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Evaluation of Nutritional Composition and Acceptability of Processed Precooked Lima Bean Using Chemometric and Descriptive Statistics Approach

Farinde E. O.[1]*, Dauda, T. O.[2] and Adeyemo, T.O.[1]

[1]*Agricultural Value Addition Programme, Institute of Agricultural Research and Training, Ibadan, Nigeria

[2]Farming System, Research and Extension Programme, Institute of Agricultural Research and Training, Ibadan, Nigeria

*Corresponding author: osekinat@yahoo.co.uk

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ABSTRACT: *Lima bean (Phaseolus lunatus), an underutilized legume in Nigeria, is a potential food and nutrition security crop. Two varieties (white and black) of lima bean were each subjected to precooking, dehydration and cooking, given six treatments and two controls to assess effect of precooking on the nutrients and acceptability of lima bean. Proximate, minerals, vitamins and anti-nutrients components of the lima bean samples were compared using Principal Component Analysis. Organoleptic assessment of the eventual lima bean samples was computed using the Kruskal-Walis statistics, variable was determined using* $\chi_{(3:0.05)} = Y$ *(P < 0.05). Results shows that Precooked-dehydrated-white-lima (PCDWL) and Precooked-dehydrated-brown-lima (PCDBL) clustered at a distinct 1st quadrat while Precooked-dehydrated-cooked-white-lima (PCDCWL) stood alone in the 4th quadrat. All other samples clustered at the 3rd quadrat. Precooked-dehydrated-brown-lima (PCDBL) recorded the least anti-nutrients, highest protein, mineral and vitamin content. Precooking technology was found to enhance the nutritional value and acceptability of lima bean.*

KEY WORDS: Lima bean, principal component analysis, precooking, nutrients

INTRODUCTION

With a growing population of about 206 million, Nigeria is still faced with problem of hunger and nutrition insecurity. Many of the local/traditional food crops production and consumption are reducing due to reasons such as climate change, urbanization and inconvenient processing of these food crops which have resulted into unavailability and inaccessibility of the food crops to the generality of the people especially the poor populace. The increase in population coupled with increased urbanization have changed consumers' feeding habits towards quality and safe foods with ease and convenient way of preparation. Transitioning toward eating more plant-based products in Western societies has been identified as a key instrument to tackle the health risks problems associated with meat and dairy consumptions (Roos *et al*., 2018).

Legumes (beans especially) have been the cheapest source of protein and dietary fibres for low income earning households in Nigeria (Maphosa and Jideani, 2017). Lima bean, domesticated in South west Nigeria, is an indigenous nutritious legume containing about 19 – 23% protein and 5-7 crude fiber, 54 - 60 % carbohydrate and about 328.10 kcal/100 g energy, with high level of potassium, phosphorous, calcium and iron. It also contains thiamin, riboflavin, niacin and vitamin B6 which are co enzymes for protein, carbohydrate and fat metabolism (Yellavila *et al*. 2015).

Despite the nutritional and health benefits of lima bean, it is still one of the under-utilized legumes going into extinction in Nigeria. Lima beans are traditionally consumed as cooked beans either as sole or in combination with cereals such as rice or tuber such as yam. Utilization of Lima beans this way started to reduce due to many constrains which includes drudgery in processing, long cooking time and presence of anti-nutrients. Precooking technology has emerged as a promising approach to mitigate these limitations and enhance the nutritional and organoleptic qualities of lima beans. Precooking involves cooking of the beans to a certain level, dehydrating and packaging it for reduced processing time and to provide convenience when further processing for consumption with enhanced palatability, nutritional value, and digestibility (Aseete et al. 2018).

Lima bean is a locally available food crop which when adequately processed could be valuable product to fight hunger and malnutrition. Moreover, existing processed packaged beans in stores in Nigeria are in the form of canned or frozen beans that are not within the reach of poor and rural people. Development of well packaged precooked dehydrated lima bean is an innovation (transition) that will increase importation substitute with subsequent enhanced food and nutrition security in the country

The study thus evaluated the nutrient composition, anti-nutrients content and consumer's' acceptability of the precooked dehydrated lima bean to optimize its quality for enhanced lima bean utilization.

THEORETICAL UNDERPINNING

In Nigeria, plant foods provide at least 50% of the dietary energy and nutrients, of which legumes stands of high importance. Lima beans, a nutritious food legume is one of the legumes not commonly consumed in the country. Considering the current challenges to food security we are facing as a planet, exploring the cultivation, domestication and use of an underutilized legume such as the lima bean could help to ameliorate the current national over-dependence on other legumes such as soybeans and common beans. Novel and convenience precooked product development from lima bean could create opportunities for agribusiness along agricultural value chains, enhances exportation and foreign exchange earnings and subsequently contributing to agricultural Gross Domestic Products (GDP).

