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Process Optimisation of Spiced African Locust Bean *(P. biglobosa)* in Different Packaging Materials

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Abstract: *A study was carried out on the process optimisation of spiced African Locust Bean in different packaging materials. African locust bean seeds were soaked, steamed, dehulled and fermented naturally for three days. The untreated sample was first subjected to proximate analysis on the first day (0 week) to serve as the control. Thereafter, the remaining sample was divided into four equal portions (400g each) with each of the three portions preserved with ground ginger, garlic, a mixture of both at a uniform concentration of 4% of each portion size while the last portion had no treatment. Each of the 400g was further divided into 16 portions making each to be 25g and samples to be 64 altogether. In this study, a 44 factorial experiment in a Completely Randomised Design (CRD) was used. The number of replicates was three, and the total number of test trials was 768. The samples were packaged in four different packaging materials (Low-Density Polythene, Polypropylene, Aluminium foil and High-Density Polythene) with each having 0%, 3%, 6%, and 9% perforations respectively. The samples were stored in a refrigerator set at 100°C temperature and 70% relative humidity for a period of four weeks. The values of moisture content, bulk density, vitamin A, Iron, calcium content and pH value were determined at an interval of seven days for a period of four weeks. The result revealed the optimum values of output parameters as follows; minimum Moisture content (6.102 %), maximum Crude protein (39.345 %), maximum Bulk density (0.450 g/ml), maximum vitamin A (163.732 mg/100g), maximum Iron (52.109 mg/100g), maximum Calcium content (1429.249 mg/100g) and maximum pH value (8.46) of the stored product at various conditions.*

Keywords: *Optimum. Bean, bulk density, crude, protein*

1. Introduction

African locust bean (*P. biglobosa)* has long been widely recognised as an important indigenous multipurpose fruit tree whose uses include food, medicine, manure, tannin, shade, wind-breaks, bee food, stabilisation of degraded environment, livestock feeds, fuel, fibre, fish poison and several other domestic uses (Sadiku, 2010). The tree is widely recognised in West Africa as an important multipurpose tree of West Africa Savannah land. African locust bean (*Parkia biglobosa*) tree is a perennial plant which belongs to sub–family *mimosodee* and family *leguminosae* (now *fabaceae*) (Akande *et al.*, 2010). Locust bean tree is a leguminous crop peculiar to the tropics. The tree is not normally cultivated but can be seen in population of two or more in the savannah region of West Africa (Hopkins, 1983). It is prominent in the entire savannah region of West Africa (Yudkin, 1985). It grows in savannah region of West Africa up to edge of Sahel zone (Campbell-Platt, 1980). Dalziel (1963) and Keay (1989) reported that locust bean tree extends from Senegal to Sudan and its habitat is in savannah land as it is characteristic of transition areas from Sahelian to Sudanian eco-zones locally on farmlands. It is common in Nigeria particularly in the Northern and South Western parts (Odunfa, 1982). The most important part of the tree is found in its seeds and the processed seed is used as a condiment for soup. It is a source of natural nutritious condiment which features frequently in the traditional diet of the people (Akande, *et al*; 2010). Apart from the flavouring, attribute of the processed locust bean also contributes significantly to the intake of protein, essential fatty acids, particularly Vitamin B, riboflavin and Vitamin A (Odunfa and Adewuyi, 1985).

A study was carried out on the process optimisation of spiced African Locust Bean in different packaging materials. The study aims at developing a simple and practical processing approach using electricity such that temperature is controlled during steaming, replacing common salt with natural spices (garlic and ginger). Efforts need to be put in place through optimisation of appropriate processing and storage conditions, development of a standard method for preservation with the view of providing an acceptable packaging material to prolong shelf life, as well as add value to the commodity for better income. An optimisation problem requires the determination of the optimal (maximum and minimum)

values of a given function called the objective function under a given set of constraints. Optimisation is the process of finding actions that maximise the value of an object function. This definition can also be adopted into storage process, by saying that, optimisation of storage is the process of finding the best conditions under which the storage of a given product can be done in order to get the best product after storage.

