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Water/Oil Absorption and Solubility Indices of Extruded African Breadfruit (*Treculia africana*) Blends

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Abstract: Five flour combinations of African breadfruit (40, 55, 70, 85, 100%), defatted soybean (55, 40, 25, 10, 0%) and yellow corn (5, 5, 5, 5,0%) were hydrated to 15, 18, 21, 24, 27% moisture, respectively. Each feed combination was thoroughly mixed in a Hobart mixer (A 200, England) and extruded in a Brabender laboratory single screw extruder (DCE 330, NJ, USA) at screw speed of 100, 120, 140, 160, 180 rpm respectively. A second order central composite response surface design was adopted in designing the experiment which generated 25 runs. Extrusion cooking significantly ($p = 0.05$) affected sample moisture, fat and energy. Trypsin inhibitor activity and tannin were reduced by 89%, while phytic acid was reduced by 38%. Water absorption index increased by 2.8 times the unextruded blends and was inversely related to water solubility index. Screw speed had significant ($p = 0.05$) quadratic effect on water absorption index and wettability. Feed moisture exhibited linear and quadratic influences on oil absorption capacity and wettability. Cross product effects of feed composition and feed moisture were significant ($p = 0.05$) only on wettability.

Key words: African breadfruit, *Treculia africana,* extrusion, water absorption/solubility indices, oil absorption capacity

INTRODUCTION

The seeds of African breadfruit (*Treculia africana*) are currently a potential source of nutrients because of their immense contributions to the diet of the people of Nigeria[1]. The crop sustains the consumers during planting seasons when major staples such as yams, cocoyam, cassava and corn are under cultivation.The consumption of blends of dehulled African breadfruit seeds with shelled "milk" corn is a popular tradition in the Southern parts of Nigeria especially during the early seasons of corn production.

Although soybean is not indigenous to Africa, it is an oil seed crop which has received tremendous popularity as a cheap protein resource in Nigeria through Research Institutes, Workshops, Seminars and Mass media. It is preferred as a more appropriate protein fortifier to other oil seed crops due to its amino acid composition[2]. It complements low protein staples which even when ingested in excess of caloric requirement do not still provide adequate protein for human requirements[3]. Ariahu *et al.*[4] reported a formulation of acceptable weaning ration from soybean and African breadfruit.

The list of ingredients used in extruded foods consists of almost every imaginable food item[5]. Its increasing popularity and rapid acceptance as an important food process operation is seen in its several different applications. While extrusion cooking of corn and soybean and their various blends has been extensively reported in literature, there is opacity of information on the application of the technology in the processing of African breadfruit and/or its blends with corn and soybean. This is a serous omission from the standpoint of product development efforts in Nigeria. It was on this premise that a study on extrusion cooking of African breadfruit –corn-soy blends was undertaken to investigate:-

- Effect of extrusion cooking on the nutritional and anti-nutritional properties of the extrudates.
- Effects of process variables on the functional properties such as water/oil absorption and solubility indices using response surface methodology. Response surface plots were demonstrated to visualize these effects.

MATERIALS AND METHODS

Raw materials: African breadfruit seeds were purchased from Mbano, Imo State while soybean and corn were purchased from Yola main market, Adamawa State.

Flour production: African breadfruit seeds were blanched in hot water (100°C) for 15 min. They were afterwards cracked in a commercial attrition mill and manually dehulled. Dehulled seeds were dried at 60°C for 17 hr and milled into flour in a Brabender roller mill.

Corn grains were mechanically dry-cleaned in a Vegvari Ferenc aspirator (OB 125 Budapest, Hungary). They were coarsely cracked in a Brook Crompton hammer mill (DN 15 8QW, England) before milling into fine flour in the roller mill (made in Germany).

Soybean seeds were first soaked in a stainless trough with potable water for 18 h at room temperature. The seeds were dehulled and dried at 60°c for 10 hr in a Chirana type air convection oven (HS 201 A). The resulting seeds were milled in the roller mill and defatted using hexane. The flour was dried and milled in the hammer mill to break up the clumps.

