DE GRUYTER OPEN

10.1515/aucft-2017-0007

ACTA UNIVERSITATIS CIBINIENSIS Series E: Food technology

DEVELOPMENT OF TEXTURIZED VEGETABLE PROTEIN FROM LIMA BEAN (*Phaseolus lunatus*)AND AFRICAN OIL BEAN SEED[*Pentaclethrama crophylla* (Benth)]:OPTIMIZATION APPROACH

– Research paper –

Gibson. L. ARUEYA[*],Bamidele. S.OWOSEN[I**], Kazeem. K. OLATOYE[***]

[*]*Department of Food Technology, Faculty of Technology, University of Ibadan, Nigeria*
[**]*Department of Food Technology, Faculty of Technology, University of Ibadan, Nigeria*
[***]*Department of Food Science and Technology, College of Agriculture ,Kwara State University, Malete, P.M.B 1530,Ilorin, Kwara State, Nigeria*

Abstract: As part of measures to combat protein shortages in form of meat analogues, extrusion processing conditions for the development of Texturized Vegetable Protein (TVP) from under-utilized sources (Lima bean and African oil bean seed) are analysed. Optimum parameters for processing were established as being: barrel temperature (92.45^{0}C), screw speed (101.48 rpm), feed moisture (59.63%) and African oil bean seed protein concentrates (AOBSPC) of 1%. Concentrations of essential amino-acids were also found to be significant (0.90-7.3%) with a near absence of anti-nutritional factors (0.0022–1.0008)g/kg. Sensory evaluation showed that TVP5 (100% LBPC) compared favourably with the control sample (cooked meat) in overall acceptability. An Acceptable and nutritious meat analogue had been developed.

Keywords: Meat analogue, Legume, Protein-malnutrition, Extrusion, Optimization.

INTRODUCTION

Inadequate protein consumption is regarded as major cause of poor nutrition in the young and grown-ups in developing nations (Okpala *et al.,* 2011; Ifeoma *et al.,* 2010).Poor Nutrition involving protein remains a major health challenge among young ones under five years of age (UNICEF, 2016).This problem emanated from inadequate supply occasioned by high price of animal proteins, which are qualitatively preferred to those of plant origin. Texturization of plant protein, especially legumes as meat alternative has been identified as a promising option in mitigating the scourge (Omohimi et al., 2013). Texturized vegetable proteins (TVP) are good alternatives to animal protein. They are carefully manipulated products of vegetable origin that could possibly be substituted for meat in foods. Indeed they can compete favourably with beef in terms of flavour and chewiness. Quite often, they are referred to as meat analogues. Attempts to widen the narrow protein-rich food base beyond meat to include meat-like products has made scientific investigation into lesser known native plants for proteins and their mechanical manipulation for use in food imperative.

Lima bean of the Family of Fabaceae is one of such underutilized legumes with high nutritional potential.It is recognised by names such as butter beans, Chad beans and papala by the Yoruba tribe of Nigeria. Grown mainly in Peru, Lima bean later found its way to European and African countries (Ezeagu et al., 2010). Like other grain legumes, it is an important source of vegetable protein (23.17%) and fibre (18.40%) but low in fat (0.21%) (Ikechukwu et al. 2010). It is also rich in niacin, thiamine and riboflavin coupled with high levels of potassium, phosphorus, calcium and iron (Osagie et al., 1996).Another under-exploited plant though with higher fat content to likely complement Lima bean in texturised vegetable protein production is African oil bean seed. This plant belongs to the natural order *Mimosaceae*, and is used as food in various parts

[1] Corresponding author. E-Mail address: luckykaykay@yahoo.com

of Africa. It is a large timber tree 40-70 feet high with fragrant, yellow-creamy flowers, (Mbajunwa, 1995). The Nigerian fermented oil bean seeds are called *Ugba* by the Ibos (*Ukpaka* by Enugu and Anambra States) and '*Ukana*' by the Efiks. It is known as oil bean tree, Congo Acacia or Atta bean tree. These trees are found growing throughout the West and Central African forest zones, covering coastal areas of Senegal, Cameroon and Nigeria. African oil bean seed is rich in protein (22.32%), but low in fibre (2.13%) with high fat content (53.98%) (Enujiugha et al., 2005), and could therefore be blended with Lima bean to develop perhaps a more acceptable texturized vegetable protein.