2. Literature Review

The application of various, evolving technological processes has resulted in modern methods of processing African locust bean (Audu *et al.*, 2004; Adewumi *et al.*, 1999). Boiling units such as steamers and pressurised vessels are employed in order to enhance good dehulling characteristics and high quality of final product. The use of gas and charcoal as fuel has also been embraced since this provides clean operation and sustained heat input during boiling. When pressure pot is used to carry out the boiling, it will make locust bean ready for dehulling in 30 to 50 minutes between temperature range of 121^0C and 151^0C (Oyewole and Odunfa, 1990). Adewumi and Igbeka (1993) reported that when locust bean seed is allowed to cool for 5 minutes after boiling, it possesses a dual advantage of both increasing the dehulling characteristics of dehulled surface and upon condensation, the water that migrated into the seed during the boiling process settles between the cotyledon and the testa thereby weakening the adhesive bond. An important mechanical property required for dehulling is shear strength (Mohsenin, 1970). Both dry and wet dehulling involve shearing of surfaces with dehulling medium (Adewumi and Igbeka 1996). Though some impact load is associated with dry dehulling when using mortar and pestle, the major strength responsible for dehulling is shear strength (Singh and Sokhansanj, 1984). Impact load on seed should not exceed shock load and compression load, otherwise the seed would be crushed and the efficiency of dehulling would be reduced (Reichert, 1987).

In lieu of impact loading and rubbing action on the wall of mortar carried out traditionally on boiled seeds, dehullers are used to achieving the same purpose with rubbing action (force) against the wall of dehulling chamber. Audu *et al.* (2004) reported that the guiding principles are very much the same as that of traditional process which is abrasion. This is usually accomplished with a rotating auger made of mild steel having a clearance of 6.5mm between the auger coil and the abrasive wall of the dehulling chamber. This is to allow shear force act on seeds whose average thickness is about 8mm, thereby obtaining dehulled seeds. Dehulling process seeks to impact the seeds with a shear force for separation to occur. Dry dehulling is carried out in some areas but this, though done with the mortar and pestle giving an impact, also seeks to provide the major required shear force. The impact force should be ensured not to exceed the compressive force on the seed otherwise; it may lead to crushing of the seeds to be dehulled and the efficiency of dehulling would be reduced (Owolarafe *et al.*, 2011).

It is also important to look at packaging as an integral part of food processing and preservation because the success of most preservation methods depends on appropriate packaging to prevent microbiological contamination of heat-processed foods or moisture pick up by dehydrated foods. It is advisable that packaging materials for food products such as *P. biglobosa*be perforated because of their relatively high moisture contents and respiration rates which make them lose water to the atmosphere, resulting in loss of weight and fast deterioration in appearance and texture (Brennan and Day, 2006).

One of the most widely used optimisation techniques is the regression analysis (Olaniyan, 2006). Olayemi (1998) described a regression analysis as an attempt to measure the amount of change (in value) of the dependent variable which is derived from a unit change (in value) of the independent variable. In other words, a regression analysis is an attempt to find out, in a specific way, how one variable is related to the other and it involves a one-way cause and effect relationship. Mitral *et al.* (2011) carried out the optimisation of the drying process of onion slices in a vacuum dryer; with a temperature range of 50 – 70^0C, onion slices of 1-5 mm thickness, and pre-treating in solution. It was discovered that the optimum conditions for the treated samples were 58.66^0C drying temperature and 4.95mm slice thickness. Gajda and Biles (1978) stated that the optimum conditions are those that produce the best, most favourable or most beneficial result from a system or process.

A lot of research work has been done on the production of African locust bean seeds and related aspects such as storage, preservation, processing, the time taken to cook, packaging and other areas (Babalola, 2012; Non-Wood News, 2009). However, the optimisation of the storage conditions to make the best combination of selected variables in order to have the best result has not been fully investigated. Hence, it is of paramount importance and worthwhile to carry out the optimisation analysis to determine optimum storage conditions for packaged African locust bean for more acceptable preservation method, better packaging material and shelf life extension.

3. Materials and Methods

3.1 Experimental Materials

The African locust bean seeds (*P. biglobosa.)* species used in this study were purchased from a local market in Odo Owa, Kwara State, Nigeria. These seeds were manually processed. A refrigerator (Haier Thermocool Mini Bar Fridge Model HR-142S TEC) was used for storage. The following instruments were used during the

experiment; digital thermo-hygrometer (Acurite - 00613), a digital pH meter (InoLab - pH7310), electric oven (Gallenkamp: BS. OV-330) and a sensitive electronic weighing balance (Camry-Ek5350).