Blending: Flour samples from African breadfruit and defatted soybean were mixed at 5 level combinations of 40, 55, 70, 85, 100% and 55, 40, 25, 10, 0% respectively. Yellow corn flour was included at 5% level and 0% for the 100 :0 (African breadfruit: soybean ratio).

Extrusion: The 5 flour portions were extruded in a Brabender laboratory single screw extruder (DCE 330, New Jersey). The extruder die diameter was 2.2 mm while the barrel length to diameter ratio was 20:1. Die zone temperatures were set at 120, 150, 170 and 150°c for feeding, compression, metering and die zones. Samples leaving the die orifice were dried and packaged per sample runs for various analysis.

Proximate composition: Proximate composition of the centre point raw and extruded blends was determined in triplicates according to AOAC[6] methods. Total carbohydrate was determined by difference while energy was by Atwater factor.

Analysis for mineral composition: The mineral composition of the centre point raw and extruded blends was determined on 1ƒÊg –1g weight samples according to methods reported to literature[7-8]. Mineral elements analysed for included Ca, Cu, Fe, Mg, Mn, Zn, P and K.

Analysis for anti –nutritional factors: Anti –nutritional properties of raw and extruded samples determined were trypsin inhibitor activity. (TIA), phytic acid and tannin according to methods reported in literature for trypsin inhibitor activity[9], phytic acid[10] and tannin[11].

Determination of Water Absorption Index (WAI): The Water Absorption Index (WAI) of raw and extruded blends of African breadfruit, corn and soybean flours was determined on 2.5 g samples according to the method reported by earlier researchers[5]. Water absorption index was calculated as the increase in weight of the gel formed after decanting the supernatural. Water density was assumed to be 1 g mL^{-1}.

Determination of Water Solubility Index (WSI): The supernatant from the water absorption index determination was decanted into a pre-weighed moisture dish and evaporated to constant weight in a precision oven (III. 60647,USA) at 103°C. Water solubility index (WSI) was calculated as the percent weight of the original sample weight recovered[5].

Oil absorption capacity (OAC): The method of determination of oil absorption capacity described by Okezie and Bello[12] was used. 1g sample was introduced into a centrifuge tube and thoroughly mixed with 30ml groundnut oil. The sample was then allowed to stand for 30min. It was centrifuged at 1500xg for 30 min. The free oil (specific gravity 0.87) was decanted into a graduated cylinder and volume read. The value was expressed as the grams of oil absorbed per gram of sample. Oil absorption capacity was determined in triplicate and mean values recorded.

Determination of sample wettability: Wettability was determined on 1g sample in triplicates according to the method reported by Okezie and Bello[12]. The sample was weighed into 25ml graduated cylinder with a diameter of 1cm. A finger was placed over the open end and the cylinder was inverted and dumped at a height of 10cm from the surface of a 600 ml beaker containing 500mL tap water. The finger was removed to allow the sample material to be dumped. The time required for the sample to become completely wet was recorded as the wettability.

Experiential design: A 2nd order central composite design on 3 independent variables and 5 level combinations was adopted. The independent process variable feed composition (*fc*): 40, 55, 70, 85, 100% African breadfruit, feed moisture (*fm*): 15, 18, 21, 24, 27% and screw speed (*ss*): 100, 120, 140, 60, 180 rpm.

The centre point (*fc*= 70%, *fm* = 21%, *ss* = 140 rpm) was replicated 10 times while the corner and star points were not, bringing the experimental runs to 25. Effects of process variables on the responses were modeled by a 2nd order polynomial. The response surface was fitted into a quadratic polynomial equation for each of the responses by using a small number of level combinations (Eq. (1))[13]

$$Y = \beta_0 + \Sigma^k \beta_i X_i + {}^k\Sigma^k_{i=ik} \beta_{ii} X_i^2 + \Sigma^k_{i=i} \Sigma^k_{i<j} \beta_{ij} X_i X_j + \epsilon \qquad (1)$$

Y = dependent variables (responses)
X_i and X_j = independent variables in the model
k = number of independent variables
$\hat{a}_0$ = intercept (constants and regression coefficient of the model)
å = random error term.