A possible technique in the production of meat-like products is the application of extrusion in the conversion of materials of plant origin into texturized fibrous meat substitute (Omohimi et al., 2013). However, a careful and well thought out choice is crucial for churning out desired products. Little information is available on optimum processing conditions for the production of texturised vegetable protein from Lima bean protein concentrate (LBPC) and African oil bean seed concentrates (AOBSPC) by extrusion technology, hence this study.

MATERIALS AND METHODS

The Lima bean seed and African oil bean seed were sourced from Ibadan (Bodija market) Oyo state, Nigeria. The hydraulic press (HFI RAM DIA. 182mm New Delhi India LOAD in KN SL.NO. HFI-07-06-17) used for defatting was sourced from Food Science Laboratory, Ladoke Akintola University, Oyo State. A laboratory size, single screw extruder in the Food Science and Technology department, Federal University of Agriculture, Abeokuta (FUNAAB) was used in the extrusion study. Materials were processed into flour and subsequently defatted using hydraulic press (Bargale, 1997). Acid-washed protein concentrate were prepared at the Food Technology laboratory, University of Ibadan by employing modified protocols of standard methods by Lusas (1995).

Experimental design

Response Surface Design expert was applied in the study of relationships between process variables (LBPC and AOBSPC) and response variables (Table 1).

Table 1. Response surface analysis results

X_1	X_2	X_3	X_4	Y_1	Y_2	Y_3	Y_4	Y_5	Y_6	Y_7	Y_8
95:5	120	105	60	0.93	1.16	0.26	1.78	1.82	1.14	30.05	0.00
95:5	105	105	70	0.94	1.14	0.26	2.08	1.82	1.35	25.59	-0.27
99:1	105	105	70	0.9	1.23	0.22	1.87	1.86	1.62	30.64	9.54
99:1	120	105	60	1.84	1.42	0.09	2.13	2.08	0.83	34.14	-0.15
99:1	105	105	50	1.08	1.00	0.36	1.89	2.01	1.06	34.93	8.14
99:1	105	90	60	1.00	0.90	0.42	2.10	2.11	1.12	34.87	5.93
97:3	120	105	50	1.19	0.71	0.55	1.84	2.39	1.05	27.96	-0.11
97:3	120	90	60	1.04	0.92	0.41	1.99	2.09	0.36	26.15	-0.24
99:1	105	120	60	0.95	1.10	0.29	2.01	1.92	0.72	30.71	8.49
97:3	105	120	70	0.91	1.19	0.25	1.78	1.96	1.01	27.92	6.41
97:3	90	105	70	0.80	1.55	0.02	2.02	2.11	1.09	30.12	7.00
97:3	105	105	60	0.90	1.23	0.21	2.20	1.89	1.00	27.97	0.25
97:3	90	90	60	0.80	1.55	0.03	2.09	2.31	0.79	34.92	8.25
97:3	90	105	50	0.91	1.20	0.24	2.12	1.86	1.07	37.23	14.7
95:5	105	120	60	0.90	1.23	0.19	1.96	2.01	0.82	29.12	-0.26
97:3	120	120	60	0.85	1.37	0.11	1.68	1.91	1.00	27.51	0.25
97:3	105	105	60	0.89	1.27	0.16	2.06	1.99	0.92	27.57	-0.28
97:3	105	105	60	0.85	1.37	0.12	1.93	2.12	1.85	27.21	-2.61

97:3	105	120	50	0.89	1.26	0.18	1.86	1.85	0.39	26.52	-0.27
95:5	105	90	60	0.88	1.30	0.17	2.32	2.25	0.90	25.64	2.75
97:3	105	105	60	0.86	1.34	0.16	2.10	1.80	0.38	27.31	-2.52
97:3	105	105	60	0.84	1.42	0.09	2.06	1.83	1.16	26.91	-2.74
97:3	105	90	50	0.91	1.20	0.23	2.15	1.98	0.45	30.26	-0.27
99:1	90	105	60	0.85	1.38	0.10	1.93	1.83	1.24	38.96	11.49
95:5	105	105	50	0.94	1.14	0.27	2.22	2.12	0.97	29.09	0.60
97:3	90	120	60	0.83	1.45	0.09	1.74	1.76	1.54	29.38	0.00
95:5	90	105	60	0.90	1.23	0.22	1.92	1.86	1.15	29.66	-0.28
97:3	120	105	70	1.29	0.60	0.62	1.94	2.10	1.36	27.54	0.00
97:3	105	90	70	0.93	1.16	0.27	1.96	1.90	0.91	26.99	6.65

Values reported are means of triplicate ± standard deviation. Lateral expansion (Y_1), bulk density (Y_2) g/cm^3, porosity (Y_3), water absorption capacity (Y_4) g/g, oil absorption capacity(Y_5) g/g, water solubility index (Y_6) %, colour (whiteness) (Y_7) % and breaking strength index (Y_8) N/mm as affected by the independent variables blend of protein concentrate (X_1) %, barrel temperature (X_2)^{0}C, screw speed (X_3) rpm, and feed moisture (X_4) %.