3.2 Experimental Procedure

Two thousand grammes (2000 g) of locust bean seeds were measured with a weighing balance into a metal sieve that was placed in a pot containing 16 litres of boiling water. It was covered tightly and steamed to 100^0C for 8 hours. The steamed beans were poured into the mortar and dehulled using a pestle. The seed coats were decanted along with washing and the cotyledons were parboiled for 50 minutes. The cotyledons were later drained through a sieve, spread into calabash tray, covered with a wooden tray, wrapped with jute sack and covered tightly to undergo natural fermentation at 28^oC temperature and 86% relative humidity for 72 hours. One thousand and six hundred grammes (1,600g) of freshly prepared locust beans were measured with an electronic sensitive weighing balance and initially divided into four equal portions making a portion to be four hundred grammes (400g) each.

According to Amagase *et al.* (2001), garlic and ginger as natural spices can be toxic if consumed in very high dosages, so supplementation should never go beyond 5% of the diet. Hence, considering a lesser percentage (4%), the preservatives were prepared by adding 4% (16g) of garlic powder to the first portion of the beans, 4% (16g) of ginger powder to the second portion and a mixture of 2% (8g) each of garlic and ginger powder (16g of garlic-ginger powder) to the third portion respectively while no preservative was added to the fourth portion.

After this, each of the four portions was measured and further divided into sixteen equal portions, to make twenty-five grammes (25g) each and sixty-four (64) samples altogether. Each of the samples was packed in four different sterilised plastic films (16cm × 8cm) each having sixteen pieces with different thicknesses and same number of perforation at the same diameters namely: Low Density Polyethylene as M1 (LDPE 0.017mm with8, 16, 24and 0 perforations), Polypropylene as M2 (PP 0.015mm with 8,16,24 and 0 perforations), Aluminium foil as M3 (AF 0.450mm with 8, 16, 24 and 0 perforations) and High Density Polyethylene as M4 (HDPE 0.013 mm with 8, 16, 24 and 0 perforations) each at 3%, 6%, 9% and 0% respectively. The total surface area of each film bag was $128cm^2$.

Storage was done carefully by packaging, labelling and storing the samples in a thoroughly sterilised refrigerator (Haier Thermocool Mini Bar Fridge Model HR-142S TEC) set at a constant temperature of 10^oC and relative humidity of 70% (monitored by a thermo-hygrometer (Acurite Model 00613)) at the Food Engineering Processing Laboratory of University of Ilorin. During the period of storage (four weeks), the environmental conditions such as temperature and relative humidity of the storage environment were constantly checked prior to proximate analyses. The nutritional qualities were determined by subjecting the processed product to proximate analyses in the laboratory using AOAC (2002) nutritional guidelines. The nutritional values determined were Vitamin A, Crude protein, Calcium, Iron and pH value. There were four levels for each of the factors, that is:

Packaging materials - M1 as LDPE, M2 as PP, M3 as AF and M4 as HDPE; Percentage perforations - P1 as 3%, P2 as 6%, P3 as 9% and P4 (no perforation); Preservatives - A1 as Garlic, A2 as Ginger, A3 as Mixture of garlic and ginger and A4 (no preservative); Time – T1 as Week 1, T2 as Week 2, T3 as Week 3 and T4 as Week 4. Figure 1 shows the flow chart for steam method of processing African Locust Bean Seeds while Figure 2 shows the exploded view of the steaming set-up.