MATERIALS AND METHODS

Processing of the lima bean samples

Lima bean seeds (two varieties - white and brown colour) were sorted and cleaned. They were both subjected to the same treatment and non-precooked lima beans served as control. Each of the two varieties of lima beans (1kg) were soaked in warm water (1500 mL) at 45^{o}C for 4 h, drained and pressure cooked for 15 minutes. The precooked beans was dried at a low temperature of 50 ^{o}C in a cabinet dryer (ST-02, China). The beans were dehydrated to a moisture content of 10%, cooled and appropriately packaged. The precooked-dehydrated and non-precooked beans were cooked to get the final product.

Determination of nutrients and anti-nutrients content of the lima bean samples

Proximate composition, minerals (potassium, calcium, iron and zinc) and vitamins (thiamin and riboflavin) were determined using AOAC (2012) method while the anti-nutrients content (trypsin inhibitor, cyanide and phytate) were determined using the method described by Farinde *et al*. (2017).

Sensory evaluation of the lima bean samples

Cooked beans from precooked dehydrated beans and non-precooked beans from the two lima bean varieties were prepared and coded and were subjected to sensory evaluation using the method described by Otunola and Afolayan, (2018). The coded samples were presented to 20 semi-trained panel of judges who are familiar with cooked beans. The panelists were asked to score the samples for each attribute (colour, appearance, texture, aroma, taste and overall acceptability) using 5 points hedonic scale where 5 = like very much and 1 = dislike very much.

Statistical analysis

Data obtained were subjected to general linear model with degree of freedom of seven and mean of significantly different source of variation were separated using Duncan Multiple Range Test (DMRT). Cluster analysis of the lima bean samples using Euclidean distance matrix was done using;

$$d = \sqrt{\left[(x_2 - x_1)^2 + (y_2 - y_1)^2\right]} \quad . \quad . \quad . \quad . \quad . \quad .(i)$$

Where
d is Euclidean Distance, (x1, y1) is Coordinate of the first point and (x2, y2) is Coordinate of the second point.

The Euclidean Distance formula between two points (x_{11}, x_{12}, x_{13}, …., x_{1n}) and (x_{21}, x_{22}, x_{23}, …., x_{2n}) in an n-dimensional space is given by (i)

Where,

i Ranges from 1 to n, d is Euclidean distance, (x_{11}, x_{12}, x_{13}, …., x_{1n}) is Coordinate of First Point and (x_{21}, x_{22}, x_{23}, …., x_{2n}) is Coordinate of Second Point

Principal component analysis of the lima bean samples, eigen values as well as the percentage variance of the values were computed. Organoleptic assessment of the eventual lima bean samples were computed using the Kruskal-Walis statistics and means of the significantly different variable were determined using $\chi_{(3:0.05)} = Y$ ($P < 0.05$).

RESULTS

Cluster and Principal Component Analysis

The result of the cluster analysis of the Lima bean indicated that Non-precooked brown lima bean (NPBL) and Non-precooked white lima bean (NPWL) clustered at the earliest Euclidean distance of 35.664 while the furthest clustering lima bean sample was the Precooked dehydrated brown lima bean (PCDBL) and Precooked dehydrated white lima bean (PCDWL) (496.629 – Figure 1). This portends that the control (non-precooked lima bean) shares more similarities of the anti-nutrient, proximate, minerals and vitamin compositions with one another. The precooked dehydrated lima bean (irrespective of the colour) share lesser similarities in term of the anti-nutrient, proximate, mineral and vitamin components.

The principal component analysis for anti-nutrients, vitamins, proximate and mineral component of the lima bean indicated that PCDWL and PCDBL clustered at a distinct 1st quadrat while Pre-cooked dehydrated cooked white lima bean (PCDCWL) stood alone in the 4th quadrat (Figure 2). All other samples, PCWL, PCDCBL, PCBL, NPWL and NPBL clustered at the 3rd quadrat with NPWL and NPBL clustering together at the 3rd quadrat. The 1st three eigen value forms more than 99% variability with Eigen values of 56414.3, 15537.7 and 2595.01 (Table 1). The loading for the Principal component analysis indicated that the first 3 samples are PCDBL (381.24), PCDWL (92.624) and Pre-cooked dehydrated cooked brown lima bean (PCDCBL) (95.039 – Table1).

