OPTIMIZATION AND END USE CHARACTERISTICS OF EXTRUDED MILLET FORTIFIED WITH SOYBEAN FOR THE MANUFACTURE OF *FURA*: A NIGERIAN TRADITIONAL FOOD

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INTRODUCTION

Agriculture and post-harvest activities plays an important role in the economic output of more than 70% of the Nigerian population. This translates to substantial number of the workforce engaged in small-scale farming and pastoralist activities for subsistence. The problem of food insecurity is worsened by the rising urban population as a result of migration. The agricultural land in Nigeria can achieve a maximum of crop yield, and any further need of increase in food supply demands more efficient and rational integration of agricultural process into the mainstream of our economy, by adoption of scientific technologies. *Fura*, an unfermented traditional thick steamed dough ball snack produced principally from millet or sorghum is very common in west Africa particularly Nigeria, Burkina Faso, Niger, Mali and Ghana (Nkama and Filli, 2006) . Depending on the community it is traditionally eaten with *nono* (local yoghurt produced from cow milk) or mashed in water before consumption in the form of porridge. Pelembe et al., (2002) reported an extruded instant 'pre-cooked' porridge from sorghum and cowpea which could make a great contribution to food security in Southern Africa. *Fura* has a short storage life of about 3 days and being a single cereal based product is limiting in the essential amino acid lysine. Furthermore the product lacks process specifications governing composition, ingredients, additives and shelf life. Processing has remained a home-based or artisanal activity that is carried out with rudimentary equipment and techniques, which is characterized by inconsistent product quality, poor hygiene, very short shelf life and unacceptable standards. Extrusion has the potential of overcoming these problems by making traditional products to be more acceptable in the fast changing society. The objectives of this work was to optimise process condition for *fura* and study the effects of feed composition, feed moisture and screw speed on extrudate physical propeties from pearl millet and soybean flour mixtures.

MATERIALS AND METHODS

Raw mateials

The variety of peral millet used was SOSAT-C88 developed by the Lake Chad Research Institute Maiduguri, Nigeria.The soybean was obtained from the farm of Adamawa State University Mubi, Nigeria. Ginger and black pepper used as spices were obtained from Mubi main market, Nigeria.

Blend preparations, moisture adjustment (%) and mass flow rate (measured in seconds)

Blend preparation, moisture adjustment and mass rate were carriedout as described by (Zasypkin and Tung-Ching Lee, 1998).

Bulk density of extrudates (cm^{-3})*, water absorption index* ($WAIg_{H_2O}\ g_{sample}^{-1}$) *and water solubility index (WSI%).*

Extrudates bulk density; WAI and WSI were calculated using the methods described by (Qing-Bo *et al.*, 2005).

Expansion ratio (puff ratio), specific mechanical energy (SME) measured in $KjKg^{-1}$

Expansion ratio and SME were determined as described by (Binoy et al.,1996).

Wettability (WTBTY) measured in seconds and effects of quantity of water on the swell volume of samples (EQWSV) measured in cm^3

Wettability and (EQWSV) were determined as described by (Filli and Nkama, 2007).

Viscosity (Nsm^{-2})

Viscosity was determined with the aid of rotational viscometer model (Rheotest 2 type).

Average residence time

This was determined by dividing the barrel (tube) volume by the volumetric flow rate of extrudate, (Lewis, 1987).

Extrusion exercise

Extrusion cooking was performed in a single screw extruder, model (Brabender, Duisburg DCE-330),

Experimental design central composite rotatable designs (CCRD)

The central composite rotatable composite design (CCRD), (Box and Hunter, 1957) was adopted**.** A three factors and three level experimental design was adopted for this work.

RESULTS AND DISCUSSIONS

The effect of extrusion condition on WAI was influenced by linear and quadratic terms significantly ($p<0.05$), Table 1. The interaction term did not show significant ($p>0.05$) influence. The WSI was equally influenced significantly by linear and quadratic terms, ($p<0.05$) Table 1, the model did not show a significant lack of fit. The $R^2 = 0.76$ suggesting a good fit of the model. The viscosity of samples was influenced by linear terms significantly ($p<0.05$) and $R^2 = 0.74$ Table 1. Viscosity profile can be thought of as a reflection of the granular changes in the starch granule that occur during gelatinization, (Thomas and Atwell, 1997). Extrusion conditions affected the ER and BD by both linear and quadratic terms significantly ($p<0.05$). The models showed good fit with $R^2 = 0.92$ and $R^2 = 0.96$ for ER and BD respectively.