RESULTS AND DISCUSSION

Proximate and mineral composition: Table 1 shows effect of extrusion on the proximate and mineral composition of the centre point raw and extruded samples. There were significant (p = 0.05) changes in moisture, fat and energy contents due to extrusion. The reduction in fat could be attributed to physical loss as droplets which were not recovered, couple with shear effects of extruder screw, pressure exertion of the dough against the die small nozzle and other process interactions. Effect of extrusion on crude protein, carbohydrate and other constituents was not significant.

This supports the report that extrusion cooking has no effect on sample chemical composition[14] and that total content of nitrogen before and after extrusion does not change[15].

Anti- nutritional factors: Anti nutritional composition of the centre point raw and extruded samples is presented in Table 2. Extrusion cooking significantly (p =0.05) lowered phytic acid, TIA and tannin contents by 38.77, 89.90 and 89.20% respectively. The magnitude of reduction in the anti nutritional factors is expected because while TIA and tannin are organic pigments and proteins, phytic acid is an acidic compound.

Extrusion cooking is an appropriate process technology that renders extruded food products nutritionally high by lowering its antinutritional factors and enhancing protein digestibility. Ordinarily, most commercially available soybean products intended for human consumption have received sufficient heat treatment to cause inactivation of at least 80% of the TIA present in raw soybean[16].

Functional properties: Functional properties of raw blends on Tables 3 shows significant (p = 0.05) decrease in water and oil absorption indices with increase in soybean or decrease in African breadfruit. Water solubility index and wettability showed a reverse pattern. This observation supports an earlier report[5,17,18] that

Table 1: Effect of extrusion cooking on the proximate and mineral composition of centre point raw and extruded formulations

Parameter%	Raw blend	Extruded product
Moisture content	5.60	4.00
Crude protein (N x 6.25)	23.64	23.60
Crude fat	11.75	9.85
Ash	2.50	3.00
Crude fibre	2.60	2.80
Carbohydrate (by difference)	53.91	56.71
Energy (Kj/g) (Atwater factor)	1753.10	1722.21
Mineral elements (mg/100g)		
K	828.00	1008.00
Na	8.00	9.00
P	15.00	150.00
Ca	166.67	233.33
Mg	313.50	312.14
Zn	0.655	0.816
Mn	1.82	0.91
Fe	312.75	312.14

Table 2: Effect of Extrusion cooking on the Anti-nutritional properties of centre point raw and extruded formulations

Parameter	Raw blends	Extruded Products
Phytic acid (mg/100g)	126.10	77.21
TIA (Tiu/mg)	20.10	2.03
Tannin (mg/100g)	17.40	1.88

Table 3: Absorption and solubility indices of raw blends

Parameter (%)	Feed composition				
	40	55	70	85	100
Water absorption index	206.00	218.40	236.00	246.80	248.00
Water solubility index	17.20	13.60	9.20	9.20	6.40
Oil absorption capacity	0.20	0.70	0.09	nd	nd
Wettability (s)	33.00	21.00	44.50	nd	nd

* = % African breadfruit in the blend, 5% corn and made up to 100% with defatted soybean except for the 100% breadfruit. nd =not determined.

Table 4: Coefficients of variables in regression models of absorption and solubility indices of extruded products

Variable	WAI	WSI	OAC	WETTA
Constant	-805.71636	-0.19304	5.26610	-798.19734
fc	1.04176	-0.34731	-0.01787	7.66241*
fm	17.26654	1.97145	-0.55412*	55.2078.3*
ss	12.16984*	-0.07010	0.01166	2.70090
fc fc	0.00177	0.00050	-0.00007	-0.01519**
fc fm	0.456394	0.00862	0.00330	-0.31263*
fc ss	0.04439	0.00218	-0.00005	-0.03161
fm fm	- 0.66532	-0.06586	0.01463**	-1.23044*
fm ss	-0.07647	0.00614	-0.00131	0.01521
ss ss	-0.02829	0.00017	0.00012	-0.01136*
R^2	0.96252	0.81911	0.57679	0.78320

(b) Analysis of variance

	WAI	WSI	OAC	WETT
fc	0.000	0.003	0.137	0.011
fm	0.003	0.011	0.425	0.037
ss	0.151	0.584	0.119	0.290

WAI = -805.71636+12.16984*ss**, WSI = -0.19304-0.06586fm^2**, OAC = 5.26610 -0.55412*fm** + 0.01463fm^2**, WETTA = -798.19734 + 7.6624*fc** +55.20783*fm** -0.01519 *fcfm*** -0.31263*fcss** -1.2344*fmss** -0.01136ss^2*
* significant at p = 0.05, ** significant p = 0.1.