Mixture components, process variables and categorical factors were fused in a single design. Some four independent variables namely feed moisture content(50-70%),temperature(90-120^{o}C),screw speed(90-120rpm) and blends of LBPC((95-99%) along with AOBSPC(1-5%) featured prominently in the experimental design(Box-Behnken).Coding of the process variables were at three levels namely(-1,0,1) (Tables 2 and 3).In all, twenty nine different combinations were evaluated including five replicates. Lateral expansion, bulk density, porosity, water absorption capacity, oil absorption capacity, colour whiteness and breaking strength index of the TVP were the response variables. In order to appropriately quantify the influence of the variables, the polynomial of the second degree was formed. The model of the response was of the form:

$$Y=\beta_0 + \beta_1X_1 + \beta_2X_2 + \beta_3X_3 + \beta_4X_4 + \beta_{11}X^2_1 + \beta_{22}X^2_2 +\beta_{33}X^2_3 + \beta_{44}X^2_4 + \beta_{12}X_1X_2 + \beta_{13}X_1X_3 + \beta_{14}X_1X_4+ \beta_{23}X_2X_3 + \beta_{24}X_2X_4 + \beta_{34}X_3X_4 \quad (1)$$

where X_1, X_2, X_3 and X_4 represent the process parameters (blend of LBPC and AOBSPC, barrel temperature, screw speed and feed moisture respectively); β_0 is the constant; β_1, β_2, β_3 and β_4 are the coefficients translating the linear weight of X_1, X_2, X_3 and X_4 respectively; β_{12}, β_{13}, β_{14}, β_{23}, β_{24}, β_{34} are the coefficients translating the interaction between the variables; β_{11}, β_{22},β_{33}, β_{44} are the coefficients translating the quadratic effects of X_1, X_2, X_3 and X_4 respectively. A basic principle of RSM according to Huang et al. (2005) is to correlate product responses that describe interactions (such as those of regression equation) in relation to input parameters and properties of product.

Table 2. Blends of protein concentrates and extrusion conditions

Parameters/ Code level	Level		
	-1	0	+1
Blends of Protein concentrate [LBPC: AOBSPC (%)]	99:1	97:3	95:5
Barrel temperature (^{0}C)	90	105	120
Screw speed (rpm)	90	105	120
Feed moisture (%)	50	60	70

Table 3. Inclusion levels of Protein concentrates in Blend formulation

Blend formulation	% Inclusion	
	LBPC	AOBSPC
1	99	1
2	97	3
3	95	5

Production of Texturized Vegetable Protein (TVP) from LBPC and AOBSPC

Following the recipe in Table 3, pastes were prepared from measured amount of (LBPC) and (AOBSPC), hydrated with appropriate quantities of distilled water as determined by (Omeire et al., 2013). The pastes were then fed into the single screw extruder. In each case, the extruder ran at maximum speed for all runs at varying conditions: Operational temperature (barrel) (90 – 120)^{0}C, screw speed (90 – 120) rpm and feed moisture (50-70%). Extrusion was effected with a locally fabricated extruder (NASOD Engineering limited, Abeokuta, Ogun State, Nigeria). The configuration of the extruder is L/D ratio of 304:18.5, screw diameter of 18.5mm, power of 2HP and barrel length of 304mm.

Evaluation of some chemical properties of LBPC, AOBSPC and TVP.