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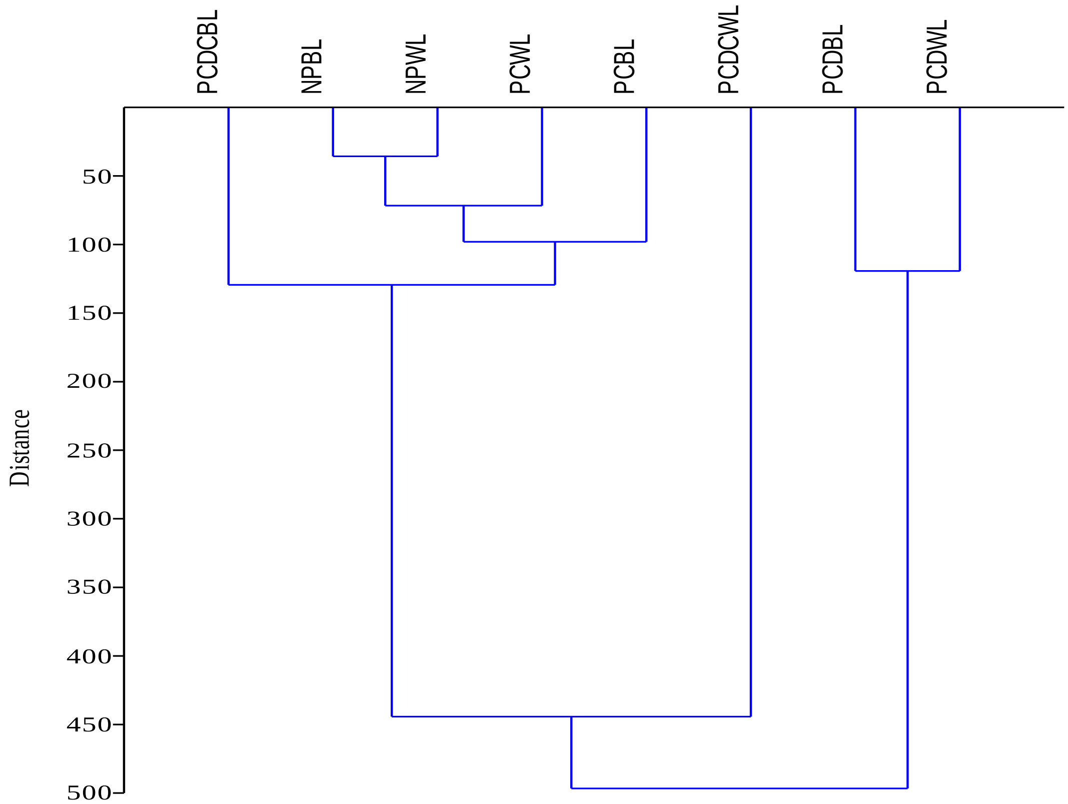

Figure 1. Agglomerative Hierarchical Clustering (AHC) Grouping Processed Lima Bean Samples into Different Classes

It is obvious that precooking has significant effects on the components of the eventual products (in terms of anti-nutrients, vitamin, proximate and mineral components). The precooked and dehydrated lima bean samples clustering together in a quadrat and the non-precooked irrespective of colour (white or black variety) clustering together in another quadrat alluded to this conclusion. The agglomeration distances of the cluster analysis shown in the above dendogram (Figure 1) are as follows;

$x_{NPBL, NPWL}$:35.664 = ($x_{NPBL, NPWL}$), ($x_{PCDCB,}$)(x_{PCWL}),(x_{PCDCW}),(x_{PCDBL}),(x_{PCDWL}),(x_{PCBL}).
$x_{NPBL, NPWL, PCWL}$:71.598 = ($x_{NPBL, NPWL, PCWL}$), ($x_{PCDCB,}$),(x_{PCDCW}),(x_{PCDBL}),(x_{PCDWL}),(x_{PCBL}).
$x_{NPBL, NPWL, PCWL, PCBL}$:97.980 = ($x_{NPBL, NPWL, PCWL, PCBL}$), ($x_{PCDCBL,}$),($x_{PCDCW}$),($x_{PCDBL}$),($x_{PCDWL}$).
$x_{NPBL, NPWL, PCWL, PCBL, PCDCBL}$:119.296 = ($x_{NPBL, NPWL, PCWL, PCBL, PCDCBL}$), ($x_{PCDCW}$),($x_{PCDBL}$),($x_{PCDWL}$).

$x_{NPBL,\ NPWL,\ PCWL,\ PCBL,}\ x_{PCDCBL;\ PCDWL}$: $129.394 = (x_{NPBL,\ NPWL,\ PCWL,\ PCBL,})(x_{PCDCBL;\ PCDWL})(x_{PCDCW}),(x_{PCDBL}),$

$x_{NPBL,\ NPWL,\ PCWL,\ PCBL,}\ x_{PCDCBL;\ PCDWL}$: $144.275 = (x_{NPBL,\ NPWL,\ PCWL,\ PCBL,})(x_{PCDCBL;\ PCDWL})(x_{PCDCW}),(x_{PCDBL}),$

$x_{NPBL,\ NPWL,\ PCWL,\ PCBL,PCDCBL,\ PCDWL,\ PCDCWL,\ PCDBL}$: $496.629 = (x_{NPBL,\ NPWL,\ PCWL,\ PCBL,\ PCDCBL;\ PCDWL,\ PCDCW,}\ x_{PCDBL})$