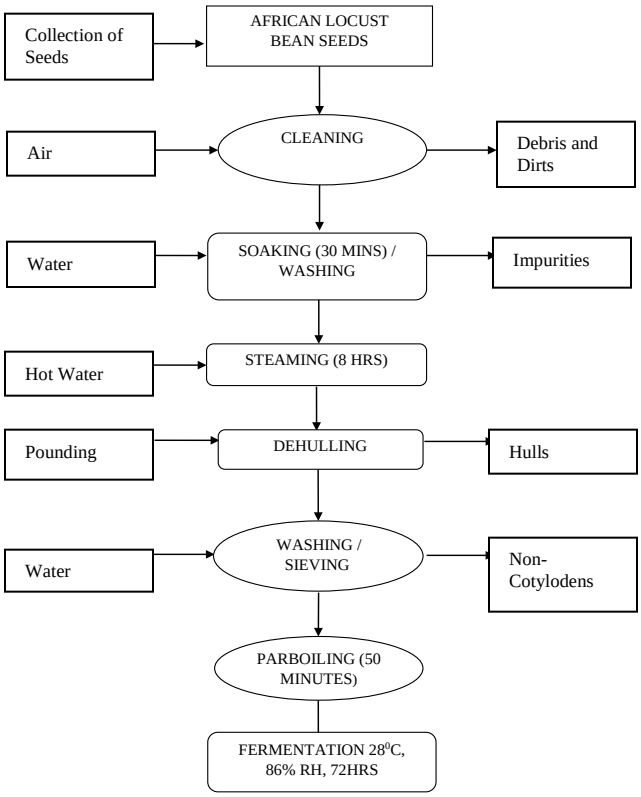

Figure 1. Flow Chart for Steam Method of Processing African Locust Bean Seeds

Also, Figures 3 and 4 show the sample preparation as well as experimental set-up and arrangement of pot, sieve and thermocouple, respectively. The packaged and labelled samples before storage and during storage are presented in Figures 5 and 6.

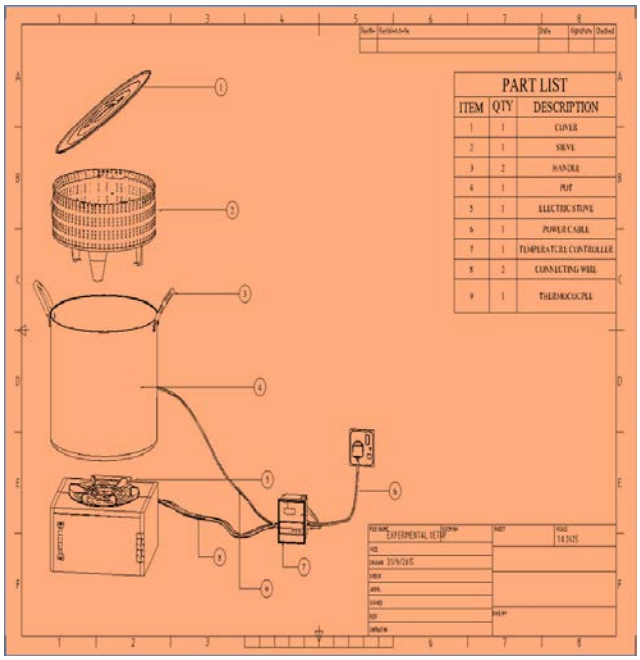

Figure 2. Exploded View of the Steaming Set-up



Figure 3. Sample preparation and Experimental Set-up for the Processing African Locust Bean Seeds



Figure 4. Arrangement of Pot, Sieve and Thermocouple for the Processing African Locust Bean Seeds



Figure 5. Packaged and Labeled Samples before Storage

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Figure 6. Samples Stored Under Refrigeration Condition (Cold Storage)

3.3 Optimisation Analysis

The optimum storage conditions for the stored produce were determined using optimisation technique with the aid of Essential regression software package. Optimisation of storage is the process of finding the best conditions under which the storage of a given product can be done in order to get the best product after storage.

4. Results

Optimisation deals primarily with finding the optimum (maximum or minimum) settings of parameters (process conditions) in mathematical model in order to obtain a desired output or response value. The optimised values of process conditions namely; Storage Time, Packaging Material, Percentage Perforation and Preservative agent present at their various levels and the optimum values of the process output or measured parameters are as presented in Table 1. All process parameters and process output were optimised to maximum and minimum extent possible. The optimised value of process conditions and the optimum values of the output are depicted. The desirable optimum conditions for this study are minimum moisture (%), maximum crude protein (%),