Major constituents such as crude protein, fat, fibre, Ash, moisture content and available carbohydrate were evaluated using standard method (AOAC,2000).The profiling of Amino acids closely followed the method of Benitez(1989).Inositol phosphate (phytic acid) content was ascertained in line with the modified method of Odumodu(2010).An estimation of the Trypsin Inhibitor activity(TIA) was done using the modified method of Kakade et al. (1974).The sample's total oxalic acid content was established through the modified method of Gupta et al. (2005)

Determination of functional Properties of TVP

The expansion of the extrudate was expressed using the ratio of it's diameter to that of the die(Fan *et al*., 2000) .Measurement of the extrudate dimension was employed in calculating bulk density (Thymi *et al*., 2005) The apparent density was evaluated using the technique of Onyango *et al.* (2004).Bulk and Apparent volumes formed the basis for the determination of porosity of the extrudates (Asare *et al*.,2004).Water absorption and solubility index of TVPs were determined using the approach of Asare *et al.* (2004) with some modification. For oil absorption index (OAI), the same method of Asare et al (2004) was applied by simply substituting Groundnut oil for distilled water. Breaking strength of extrudate was determined using a flexural analyzer [Universal material testing machine, England (Surrey)] in conjunction with a load cell (M500 – 25KN) and a Warner–Bratzler shear cell (1-mm thick blade) (Onwulata et. al., 2001).

Colour

Color parameters (L*,a*,b*)[L*=Lightness(0-100), a*=red-green, b*=yellow-blue] were evaluated with a colorimeter(Color Tec PCM; Color Tec Associates Inc., Clinton, NJ, USA)[Commission Internationale de l'Eclairage (CIE)].A white paper(80g) Business Xerox was used to standardise the instrument prior to use. Several determinations (10points) of the aforementioned parameters were made for each sample. Using the method of Park(2000), blind sample as an indicator for general appearance was calculated.

$$\text{Blind } (\%) = 100-[(100-L^*)^2 + a^{*2} + b^{*2}]^{0.5} \qquad (2)$$

Sensory evaluation:

Freshly produced TVP samples were evaluated for aroma, colour, texture, taste, chewiness and acceptability by twenty panelists on a hedonic scale(9-point) where 1 represent dislike extremely and 9 extremely like (Iwe, 2002).

Statistical analysis

Determination and measurements done were subjected to statistical analysis using statistical package for social sciences (SPSS version 21). Duncan multiple range test was applied in separating means ($P \leq 0.05$).

RESULTS AND DISCUSSIONS

Proximate compositions

The crude protein content of LBPC (70.39%) is about twice that of AOBSPC (32.42%) with the former retaining its high intrinsic moisture content (14.1%) (Table 4).This may be attributable to the leguminous nature of the source. AOBSPC had a 30.01% crude fat content, a figure much higher than the 2.5% obtained for LBPC. Enujiugha et al. (2005) though reported a higher fat content of 53% for AOBSPC on dry weight basis. Fat as a proximate component of foods contributes significantly to juiciness and flavor development - desirable attributes in meat and meat-like products. The 6.54% crude fibre content of AOBSPC is over twice the level in LBPC (2.4%).Crude fibre plays a leading role in textural (mouthfeel) properties of foods. Ash contents of LBPC (1.39%) and AOBSPC (1.73%) were quite low – an indication that the products are poor sources of Minerals. Supplementation of LBPC with AOBSPC (1-5%) followed by extrusion cooking at constant conditions had significant impact ($p<0.05$) on crude protein and moisture contents of TVP (Table 5).With 1-5% substitution of LBPC with AOBSPC [temperature (90^0C), screw speed (120 rpm) and feed moisture (60 %)], crude protein values varied from 67.24% for LBPC(100%)TVP to 67.92% for LBPC:AOBSPC(95:5)%TVP (Table 5).Moisture content followed a similar trend. Extrusion temperatures significantly affects the moisture content of food materials (Anuonye et al., 2012). No significant effect was observed in crude fibre and ash contents, except at 95:5 TVP. Anjum et al (2011) made a similar observation. Texturized vegetable protein varied in crude fat from 1.92% for LBPC (100%) TVP to 2.13% for LBPC: AOBSPC (95:5%) TVP. A comparable pattern was exhibited by carbohydrate content.

Table 4. Proximate composition of protein concentrates

Parameter	% composition	
	LBPC	AOBSPC
Moisture	14.10	9.20
Crude protein	70.39	32.42
Crude Fat	2.50	20.01
Crude Fibre	2.40	6.54
Total Ash	1.39	1.73
Carbohydrate	9.67	20.10

LBPC- Lima bean protein concentrates; AOBSPC- African oil bean seed protein concentrate

Table 5. Proximate composition of different blends of texturized vegetable protein

Parameter	% Composition			
	99:1 TVP	97:3 TVP	95:5 TVP	100 LBPC TVP
Moisture	11.91	12.17	11.27	12.30
Crude protein	67.36	67.27	67.92	67.24
Crude Fat	1.98	2.01	2.13	1.92
Crude Fibre	1.68	1.67	1.69	1.64
Total Ash	2.25	2.16	1.31	2.23
Carbohydrate	14.82	14.72	15.68	14.67