Note - PCBL = Precooked Brown Lima; PCDBL = Precooked Dehydrated Brown Lima; PCDCBL = Precooked Dehydrated Cooked Brown Lima; NPBL = Non-Precooked Brown Lima; PCWL = Precooked White Lima; PCDWL = Precooked Dehydrated White Lima; PCDCWL = Precooked Dehydrated Cooked White Lima; NPWL = Non-Precooked White Lima

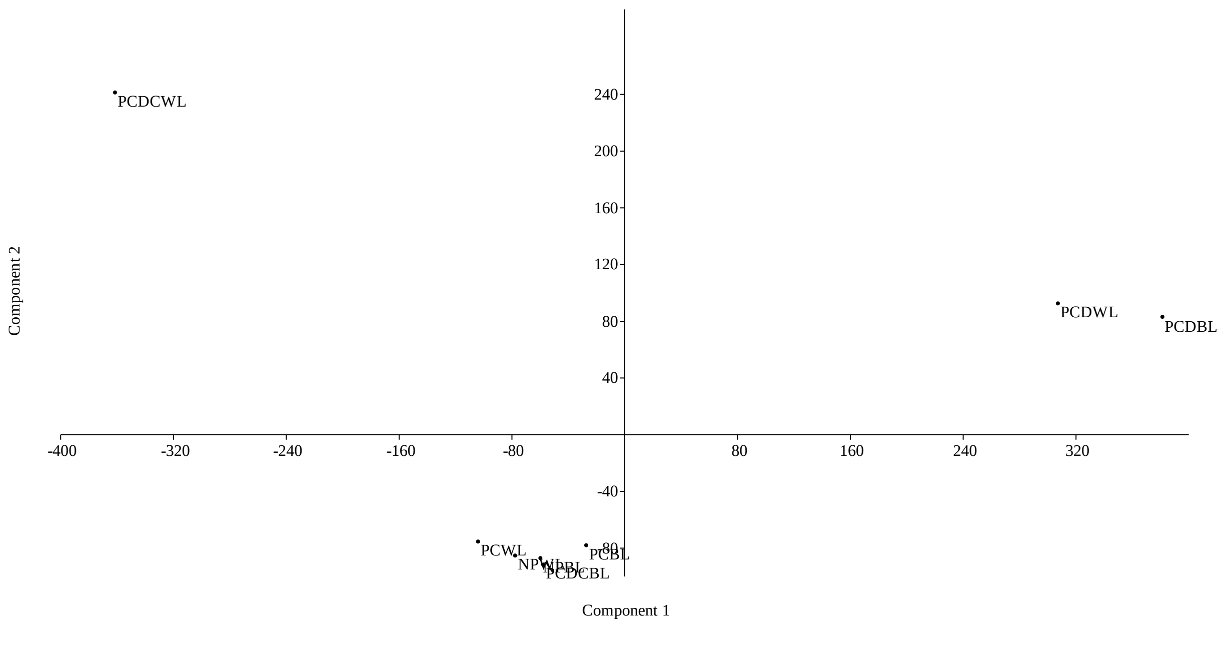

Figure 2. Principal Component Analysis Diagram Showing 2 Distinct Components.

Note - PCBL = Precooked Brown Lima; PCDBL = Precooked Dehydrated Brown Lima; PCDCBL = Precooked Dehydrated Cooked Brown Lima; NPBL = Non-Precooked Brown Lima; PCWL = Precooked White Lima; PCDWL = Precooked Dehydrated White Lima;

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PCDCWL = Precooked Dehydrated Cooked White Lima; NPWL = Non-Precooked White Lima.

Table 1. Principal Components Analysis Statistics

Variables	**PC**			**Axis Loading**		
Options	Eigenvalue	% variance		Axis 1	Axis 2	Axis 3
1	56414.3	74.967	PCBL	-27.339	-77.959	6.9321
2	15537.2	20.647	PCDBL	381.24	83.163	41.27
3	2595.01	3.4484	PCDCBL	-57.834	-91.673	95.039
4	510.962	0.679	NPBL	-59.857	-86.999	-12.557
5	151.481	0.2013	PCWL	-104.07	-75.34	-60.46
6	35.9237	0.047738	PCDWL	307.13	92.624	-51.172
7	6.97601	0.00927	PCDCWL	-361.48	241.41	10.071
			NPWL	-77.789	-85.221	-29.123

Note - PCBL = Precooked Brown Lima; PCDBL = Precooked Dehydrated Brown Lima; PCDCBL = Precooked Dehydrated Cooked Brown Lima; NPBL = Non-Precooked Brown Lima; PCWL = Precooked White Lima; PCDWL = Precooked Dehydrated White Lima; PCDCWL = Precooked Dehydrated Cooked White Lima; NPWL = Non-Precooked White Lima

General Linear Model Analysis of the Anti-nutrients, Proximate, Minerals and Vitamin Content of the Lima bean Samples.