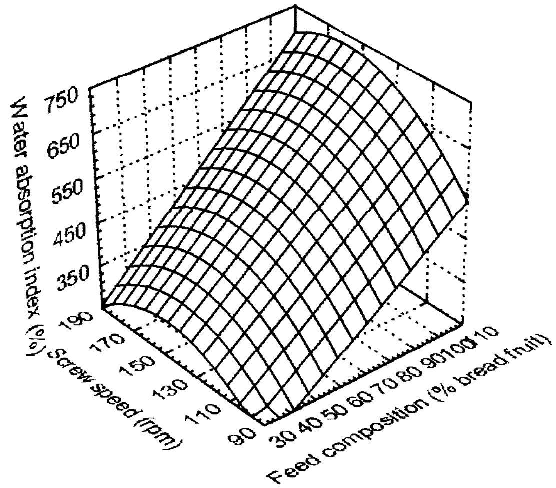

Fig. 1. Response surface plot of effect of feed composition (% African breadfruit) and screw speed on water absorption index.

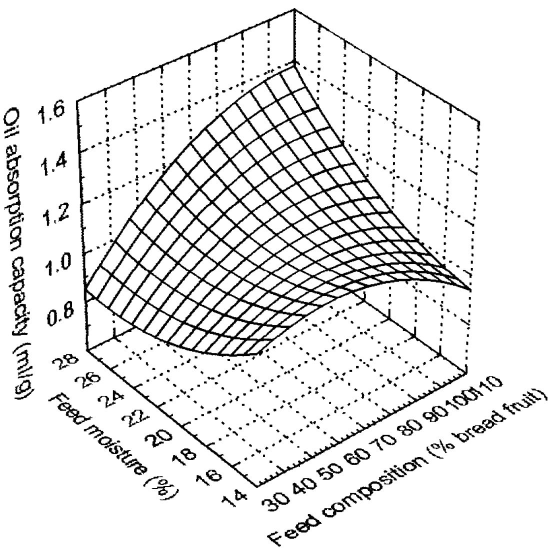

Fig. 2. Response surface plot of effect of feed composition (% African breadfruit) and feed moisture on water solubility index.

increase in protein sources decreased WAI while increase in carbohydrate (starch) increased it. The inverse relationship between WAI and WSI in this study agrees with reports in literature[3]. The effect of soybean in OAC and wettability is related to increased fat value in the blend due to soybean addition which lowered oil absorption capacity and increased its dissolution (wettability) in water. OAC was generally lower than WAI irrespective of feed composition. Similar observation has been reported for soybean

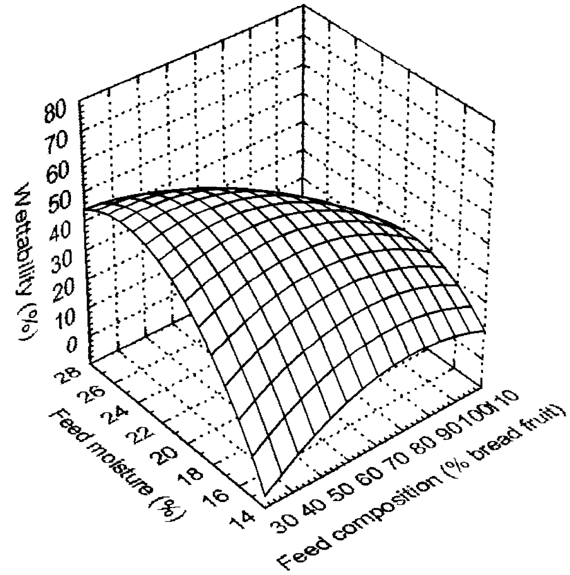

Fig. 3. Response surface plot of effect of feed composition (% African breadfruit) and feed moisture on extrudate wettability.