99:1 TVP- Texturized vegetable protein made from 99% LBPC and 1% AOBPC; 97:3 TVP- Texturized vegetable protein made from 97% LBPC and 3% AOBPC; 95:5 TVP- Texturized vegetable protein made from 95% LBPC and 5% AOBPC; 100 TVP- Texturized vegetable protein made from 100% LBPC and 0% AOBPC

Amino acid profile of TVP2 [LBPC: AOBSPC, (99:1)% ; TVP5 (LBPC:AOBSPC, (100:0)%]

The total amino acid composition of the two most preferred samples (TVP2 and TVP5) by the panelists were close to WHO reference amino acid pattern (Table 6). Both samples had fairly good concentration of essential and non-essential amino acids. Tyrosine and phenylalanine, both essential amino acids exceeded the amino acid reference requirement for adult but fell slightly short of those for children. However, cysteine was lower than those specified in the amino acid reference pattern. Lysine content for the two samples fully met the FAO/WHO requirement. This is quite significant when viewed against the backdrop that staple foods such as cassava in developing countries are low in lysine and indeed in a number of essential amino acids. It should be noted that the absence of data on the tryptophan content was as a result of its instability under the acidic conditions of hydrolysis.

Table 6. Amino acid profile of samples of protein concentrates TVP2 and TVP5

Amino acids(g/100g)	TVP2	TVP5	XX	YY
Essential	---	----	----	---
Isoleucine	4.21	4.11	1.3	2.8
Leucine	7.31	7.29	1.9	6.6
Lysine	5.81	5.83	1.6	5.8
Methionine	1.50	1.51	1.7	2.5
Cysteine	0.97	0.92	1.7	2.5
Tyrosine	3.14	3.12	2.8	6.3
Phenylalanine	4.66	4.91	2.8	6.3
Threonine	3.89	3.92	0.9	3.4
Tryptophan	-	-	0.05	1.1
Valine	4.65	4.59	1.3	3.5
Histidine	2.44	2.42	1.6	1.9
Nonessential	---	-----	-----	----
Aspartic acid	10.54	10.47		
Glutamic acid	13.22	12.95		
Alanine	4.52	4.46		
Arginine	5.19	5.21		
Glycine	4.20	4.16		
Proline	2.90	2.82		
Serine	3.20	3.15		

NB: XX and YY are FAO/WHO (1991) Requirement (g/100g) for adult and Children respectively.

Anti-nutritional factor of TVP2 (99% LBPC and 1% AOBPC) and TVP5 (100% LBPC)

The observed anti-nutritional factors such as phytic acid, trypsin inhibitors and oxalates (Table 7) were quite low and is comparable to commonly consumed foods - indicating an enhanced bioavailability of nutrients (Siddhuraju *et al.,* 1996).The absence of polyphenols in the concentrate is also noteworthy as it's presence has been linked to poor digestibility and biological value of proteins (Krupa, 2008). These low anti-nutritional profile is evidently a function of the different processing conditions associated with protein isolation techniques and extrusion (Omohimi et al., 2013).

Table 7. Anti-nutritional composition of the protein concentrates.

Antinutritional Factors(g/Kg)	TVP5(100:0)	TVP2 (99:1)
Polyphenols	Not Detected	Not Detected
Phytic Acid	0.0600	0.0530
Oxalate	0.0022	0.0020
Trypsin inhibitor	1.0008	0.9300

Functional properties of TVP

The lateral expansion (Y_1), bulk density (Y_2), porosity (Y_3), water absorption index (Y_4), oil absorption index (Y_5), water solubility index (Y_6), colour (whiteness) (Y_7) and breaking strength index (Y_8) of the extruded texturized vegetable protein ranged between 0.80 and 1.84, 0.60 and 1.55, 0.02 and 0.62, 1.68 and 2.32; 1.76 and 2.39, 0.36 and 1.85, 25.59 and 38.96 and -2.74 and 14.70 respectively (Table 8). Results of statistical evaluation of the response data derived from the quadratic model(equation 1) are shown in Table 8 varying between (R^2) 0.411 and 0.9447 with Y_7 having the Peak value and Y_6 the least. Lateral expansion (Y_1), bulk density (Y_2) g/cm^3, porosity (Y_3), water absorption index (Y_4) g/g, oil absorption index (Y_5) g/g, water solubility index (Y_6) %, colour (whiteness) (Y_7) % and breaking strength index (Y_8) N/mm as affected by the independent variables; blend of protein concentrate (X_1) %, barrel temperature (X_2)^{0}C, screw speed (X_3) rpm, and feed moisture (X_4) %.