The general linear model of the anti-nutritional properties of the samples indicated that there exist significant differences in the Cyanide, Phytate and Trypsin inhibitor obtained for the samples. The results – $F_{(7, 16: 0.05)}$ = 122.91, 4698.66 and 1698.86 obtained for Cyanide, Phytate and Trypsin inhibitor were significant ($P < 0.01$ – Table 2). The cyanide obtained ranged between 0.111mg/100mg for PCDBL and 0.156mg/100mg for NPWL and are significantly different from one another. Similarly, NPWL has the highest phytate of 0.590mg/100mg and is significantly the highest while the least phytate (0.305) was obtained for PCDBL and significantly lesser than others (Table 2). Trypsin-inhibitor of the samples falls between 0.256 TIU/mg protein for PCWL and 0.386 TIU/mg protein for NPBL and these are significantly different from one another. PCDBL could be adjudged the best of the sample with the least anti-nutritional properties.

The result of the general linear model analysis of the mineral components and vitamins of the Lima beans indicated that there exist significant differences in the means of the Potassium, Calcium Iron, Zinc Vitamin B1 and B2 obtained for the samples. The $F_{(7, 16: 0.05)}$ = 3.19, 1823.81, 1341.44, 11319.50, 468.38 and 405.59 obtained for potassium, calcium, Iron, Zinc, Vitamin B1 and Vitamin B2 were all significant ($P < 0.05$ – Table 3). Mean potassium obtained for the samples were partitioned into 3 significantly different classes. PCDBL returned the highest potassium of 663.13mg/100mg while PCDCWL has the least significantly different mean potassium (351.84mg/100mg – Table 3). Mean potassium obtained for other samples formed intermediate classes between the highest and the least significantly different classes. Mean calcium was partitioned into 8 significantly different classes with no intermediary class (Table 3). The trends of the mean calcium follow the order:

PCDBL (164.390) > PCDWL (151.943) > PCBL (131.14) > PCDCBL (120.14) > PCWL (117.143) > NPBL (96.28).

Mean iron was conveniently stratified into 6 significantly different classes. Mean iron obtained for PCDBL (6.600mg/100mg) was significantly different from mean iron obtained for PCDWL (5.533) which is in turn significantly different from mean iron obtained for PCBL (4.927). Mean iron returned for NPWL was significantly the least and it is lesser than mean iron obtained for both NPBL (4.433) and PCWL (4.463 – Table 3). Mean zinc ranged between 5.96mg/100mg for PCDBL and 2.537mg/100mg for NPWL and they are significantly different from one another. Mean vitamin B1 obtained for PCGWL (0.559) was significantly the highest and it is higher than PCDBL (0.556 – Table 3). The least significantly different vitamin B1 was obtained for both PCWL and PCBL (0.515) and are significantly different from both NPWL (0.520) and PCDCWL (0.518). Mean vitamin B2 was similarly partitioned into 6 significantly different classes. Mean Vitamin B2 obtained for PCDBL (0.225) was significantly higher than mean vitamin B2 obtained for PCDWL (0.215) and in turn significantly higher than mean vitamin B2 returned for NPBL

(0.209 – Table 3). From these results, it is obvious and advisable to conclude that PCDBL remains the best of all the samples by returning the highest values of almost all the parameters/variables.

The results of the General Linear Model (glm) of the proximate composition of the Lima beans showed that means of the proximate components for the samples were significantly different from one another. The statistics, $F_{(7,\ 16:0.05)}$= 2118.58, 155.9, 101.96, 376.96, 11379.56 and 1726.14 obtained respectively for moisture content, protein, fat, crude fibre, carbohydrate and energy were significant ($P < 0.01$ - Table 4). Mean ash content ($F_{(7,\ 16:0.05)}$= 1.13) was however not significant ($P > 0.05$). The moisture content of the Lima bean samples ranged between 8.00 for PCDBL and 63.833 for PCDCBL and were all significantly different from one another. Moisture content of some of the samples however falls within the same class (Table 4). The ash content ranged between 3.967 for PCDCWL and 22.533 for PCBL and were not significantly different from one another. PCDBL had the highest significantly different mean protein (16.080) and it is significantly higher than mean protein of PCDWL (13.520) which is in turn higher than mean protein of PCDCBL (12.533). The least significantly different proteins were obtained for both NPBL (7.957) and NPWL (7.943) and were significantly lesser than mean protein obtained for PCWL (9.157 – Table 4). Highest mean fat (1.127) was recorded for PCBL and was significantly higher than mean fat obtained for PCWL (1.087) while mean fat obtained for NPWL (0.97), PCDBL (0.967), PCDCWL as well as PCDWL (0.963) and PCDCBL (0.960) formed the least significantly different group (Table 4).