and winged bean flours[19], cowpea flour[20], African Yam bean flour[21] and African breadfruit flour[22]

Effect of extrusion on the functional properties: Table 4 shows that extrusion cooking enhanced the functional properties of the blends. This denotes effect of changes in the state of the main chemical components. There was a general increase in WAI by 2.8 times due to extrusion. Chauhan and Bains[17] made and observation of 3-fold increase in WAI of extruded products over non- extruded blends of different blends of rice flour and defatted soybean. Low values of WAI in raw samples indicate the presence of almost intact starch granules[23] while high values in the extrdates are attributable to protein denaturation, starch gelatinization and swelling of the crude fibre[24]. Damaged/transformed starch has the ability for high water absorption to form paste at room temperature by mechanism of gelatinization. Degree of starch gelatinization has been reported[23] to correlate with WSI which could be considered an indicator of the extent of starch degradation rather than an index of gelatinization.

Lower values of wettability indicates faster reconstitution properties. Increase in the parameter due to extrusion is related more to physical properties such as particle size than to chemical changes in the product.

Effect of process variables on functional properties: Regression coefficients and analysis of variance of data on functional properties of extrudates are presented on Table 4.

Water absorption index : Linear effect of screw speed on water absorption index was significant. Effects of other variables were not significant. From analysis of variance feed composition and feed moisture significantly (p = 0.05) affected WAI (Table 4b). The response surface associated with the analysis is shown in Fig. 1. There was increased WAI at high feed composition irrespective of feed moisture and screw speed. Water absorption index could be a functional indicator of degree of cooking in the extrudate. The model contributed 96.25% of total variation in WAI. The polynomial after removing non significant terms becomes:

$$WAI = 805.71636 + 12.16984\, ss \qquad (2)$$

Water solubility index: The regression coefficients indicated that there were no significant linear, cross product or quadratic effects of process variables on water solubility index. However, analysis variance (Table 4b) shows that feed moisture and feed composition significantly affected the response. The model accounted for 81% of total variation in WSI.

Oil absorption capacity: Table 4a information shows that feed moisture had significant (p = 0.05) linear and quadratic influence on oil absorption capacity. On removing the non- significant terms, the polynomial becomes:

$$OAC = 5.26609 - 0.554412\, fm + 0.01463\, fm^2 \qquad (3)$$

The model developed on this response accounted for 57.7% of the total variation in oil absorption capacity. The response surface for the effect of feed moisture is shown in Fig. 2.

Wettability of extrudate: The information on Table 4a shows that feed moisture and feed composition had significant (p=0.05) linear and cross product effects on extrudate wettability. The analysis of variance in Table 4b further confirmed the significance of effects of these variables on wettability. Feed moisture and screw speed affected wettability quadratically. The model developed on wettability contributed 78% of total variation in the response. The polynomial equation after removing the non significant terms becomes:

$$Wetta = 798.19734 + 7.66241\, fc + 55.20782\, fm - 0.31263\, fcfm - 1.2304 fm^2 - 0.01136 ss^2 \qquad (4)$$

Equation (4) indicated that the linear effect of feed moisture is higher than that due to feed composition. The response surface plot in Fig. 3 confirms this effect. Increasing the concentration of African breadfruit or reducing percent defatted soybean in the blend increased extrudate wettability as feed moisture was increased.

CONCLUSION

Extrusion cooking of blends of African breadfruit, corn and defatted soybean flours is beneficial in some way. It improved the nutritional quality of the product by drastically lowering its antinnutritional content and by modifying extrudate components such as protein and starch for better utilization.

Water and oil absorption indices were increased for extruded products over the values for the raw blends. Extrudate oil is an important property that contributes to its flavour and mouth feel. Water absorption index decreased with increase in defatted soy concentration in the blend. The major component in feed composition that caused increase in water solubility index was gelatinized starch. Water absorption and solubility indices could therefore be used as indicators of degree of cooking in extrusion cooking of blends of African breadfruit, corn and defatted soybean.

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