Sensory evaluation of texturised vegetable protein (TVP)

Mean sensory scores (Table 9) were significantly different ($p<0.05$) for most attributes. Samples TVP 2 and 3 compared favourably with each other in aroma but were significantly different from TVP 4, 5 and 6. Extrudate sample TVP 5 had the highest sensory score for colour more than the control (TVP 6). The concentration of AOBSPC may be a factor in the variation of the colour (Gujral *et al.,* 2002).The comparable mean sensory score for colour for samples TVP 2 and 6 is indeed noteworthy since it falls within one of the primary objectives of the study. Sample TVP 6 (control) was rated the best for texture and chewiness, with TVP 5 following closely in both parameters. Layer structure and fibre characteristics of TVP 6 (control) may have been a significant factor in this development (Riaz et al., 2003). TVP 5 was adjudged as next to TVP 6 in overall acceptability scores by the panellists.

Table 8. Regression coefficients of process variables for the functional properties of the texturized vegetable protein

Z	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8
X0	+0.870	+1.330	+0.150	+2.070	+1.930	+1.060	+27.390	-1.580
X1	-0.094	+0.014	-9.167E-003	+0.029	+5.833E-003	-0.022	-2.930	-3.410
X2	+0.170	-0.180	+0.110	-0.038	+0.055	-0.095	-2.240	-3.450
X3	-0.019	+0.048	-0.035	-0.130	-0.100	+0.079	-0.640	-0.700
X4	-0.012	+0.030	-0.016	-0.036	-0.038	+0.200	-1.430	+0.540
X11	+0.100	-0.067	+0.039	+0.017	+2.000E-003	+0.087	+2.730	+2.860
X22	+0.120	-0.028	+0.025	-0.11	+0.056	+0.049	+2.760	+2.220
X33	-0.050	-0.017	+0.012	-0.054	+0.047	-0.280	-0.190	+1.820
X44	+0.050	-0.170	+0.120	-0.043	+0.036	+0.013	+0.410	+3.620
X12	-0.240	-0.027	+0.013	-0.085	-0.072	+0.100	+1.300	+2.980
X13	+0.018	-0.068	+0.037	-0.067	-0.013	+0.080	+1.910	-1.390
X14	+0.045	-0.058	+0.032	-0.030	-0.038	-0.045	+0.200	-0.570
X23	-0.055	+0.140	-0.090	+1.000E-002	+0.093	-0.028	+1.730	+2.180
X24	+0.053	-0.120	+0.073	+0.050	-0.130	+0.072	+1.670	+1.950

X34	+0.000	-7.50E003	+7.500E-003	+0.027	+0.047	+0.040	+1.170	-0.060
R^2	0.8094	0.5911	0.5833	0.6482	0.4957	0.4111	0.9447	0.8053
LoF	31.70	9.16	10.74	2.03	1.74	0.33	11.85	5.41
F-V	4.25	1.45	1.40	1.84	0.98	0.70	17.07	4.14
P-V	0.0053	0.2497	0.2687	0.1325	0.5125	0.7450	< 0.0001	0.0060

Significant values at 5% level; Xo is intercept. Y_1–Y_8 are lateral expansion, bulk density, porosity, water absorption index, oil absorption index, water solubility index, colour (whiteness) and breaking strength index respectively.Z: Coefficients; LoF: lack of fit; F-V: F-value; P-V: P-value

Table 9. Mean sensory scores for selected attributes of the Texturized vegetable protein