Table 2. Anti-nutritional Properties of the Lima Bean Samples

Variable	Cyanide (mg/100g)	Phytate (mg/100g)	Trypsin-inhibitor(TIU/mg protein)
DF	7	7	7
F-statistics	122.91**	4698.66**	1698.86**
NPWL	0.156333^{a}	0.590000^{a}	0.361667^{b}
PCWL	0.152667^{ab}	0.465667^{e}	0.256333^{g}
PCDCWL	0.151333^{b}	0.366667^{g}	0.301667^{e}
PCBL	0.132333^{c}	0.375000^{f}	0.301000^{e}
PCDWL	0.131333^{c}	0.509333^{c}	0.311333^{d}
NPBL	0.130667^{c}	0.553000^{b}	0.385667^{a}
PCDCBL	0.125333^{d}	0.492667^{d}	0.289667^{f}
PCDBL	0.110667^{e}	0.305000^{h}	0.353000^{c}

Note - PCBL = Precooked Brown Lima; PCDBL = Precooked Dehydrated Brown Lima; PCDCBL = Precooked Dehydrated Cooked Brown Lima; NPBL = Non-Precooked Brown Lima; PCWL = Precooked White Lima; PCDWL = Precooked Dehydrated White Lima; PCDCWL = Precooked Dehydrated Cooked White Lima; NPWL = Non-Precooked White Lima

Table 3. Mineral and Vitamins of the Lima Bean

Variable	Potassium (mg/100g)	Calcium (mg/100g)	Iron (mg/100g)	Zinc (mg/100g)	Vitamin B1(mg/100g)	VitaminB2 (mg/100g)
DF	7	7	7	7	7	7
F-statistics	3.19**	1823.81**	1341.44**	11319.5**	468.38**	405.59**
NPWL	466.58^{bc}	98.67^{g}	4.063^{f}	2.537^{f}	0.520^{e}	0.202^{f}
PCWL	438.62^{bc}	117.143^{e}	4.463^{e}	2.637^{e}	0.515^{f}	0.208^{de}
PCDCWL	351.84^{c}	111.237^{f}	4.860^{d}	2.803^{d}	0.518^{e}	0.203^{f}
PCBL	494.54^{abc}	131.14^{c}	4.927^{c}	2.987^{c}	0.515^{f}	0.207^{e}
PCDWL	595.89^{ab}	151.943^{b}	5.533^{b}	4.720^{b}	0.559^{a}	0.215^{b}
NPBL	480.55^{bc}	96.28^{h}	4.433^{e}	2.787^{d}	0.523^{d}	0.209^{c}
PCDCBL	522.49^{abc}	120.14^{d}	4.803^{d}	2.793^{d}	0.541^{c}	0.209^{dc}
PCDBL	663.13^{a}	164.390^{a}	6.600^{a}	5.960^{a}	0.556^{b}	0.225^{a}

Note - PCBL = Precooked Brown Lima; PCDBL = Precooked Dehydrated Brown Lima; PCDCBL = Precooked Dehydrated Cooked Brown Lima; NPBL = Non-Precooked Brown Lima; PCWL = Precooked White Lima; PCDWL = Precooked Dehydrated White Lima; PCDCWL = Precooked Dehydrated Cooked White Lima; NPWL = Non-Precooked White Lima

Table 4. Proximate Composition of the Lima Bean Samples

Variable	Moisture (mg/100g)	Ash (mg/100g)	Protein (mg/100g)	Fat (mg/100g)	CrudeFibre (mg/100g)	Carbohydrate (mg/100g)	Energy(kcal)
DF	7	7	7	7	7	7	7
F-statistics	2118.58**	1.13	155.9**	101.96**	376.96**	1379.56**	1726.14**
NPWL	56.833^{b}	4.567^{a}	7.943^{f}	0.97^{d}	5.547^{f}	24.140^{c}	138.403^{c}
PCWL	55.667^{b}	5.267^{a}	9.157^{e}	1.087^{b}	5.747^{e}	23.077^{c}	140.043^{bc}
PCDCWL	8.100^{d}	3.967^{a}	10.560^{d}	0.963^{d}	6.053^{d}	15.790^{d}	115.143^{d}
PCBL	53.600^{c}	22.533^{a}	10.487^{d}	1.127^{a}	5.750^{d}	23.303^{c}	146.693^{d}
PCDWL	8.100^{d}	4.800^{a}	13.520^{b}	0.963^{d}	6.843^{ab}	65.787^{a}	115.143^{d}
NPBL	56.100^{b}	4.300^{a}	7.957^{f}	1.033^{c}	6.200^{c}	24.410^{c}	140.11^{bc}
PCDCBL	63.833^{a}	4.533^{a}	12.533^{c}	0.960^{d}	6.767^{b}	11.373^{e}	105.223^{e}
PCDBL	8.000^{d}	6.200^{a}	16.080^{a}	0.967^{d}	6.877^{a}	61.877^{b}	329.37^{a}

Note - PCBL = Precooked Brown Lima; PCDBL = Precooked Dehydrated Brown Lima; PCDCBL = Precooked Dehydrated Cooked Brown Lima; NPBL = Non-Precooked Brown Lima; PCWL = Precooked White Lima; PCDWL = Precooked Dehydrated White Lima; PCDCWL = Precooked Dehydrated Cooked White Lima; NPWL = Non-Precooked White Lima.

