 240^{0}C for 40 min with occasional stirring of the seeds at intervals of 5 min to ensure uniform roasting. The roasted seeds were milled in the attrition mill and sieved through a 500 micron mesh sieve. The flour produced was packaged in an airtight plastic container and kept in a freezer until needed for analysis.

2.4 Preparation of Autoclaved Lima Bean Flour

The autoclaved lima bean flour was prepared according to the method of Ugwu and Oranye (2006). During preparation, five hundred grams (500g) of lima bean seeds which were free from dirt and other extraneous materials were weighed, cleaned and soaked in 2 litres of potable water at room temperature (30±2^{0}C) for 12 h. The soaked seeds were drained, rinsed and dehulled manually by rubbing in between palms to remove the hulls. The dehulled seeds were placed in a beaker and autoclaved in an autoclave (Model 75xG) at temperature of 121^{0}C and pressure of six atmospheres for 40 min. The autoclaved seeds were spread on the trays and dried in a hot air oven (Model DHG 9101 ISA) at 60^{0}C for 4 h with occasional stirring of the seeds at intervals of 30 min to ensure uniform drying. The dried seeds were milled into flour using the locally fabricated attrition mill and sieved through a 500-micron mesh sieve. The flour produced was packaged in an airtight plastic container and kept in a freezer until needed for analysis.

2.5 Chemical Analysis

The moisture, crude protein, fat ash and crude fibre contents of the samples were determined in triplicate according to the method of AOAC (2006). Carbohydrate was determined by difference *(Anton et al., 2008)*. The energy content of the flours was calculated from the proximate composition using the Atwater factor 4×protein, 9×fat, 4×carbohydrate *(Shumaila and Mahpara,2009).* The potassium and iron contents of the flours were determined after ashing by the use of a flame photometer (Model 405, Coming, UK) according to the method of Onwuka (2005). The calcium, magnesium and sodium contents of the samples were determined using atomic absorption spectrophotometer (Perkin-Elmer, Model 1033, Norwalk, CT, USA) according to the method of AOAC (2006). Phosphorus was determined by the vanadomolybdate colorimetric method of Chapman and Pratt (1996).

2.6 Functional Properties

The water and oil absorption capacities of the flours were determined in triplicate according to the method of AACC (2000). The cold water extraction method described by Okoye and Mazi (2012) was used for the determination of solubility index. The method of Onwuka (2005) was used for the determination of foam and swelling capacities of the samples. The bulk density of the flours was determined according to the method of Giami *et al.* (1992).

2.7 Statistical Analysis

The data generated after the analysis were subjected to Analysis of Variance (ANOVA) using special package for social sciences (SPSS version 20, 2013) to detect significant differences among the sample means at ($p \leq 0.05$). Significant means were separated using Turkey's Least Significance Difference (LSD) test.

3.0 RESULTS AND DISCUSSION

3.1 Proximate Composition

The proximate composition of the samples is presented in Table 1. The moisture content of the sample was significantly ($p<0.05$) higher in boiled sample compared to the samples processed by autoclaving and roasting. The increase could be attributed to the inhibition of large quantity of water by the seeds because of boiling during processing. The observation is in agreement with the report of Nsa and Ukachukwu (2009).The high moisture affects the storage stability of legume and other flour products. The crude protein content of the flour was significantly ($p<0.05$) lower in boiled and autoclaved samples than in roasted flour sample. The reduction in the protein content of the boiled flour could be attributed to leaching of some soluble protein into the boiling water during processing (Obasi and Wogu, 2008). Dietary proteins are needed for the synthesis of new cells enzymes and hormones required for the development of the body. (Okaka *et al.,* 2006). The ash content of the raw sample which was originally 4.82% was found to be significantly ($p<0.05$) reduced to 3.94% by autoclaving treatment compared to the values of 4.66% and 4.32% recorded by roasted and boiled samples, respectively. The high ash content by boiled and roasted flour is an indication that they are food sources of minerals than in the autoclaved sample. (Okoye and Mazi, 2012). The fat content of the flours which ranged from 1.47 to 1.68% was significantly ($p<0.05$) reduced by autoclaving followed by boiling and roasting treatments. Fat is important in human diets because it is a high energy-yielding nutrient. Legumes seeds are generally low in fats and oil (Okaka *et al.,* 2006). The crude fibre content of the samples was significantly ($p<0.05$) reduced by autoclaving compared to boiling and roasting treatments. Fibre has been credited for promotion of increased excretion of bile acids, sterols and fats which have been implication in the etiology of certain ailments in humans (Okaka *et al.,* 2006). The carbohydrate content of the flours was significantly ($p<0.05$) lower in boiled and autoclaved flour than in the sample processed by roasting. The decrease could be attributed to thermal decomposition of some carbohydrate components into carbonic acid and carbon dioxide by boiling and roasting treatments (Obasi and Wogu, 2008). The energy content of the sample was significantly ($p<0.05$) increased by autoclaving and roasting treatments compared to the sample processed by boiling. The increase in energy content of the sample could be a reflection of their high protein and carbohydrate content (Obum *et al.,* 2006). Generally, boiling, roasting and autoclaving treatments greatly increased some nutrient contents of lima bean flours by reducing their anti-nutrient contents.