TVP samples (LBPC:AOSBPC)	Aroma	Colour	Texture	Taste	Chewiness	Overall Acceptability
TVP1(0:100)	$6.70{\pm}0.92^{b}$	$3.25{\pm}1.25^{d}$	$5.75{\pm}1.41^{b}$	$6.00{\pm}1.12^{c}$	$5.60{\pm}1.05^{b}$	$5.75{\pm}1.02^{c}$
TVP2(99:1)	$5.85{\pm}1.09^{c}$	$6.00{\pm}0.65^{b}$	$5.40{\pm}1.05^{b}$	$5.85{\pm}0.99^{c}$	$5.65{\pm}0.93^{b}$	$5.95{\pm}0.69^{c}$
TVP3(97:3)	$5.85{\pm}0.99^{c}$	$4.95{\pm}0.60^{c}$	$5.15{\pm}0.75^{b}$	$5.75{\pm}0.64^{c}$	$5.50{\pm}1.05^{b}$	$5.70{\pm}0.80^{c}$
TVP4(95:5)	$6.20{\pm}1.20^{bc}$	$4.50{\pm}0.95^{c}$	$5.10{\pm}0.85^{b}$	$6.05{\pm}1.10^{bc}$	$5.75{\pm}0.91^{b}$	$5.60{\pm}1.14^{bc}$
TVP5(100:0)	$6.65{\pm}1.39^{b}$	$7.95{\pm}0.83^{a}$	$5.75{\pm}0.97^{b}$	$6.60{\pm}0.75^{b}$	$6.00{\pm}0.73^{b}$	$7.10{\pm}0.64^{b}$
TVP6(Control)	$7.60{\pm}0.99^{a}$	$6.20{\pm}1.11^{b}$	$8.05{\pm}0.94^{a}$	$8.55{\pm}0.60^{a}$	$8.65{\pm}0.49^{a}$	$8.75{\pm}0.44^{a}$

Mean sensory scores with different superscript within a column are significantly different (P< 0.05). TVP 6(Control) - meat.

CONCLUSIONS

A nutritious and acceptable texturized vegetable protein had been produced from various blends of AOBSPC and LBSPC at optimum operating conditions. These variables evidently impacted on the product properties. Barrel temperature and screw speed apparently exerted the most effect. Lateral expansion and porosity rose as barrel temperature increased. The reverse was indeed the case with product parameters - bulk density, water and Oil absorption indices, colour (whiteness) and breaking strength. Optimized conditions- barrel temperature (92.45^{0}C), screw speed (101.48rpm), feed moisture (59.63%), AOBSPC (1% inclusion level) were the most desirable (desirability concept).

The design, ease of use and operational principles of the extruder could be enhanced, perhaps by automation. The high protein content associated with the extrudate makes it a veritable product for combating protein deficiency. Further study should be carried out on the microbial profile and storage stability of the texturized vegetable protein.

REFERENCES

1. Anjum S.A, Wang L.C, Farooq M, Hussain M, Xue LL, Zou C.M.(2011). Brassinolide application improves the drought tolerance in maize through modulation of enzymatic antioxidants and leaf gas exchange.J.Agron. Crop Sci.,doi:10.1111/j.1439 037X.2010.00459.x
2. Anuonye J. C., Jigam A. A and Ndaeko G. M (2012) Effects of Extrusion-Cooking on the Nutrient andAnti-Nutrient Composition of Pigeon Pea and Unripe Plantain Blends Journal of Applied Pharmaceutical Science 02 (05); 2012: 158-162
3. Asare, E.K., Seta-De deb, S., Sakyi-Dawson, E. & E.O. Afoakwa (2004). Application of response surface methodology for studying the product characteristics of extruded rice-cowpea-groundnut blends. *International Journal of Food Sciences and Nutrition,* 55(5) 431-439
4. Bargale P (1997) Mechanical Oil Expression from Selected Oil- seeds under UniaxialCompression Saskatoon: Department of Agricultural and Bioresource Engineering, University of Saskatchewan, p. 337
5. Benitez, L. V. (1989). Amino Acid and fatty acid profiles in aquaculture nutrition studies, p. 23- 35.in S.S. De Silva (ed.) Fish Nutrition Research in Asia. Proceedings of theThird Asian Fish Nutrition Network, Meeting Asianfish. Society Special Publication.4:166 p.
6. Ding, Q.B, Ainsworth, P., Plunketh, A., Tucker G., and Marson, H. (2006).“Effect of extrusion cooking on the functional and physical properties of wheat-based expanded snacks.” Journal of Food Engineering, 73:142-148