Mean crude fibre of the Lima bean samples were partitioned into 6 significantly different classes. This includes mean crude fibre obtained for PCDBL (6.877) which is not significantly different from that of PCDWL (6.843). The least significantly different crude fibre was obtained for NPWL (5.547) and it was significantly lesser than crude fibre of PCWL (5.747 – Table 4). Mean carbohydrate ranges between 11.373mg/100mg for PCDCBL and 65.787mg/100mg for PCDWL while mean carbohydrates of other Lima samples fall in between the carbohydrate range. Highest energy was obtained for both PCDWL (329.37kcal) and PCDBL (324.057) and were significantly higher than mean energy obtained for PCBL (146.693). Least significantly different mean energy was obtained for PCDCBL (105.223) and it was significantly different from mean energy chalk up by PCDCWL (115.143 – Table 4). The precooked dehydrated brown lima bean (PCDBL) is visibly the best treatment with the highest ash content, protein, crude fibre and energy

The Kruskal-walis analysis of the precooked lima bean test results indicated that there exist significant difference in the assessor rating of the lima bean (in term of color, appearance, taste, texture and overall acceptability.. More than 0.6 of the rating of the lima bean color were favourable and this result $\chi^2_{19:0.05)}$ = 38.64 was significant (Table 5). The Kruskal-walis analysis of the precooked lima bean test result indicated that there exist significant difference in the assessors rating for appearance of the lima bean. More than 0.5 of the rating of the lima bean appearance were favourable and the $\chi^2_{(19:005)}$ = 27.96 was significant (P<0.05 – Table 5). Similarly, the assessors differ significantly in the scoring of the aroma of the precooked lima beans with less than 0.25 of them rating the samples high and this statistics, $\chi^2_{(19:005)}$ = 28.19 was significant. The result of the Kruskal walis analysis of the texture of the precooked lima been indicated that the lima bean sample were poorly rated by the assessors except few (0.25) of them. The statistics - $\chi^2_{(19:005)}$ = 23.16 obtained was significant (P<0.05 – Table 5). Greater numbers of the assessors (0.35) were okay with the taste of the precooked lima bean hence rated the samples higher. The $\chi^2_{(19:005)}$ = 47.93 of the analysis was significant (P < 0.05). More of the assessors (0.4) rated the precooked lima bean samples higher and the statistics, $\chi^2_{(19:005)}$ = 24.23 was significant (Table 5). Sample NPCBL of the precooked lima beans was the most highly rated lima bean in term of both colour and appearance with majority of the samples (3/4) in both cases favourably rated. These results, $\chi^2_{(3:005)}$ = 11.13 (colour) and 16.34 (appearance) are significant (P<0.01 - Table 5). Both sample NPCBL and NPCWL were the most highly rated lima bean in terms of aroma as well as taste and majority of the samples were 50% favourably rated. The results, $\chi^2_{(3:005)}$ = 3.1(aroma) and 3.7 (taste) were not significantly different (P > 0.05). The most highly rated lima bean in term of texture and overall acceptance are both sample PCDCBL and NPCBL with majority of the sample (50%) favourably rated. The Kruskal-Walis test of the texture and overall acceptance of the lima bean, $\chi^2_{(3:\,005)}$ = 10.97 (texture) and 9.57 (overall acceptance) are significant (P<0.01 - Table 5). From this organoleptic assessment, the PCDCBL remained the more preferable apart from the control.

Table 5. Organoleptic Assessment of Precooked Lima Bean

Variables	Options	Colour	Appearance	Aroma	Texture	Taste	OA
Assessors	A1	3.5	4	3.5	3	3	3.5
	A2	3.5	2.5	3	2.5	3.5	3.5
	A3	4.5	4.5	4.5	3	4	4
	A4	3.5	3.5	4	3	5	3.5
	A5	4.5	4.5	4	3	3	4
	A6	3	3.5	3	3.5	3	3
	A7	4	4	3.5	3	4	4
	A8	5	5	2.5	5	2	3
	A9	3	3	3	2	2	3
	A10	3.5	3.5	2	3	4	4
	A11	2.5	3.5	2.5	3.5	3	3.5
	A12	5	3.5	4	3.5	2.5	3.5
	A13	5	4.5	3.5	4	5	4
	A14	4	3.5	2	3	3	3
	A15	4	4	3.5	2.5	3.5	3.5
	A16	3	3	3.5	3.5	3	3.5
	A17	4	4	3.5	4	3.5	3.5
	A18	5	5	4	4.5	5	5
	A19	4	3.5	3	4	3.5	4
	A20	4	4.5	3.5	5	4.5	4.5
	$\chi^2_{(19:0.05)}$	38.64**	27.96**	28.19**	23.16	47.93**	24.23
Samples	PCDCBL	4	4	3	4	3.5	4
	PCDCWL	3	3	3	3	3	3
	NPCBL	4.5	5	3.5	4	4	4
	NPCWL	4	3	3.5	3.5	4	3
	$\chi^2_{(3:0.05)}$	11.13**	16.34**	3.1	10.97**	3.7	9.57**