3.2 Mineral Contents

Table 2 shows the mineral contents of lima bean flours. The calcium content of the samples was significantly ($p<0.05$) reduced by autoclaving and boiling treatments compared to the sample processed by roasting. The decrease could be due to oxidation and leaching out of the mineral element into boiling water during autoclaving and boiling treatments. Calcium in conjunction with magnesium, phosphorus and protein are involved in bone formation (Okaka *et al.,* 2006). The iron content of the flour ranged from 163.73 to 195.33mg/100g with boiled and autoclaved samples having the least and highest values, respectively. Iron is an important component of haemoglobin, which is an oxygen carrying pigment in the blood (Potter and Hotchkiss, 2006). The sodium content of the raw sample which was found originally to be 73.62mg/100g was significantly ($p<0.05$) reduced by autoclaving followed by boiling and roasting treatments. The observation is in agreement with the report of Antom *et al.* (2008) for soaked and germinated navy and pint bean flours. Sodium is one of the chief extracellular ions of the body, which is primarily involved in the maintenance of osmotic equilibrium and body fluid volume (Graham and Welch, 1996). The magnesium content of the flour ranged from 163.73 to 195.33mg/100g was significantly ($p<0.05$) reduced by autoclaving than the boiling and roasting treatments. Magnesium helps in the maintenance of electrical potential in nerves (Graham and Welch, 1996). The potassium content of the flours ranged from 125.86 to 136.76mg/100g. The values obtained in this study were higher than those (124.2 to 131.8mg/100g) reported by Obizoba (1990) for soaked and germinated Bambara groundnut flours. Potassium is very essential in blood clotting and muscle contraction. The phosphorus content of the flours was significantly ($p<0.05$) reduced by autoclaving and boiling treatments compared to the sample processed by roasting. Generally, the phosphorus content of the raw sample, which was found to be 184.29mg/100g, was drastically affected by autoclaving followed by boiling and roasting treatments. The decrease could be due to oxidation and leaching of the mineral elements into boiling water during autoclaving, roasting and boiling treatments. Phosphorus and calcium are the minerals that humans require in the greatest amounts. It also helps to control the acid-base balance of the blood and it is required in highest amounts by young child, pregnant and nursing mothers (Okaka *et al.,* 2006). Generally, roasting had a greater effect on the improvement of micro-nutrient contents in Lima bean flours than the autoclaving and boiling treatments.

3.3 Functional Properties

Table 3 shows the functional properties of lima bean flours. The water absorption capacity of the sample was significantly ($p<0.05$) higher in roasted flour compared to the samples processed by boiling and autoclaving. The values obtained in this study were lower than those (2.18-3.12ml/g) reported by Malomo *et al.* (2012) for boiled and roasted Kanya seed flours. Flours with good water absorption capacity will be desirable for use in the preparation of complementary or baby foods. The solubility index of the flours which ranged from 18.71 to 21.53% was significantly ($p<0.05$) higher in the roasted sample than in boiled and autoclaved flours. The observation is in agreement with the report of Giami (1993) for roasted and autoclaved cowpea flours. Flours with the good solubility index will be useful in the preparation of ice creams. The foam capacity of the flours was significantly ($p<0.05$) reduced by autoclaving compared to the samples processed by boiling and roasting treatments. The decrease could be due to treatment effect. The foam capacity is used as an index of the whipping characteristics of the flour. Graham *et al* (2003) reported that flexible protein molecules can rapidly reduce surface tension to give good foamability. Flours with good foam capacity are desirable for use in the preparation of whipped cream and salad dressings. The oil absorption capacity of the flours ranged from 1.48 to 2.05% with autoclaved and boiled samples having the least and highest values, respectively. The result is in agreement with the report of Madubuike *et al.,* (1994) for boiled and roasted Afzeila Africana flours. The oil absorption property of the flour is known to be of great importance in enhancing the sensory characteristics such as flavour and mouth feel. Flours with excellent oil absorption capacity may be useful in the preparation of pastries and doughnuts. The swelling capacity of the flours which ranged from 1.42 to 1.68% was significantly ($p<0.05$) reduced by boiling and autoclaving than the roasting treatment. The variation in swelling capacity could be related to associative binding within the starch granules while the strength and character of the miscellar network may be related to the amylose content which confers high swelling power to boiled and autoclaved samples than the roasted flour (Banigo and Akpapunam, 1987). Flours with good swelling capacity are primarily used for thickening of soups, sauces and gravies etc. The bulk density of the raw sample which was found to be 0.81g/ml was significantly ($p<0.05$) reduced by boiling and autoclaving followed by the roasting treatment. The bulk density is influenced by the particle size (the structure of the starch polymer) and the loosed structure of the starch polymers accounted for the reduction in bulk density. Bulk density is important in determining the packaging requirement and material handling in food processing and preparation (Malomo *et al.,* 2012). Product density influences the amount and the strength of the packaging material, texture or mouth feel (Webb, 2006). Generally, the functional properties of the flours with the exception of the oil absorption capacity were drastically reduced by autoclaving than the boiling and roasting treatments.