7. Enujiugha,V. N. and Agbade, J.O (2005). Nutritional and anti-nutritional characteristics of African oil bean seeds (Pentaclethra macrophylla Benth). Appl Trop Agric. 5: 11-14
8. Ezeagu I.E., and Ibegbu M.D., (2010).Biochemical composition and nutritional potential of ukpa: a variety of tropical lima beans (*Phaseoluslunatus*) from Nigeria.Pol. J. Food Nutr. Sci. 60.3: 231-235.
9. Ezeagu I.E., Ologhobo A.D.,(1995) Proximate composition of unfamiliar plant seeds in Nigeria – A short report. Pol. J. Food Nutr. Sci., 4.5:79–83
10. Fan, G.Y. and Ellisman, M. H.(2000). Digital imaging in transmission electron microscopyJournal of Microscopy, 200: 1–13. doi:10.1046/j.1365-2818.2000.00737.x
11. Gupta,S,Lakshmia,A.Manjunathb,M.and Prakash,J.(2005).Analysis of nutrient and anti-nutrient content of underutilized green leafy vegetables. LWT - Food Sci. Tech.38:339-345.
12. Haung D, Ou B, Prior RL (2005). The chemistry behind antioxidant capacity assays. J. Agric. Chem. 53: 1841-1856.
13. Ifeoma I.J.,Chukwunonso E.E, Obinna M.N, Bryan C.N.(2010) Effects of traditional processing techniques on the Nutritional and phytochemical composition of African Breadfruit (Treculia africana) seeds: Journal of Applied science, Environmental management, (JASEM) ISSN 1119-8362.
14. Ikechukwu, E. C. F, Obri A.I,Akpa O (2010). Phytochemical and Micronutrient Composition of Anacardium Occidentale Linn (cashew) stem-bark hydroethanolic extract and its effect on the fasting blood glucose levels and body weight of diabetic Wistar rats. Internet J.Nutr.Wellness.10(1).
15. Iwe M.O.(2002).Handbook of sensory analysis and methods. Projoint communications services Ltd., Enugu. pp 70-72.
16. Kakade, M. L., Hoffa, D. E., &Liener, I. E.(1973). Contribution of trypsin inhibitors to the deleterious effects of unheated soybeans fed to rats. Journal of Nutrition, 103,1172.
17. Lusas E.W, Riaz M.N. 1995. Soy protein products: processing and use. J Nutr 125:573S –80S.
18. Mbajunwa, O.K. (1995). Effect of Processing on some Antinutritive Toxic components and on nutritional composition of the African Oil Bean seed (*Pentaclethramacrophylla*Benth). J.Sci. Food Agric. 68, 153 – 158
19. Odumodu, C.U. (2010) Nutrients and anti-nutrients content of dehulled soybean. Continental J. Food Science and Technology 4: 38 – 45
20. Okpala, L.C., and Okoli, E.C.(2011) Nutritional Evaluation of cookiesproduced from pigeon pea, cocoyam and sorghum flour blends. *Afr. JBiotechnology*.10 (3): 433-438.
21. Omeire, G.C (2012).Amino acid profile of raw and extruded blends of African yambean (*Sphenostylis stenocarpa*) and cassava flour. *American journal of Food and Nutrition*2(3):65-68
22. Omohimi C.I., Sobukola P.O.,Sarafadeen K.O., and Sanni L.O.(2013).Effect of Process Parameterson the Proximate Composition, Functional and Sensory Properties of Extruded Meat Analogue from Mucuna Bean Seed Flour. World Academy of Science, Engineering and Technology,76.
23. Onwulata C.I., Konstance R.P., Smith P.W., Holsinger V.H. (2001): Co-extrusion of dietary fiber and milk proteins in expanded corn products. LWT-Food Science and Technology, 34: 424–429.
24. Onyango,C., Noetzold, H. & T. Bley.(2004) Proximate composition and digestibility of fermented and extruded uji from maize-finger millet blend. LWT - *Food Science and Technology, 37(8), 827-832.*
25. Osagie, A.U., Muzquiz, M., Burbano, C., Cuadrado, C., Ayet,and Castano, A.(1996).Some antinutritional constituents in ten staple foods grown in Nigeria. Trop. Sci. 36: 109 – 115.
26. Riaz.M.N.(2003).Textured Soy protein and its Uses.Extrusion Technology Program and Graduate Faculty, Food Sci. & Tech. Program, Food Protein R%D Centre, Texas A&M University, College Station,TX 778843-2476.
27. Siddhuraju P, Vijayakumari K, Janardhanan K (1996). Chemical composition and protein quality of the little-known legume, velvet bean (Mucuna pruriens(L.) DC). J. Agric. Food Chem.,44: 2636-2641.
28. Thymi,S.,Krokida, M.K., Paps, A. & Z.B. Maroulis.(2005).Structural properties of extruded corn starch. *Journal of Food Engineering*, 68(4), 519-526.
29. United Nations Children Emergency Fund (UNICEF).(2016).State of the World's Children ,NewYork,USA.Published for UNICEF by Oxford Universities Press.