Note- PCDCBL = Precooked Dehydrated Cooked Brown Lima; PCDCWL = Precooked Dehydrated Cooked White Lima; NPBL = Non-Precooked Brown Lima; NPWL = Non-Precooked White Lima

DISCUSSION

The goal of this study is to establish the effects of precooking technology on the anti-nutrient, proximate, mineral and vitamins contents of lima beans. Similarities and diversity in the anti-nutrients, proximate, vitamin and minerals established in the presented study is similar to Mamadou *et al*, (2018). It is however established in the present study that precooking and dehydration irrespective of varieties or colour impact on both nutrient similarities and diversity of the lima bean samples. Soaking of lima bean was found to reduce the anti-nutritional factor of lima bean in previous study (Adebayo, 2014). Also, the positive effect of processing on the cyanide, phytate and trysin inhibitor content of the precooked lima bean samples in this study is in agreement with the report of Farinde et al. (2018) on processed lima bean. PCDBL has the least anti nutrient component hence it remains the safest. It can be fathomed from this findings that precooking and dehydration influenced the anti-nutrient contents of the bean. This is also in accord with El-Gohery (2021) who established that many treatments to which lima bean are subjected to reduce the anti-nutrients in a varying degree and that raw lima beans contains the highest values of these anti nutrients. Similarly, moist cooking was found to have reduced trypsin inhibitor by 100% (Adebayo, 2014, Tchumou *et al*, 2023). The range of anti-nutrients present in the lima bean samples were higher than those established in Adebayo (2014) and lower than those in Farinde *et al* (2018). This can be due to the value of the inhibitor found *ad initio* in the lima bean as well as the importance of the pre-cooking in the present study. It has been found that lima bean seed from a specific region might have different characteristics from others (Palupi *et al*, 2022).

It was established in the present study that precooking has significant effects on the components of the eventual lima bean (in terms of vitamin, proximate and mineral components). This is in contrast with Tchumou *et al*, (2023) and Farinde *et al* (2018) where cooking enhances nutrient composition of eventual lima bean. This disparity might be linked to pre-cooking treatment to which lima bean were subjected to in the present study. It was also established that the brown lima bean variety responded to the treatment more than the white variety. The proximate composition variables of the lima bean established in the present study were higher comparatively from those established for lima bean in Ibeabuchi *et al*, (2019) report and compared favourably with those established in Farinde *et al* (2018) report. The organoleptic assessment of the eventual lima bean samples established in the present study favours the control NPCBL and NPCWL more than the other samples. This is in contrast with Dibia-Emanuel and Olumati (2020) where the control was the least preferred. This disparity might be hinged on the type of treatment meted out on the lima bean. Precooking, dehydration and cooking were the processing treatment in the current study while baking, boiling and steaming were the treatment in Dibia-Emanuel and Olumati (2020) report.

IMPLICATION OF THE RESEARCH AND PRACTICE

Lima bean is a nutritious food crop. Hard to cook problem in lima bean renders the bean underutilized, due to drudgery in processing and long cooking time. Precooking (a food transition system) technology has the potential to reduce the final cooking time for lima bean thus providing convenience and enhancement of its utilization. Chemometric evaluation of lima bean provides tangible detailed overview of the nutrients composition of the processed lima bean which can help optimize the processing conditions that can help in enhancing the nutritional value of the lima bean.

CONCLUSIONS

It is glaring that the preprocessing methods are diverse including heat treatment, dehulling, fermentation and precooking among others. Each of these preprocessing methods plays a crucial role in improving the nutritional quality, taste, and texture of the final product. Furthermore, the choice of preprocessing method can also impact the shelf life and overall consumer acceptance of the food product. It is advisable based on the present study to adjudged precooking as a good preprocessing method for convenience, improved nutrient content and acceptability of the final lima bean product and that precooked dehydrated brown lima bean (PCDBL) gave the best quality in terms of least anti-nutrients and the high proximate, minerals and vitamins contents. Precooked dehydrated lima bean is thus recommended for incorporation into diets for improved health and enhancement of food and nutrition security.

FURTHER RESEARCH

Further research into methods of improving the sensory qualities and shelf life stability of the precooked lima bean products should be looked into.

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