4.0 CONCLUSION

The study showed that autoclaving followed by boiling resulted in products with reduced protein, ash, fat, fibre, calcium, magnesium and phosphorus contents. The use of roasting in the processing of lima beans into flour drastically increased the carbohydrate, iron, sodium and potassium contents of the product. The observed difference could be as a result of the liberation of cell bound nutrients which otherwise would not have been available as pure nutrients. In addition, autoclaving generally improved the physical characteristics of flour than the boiling and roasting treatments. It is therefore suggested that any of the heat treatment processes can be used for processing lima beans, however, due to the fact that autoclaves may not be readily available for the local or home-made processors of lima bean products, boiling and roasting which are very common can be easily used.

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Table 1: Proximate Composition of Lima Bean Flours.

Parameters	Raw	Boiled	Roasted	Autoclaved
Moisture (%)	9.21c+ 0.13	10.21a+ 0.06	8.25d+ 0.01	9.85b+ 0.01
Crude Protein (%)	22.72a+ 0.00	18.72c+ 0.04	19.80b+ 0.00	18.24d+ 0.02
Ash (%)	4.82a+ 0.02	4.34c+ 0.03	4.66b+ 0.06	3.94d+ 0.13
Fat (%)	1.68a + 0.00	1.53c + 0.01	1.61b + 0.01	1.47d + 0.03
Crude Fibre (%)	4.27a + 0.02	3.84c + 0.00	4.13b + 0.00	3.62d + 0.00
Carbohydrate (%)	57.31d + 0.13	61.37c + 0.07	61.56b + 0.08	62.89a + 0.01
Energy (kj/100g)	335.24c + 0.51	334.11d + 0.30	339.91a + 0.18	337.73b + 0.17

Values are mean + standard deviation of triplicate determinations.

Means in the same row with different superscripts are significantly different (p<0.05).

Table 2: Mineral Contents of Lima Bean Flours

Parameters	Raw	Boiled	Roasted	Autoclaved
Calcium	234.72a + 0.17	195.24c + 0.00	232.76b+ 0.00	176.89d + 0.02
Iron	3.24a + 0.00	2.38d + 0.03	2.84b + 0.00	2.42c + 0.00
Sodium	73.62a + 0.26	70.66c + 0.20	72.45b + 0.07	68.36d + 0.00
Magnesium	195.33a + 0.01	185.80c + 0.00	192.74b + 0.00	163.73d + 0.11
Potassium	136.76a + 0.06	125.86d + 0.00	128.32b + 0.00	126.30c + 0.00
Phosphorus	184.29a + 0.01	162.27c + 0.05	175.30b + 0.00	158.78d + 0.03

Values are mean + standard deviation of triplicate determinations.

Means in the same row with different superscripts are significantly different (p<0.05)

Table 3: Functional Properties of Lima Bean Flours

Parameters	Raw	Boiled	Roasted	Autoclaved
Water Absorption capacity (ml/g)	2.45a + 0.04	1.54d + 0.08	1.94b+ 0.02	1.63c + 0.00
Solubility (%)	21.53a + 0.11	19.34c + 0.02	20.35b + 0.04	18.71d + 0.01
Foam Capacity (%)	19.23b + 0.04	15.42c + 0.25	23.83a + 6.97	14.44d + 0.23
Oil absorption capacity(ml/g)	2.05a + 0.01	0.19d + 0.01	1.81b + 0.01	1.48c + 0.00
Swelling capacity (%)	1.68a + 0.00	1.42c + 0.04	1.61b + 0.01	1.45c + 0.00
Bulk density g/ml	0.81a + 0.02	0.65b + 0.00	0.76c + 0.00	0.68b + 0.00

Values are mean + standard deviation of triplicate determinations.

Means in the same row with different superscripts are significantly different ($p<0.05$).

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