Table 1: Optimised Values of Process Parameters and Nature of Solution

Parameters	M	P	**Q**	**T**	**Optimised value**	**Nature of solution**
Moisture (%) Content	2	4	0	4	7.905	Maximised
	1	1	0	1	6.102	Minimised
Crude Protein (%)	4	4	0	1	39.345	Maximised
	1	1	9	4	34.077	Minimised
Bulk Density (g/cm^3)	4	4	0	4	0.450	Maximised
	4	1	0	1	0.380	Minimised
Vitamin A (mg/100g)	4	4	0	4	163.732	Maximised
	1	1	3	1	157.731	Minimised
Iron (mg/100g)	2	2	9	4	52.071	Maximised
	1	4	3	1	50.109	Minimised
Calcium (mg/100g)	4	1	3	2	1429.249	Maximised
	1	3	0	4	1425.422	Minimised
pH Value	1	4	9	4	8.46	Maximised
	1	1	0	1	8.11	Minimised

Keys:
M - Packaging Materials (1- Low-Density Polyethylene, 2- Polypropylene, 3- Aluminum Foil, 4- High-Density Polyethylene)
P- Preservative (1 - Garlic, 2 - Ginger, 3 - Garlic + Ginger, 4 - No Preservative)
Q - % Perforated (0%, 3%, 6%, 9% Perforations)
T - Time (1 - Week One, 2 - Week Two, 3 - Week Three, 4 - Week Four)

maximum bulk density (g/cm^3), maximum vitamin A (mg/100g), maximum iron (mg/100g), maximum calcium (mg/100g) content and maximum pH value.

5. Discussion

As showed in Table 1, the optimum (minimum) value of Moisture content was achieved by combining African locust beans in Low-Density Polythene, garnished with Garlic, with no (0) perforation and stored for one (1) week. The combination yielded a value of 6.102 %. The optimum value of Crude protein was generated by combining African locust beans in High-Density Polythene, with no preservative, no (0) perforation and stored for one (1) week. This combination gave a maximum value of 39.345 %.

The optimum Bulk density was achieved by combining African locust beans in High-Density Polythene, with no preservative, no (0) perforation and stored for four (4) weeks. This combination yielded a maximum value of 0.450 g/cm^3. Similarly, the optimum Vitamin A content was generated by combining African locust beans in High-Density Polythene, with no preservative, no (0) perforation and stored for four (4) weeks. This combination gave a maximum value of 163.732 mg/100g.

Moreover, the optimum Iron content was derived from combining African locust beans in Polypropylene material, garnished with Ginger, with 9% (24) perforations and stored for four (4) weeks. This combination yielded a maximum value of 52.071 mg/100g. For higher Calcium content, however, the maximum value of 1429.249 mg/100g was achieved by combining African locust beans in High-Density Polythene, garnished with Garlic, with 3% (8) perforations and stored for two (2) weeks. This combination gave the maximum value.

Finally, the optimum pH value was also generated by combining African locust beans in Low-Density Polythene, with no preservative, with 9% (24) perforations and stored for four (4) weeks. This combination yielded a maximum value of 8.46. For the seven outputs considered (moisture content, crude protein, bulk density, vitamin A, Iron, Calcium and Ph), the higher their values in the spiced products, the better the product and the better the application in improving the nutritional qualities of the stored locust beans since the goal of the optimisation process for the seven (7) outputs was to maximise them in the spiced African locust beans. It is possible to control the packaging conditions by fixing the values of different parameters needed to achieve optimum nutritional values of packaged African locust beans.

6. Conclusion

The study focused on the optimisation of spiced African Locust Bean (*P. biglobosa)* in different packaging materials. It was established that useful information on the optimum values of output parameters with respect to process conditions of African Locust Beans (*P. biglobosa)* was provided from optimisation analysis. The High Density Polythene and 6% perforation best improved the nutritional qualities of the stored locust beans at the end of the storage period. The preservative agents (garlic, ginger and mixture) and storage time used were seen to improve the nutritional qualities of the stored locust beans depending on the packaging material and percentage perforation. Ginger increased most of the nutritional qualities and other parameters compared to garlic but the mixture of ginger and garlic best increased the output parameters for four (4) weeks higher than either ginger or garlic alone. This optimisation analysis would help in selecting the optimum nutritional value of processed

African Locust Beans (*P. biglobosa)* under various packaging and storage conditions.

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