The regression coefficient show that linear and quadratic terms influenced EQWSV significantly ($p<0.05$) and WBLT showed no significant influence by any of the terms. The effect of quantity of water added on the swelling capacities of products gives an indication of quantity of the minimum amount water required for full swelling.

The regression equation coefficients for ART, SME and MFR are presented in Table 1. Examination of these parameters indicated that linear and quadratic terms were significant ($p<0.05$) for ART and SME, however for MFR linear, quadratic and interaction terms were significant ($p<0.05$). The regression models for the data were significant (<0.05) with satisfactory coefficients of $R^2 = 0.787$, 0.871 and 0.826 for ART, MFR and SME respectively. The coefficients of variation (CV) were less than <10% (result not shown) suggesting the models could be reproducible (Montgomery, 1984). Results from Table 1, suggest that the linear effect and interaction effects of the three variables were the primary determining factors of the responses and no significant interaction between any two of them.

Table 1. Regression equation coefficients for objective responses[a, b]

Coefficient	WAI	WSI	VSCSITY	ER	BD	EQWS	WBLTY MFR	ART	TORQUE	SME	
Linear											
b_0	-0.3780	-0.1177	-0.4230	-0.2424	0.2005	0.8209*	-0.2476 0.6982*	-0.8345*	0.5989*	0.2522	
b_1	- 0.5860*	-0.3781	-0.7553*	- 0.2890*	0.2558*	0.5413*	-0.4362 0.0311	-0.2945	-0.0117	0.0420	-
b_2	- 0.4960*	- 0.5936*	0.3928	- 1.0588*	1.0557*	-0.0510	-0.3904 0.5450*	-0.4039*	-0.2601*	-0.0254	
b_3	-0.2210	-0.3138	-0.2150	0.0722	- 0.2084*	0.3823*	-0.0664 0.3468*	-0.2912	-0.7184*	-0.7689*	
Quadratic											
b_{11}	-0.0353	-0.2303	0.1738	0.2251	- 0.2652*	-0.0549	-0.0542 0.1324	0.3956*	-0.4477*	-0.3444*	-
b_{22}	0.1588	-0.1224	0.2160	0.0845	0.0853	- 0.4342*	0.0891 0.7265*	0.7100*	-0.6184*	-0.3985*	-
b_{33}	0.4306*	0.5253*	0.2301	0.0457	-0.1139	- 0.7142*	0.3279 0.1645	0.1175	0.1882	0.3732*	-
Interaction											
b_{12}	0.1096	-0.1269	-0.1984	0.0308	0.0095	0.2001	0.1348 0.4419*	0.2647	0.2758	0.3666	
b_{13}	-0.3836	-0.2793	0.0198	-0.0993	0.1068	-0.0150	-0.2022 0.3512	0.3393	0.2031	-0.0354	
b_{23}	0.3288	0.1269	0.4564	-0.0034	-0.1581	-0.0650	0.4718 0.2606	0.1177	-0.0269	-0.0831	-
R^2	0.7274	0.7592	0.7406	0.9150	0.9639	0.825	0.4580 0.871	0.7870	0.934	0.826	
Adjusted R^2	0.4821	0.5425	0.5071	0.8384	0.9315	0.667	-0.0297 0.755	0.5950	0.875	0.670	
Lack of fit	NS	NS	*	*	*	NS	* NS	*	*	*	
Model	*	*	*	*	*	*	NS *	*	*	*	

[a] $Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_{11}X_1^2 + b_{22}X_2^2 + b_{33}X_3^2 + b_{12}X_1X_2 + b_{13}X_1X_3 + b_{23}X_2X_3$ X_1 = Feed Composition, X_2 = Feed Moisture, X_3 = Screw Speed, [b]* Significant at $P < 0.05$, NS, not significant

Optimum conditions

The feed composition (X_1) and Feed moisture (X_2) affected WAI significantly in their linear term. The optimal combination of feed composition (17.7%), feed moisture (37.3%) and screw speed (160.8) resulted in optimal WAI of (4.6 $g_{H_2O}\ g_{sample}^{-1}$)). Apart from the stationary point for feed moisture all were located within the range of experimental values of the independent variables, hence the fitted response equation was adequate for depicting responses near the stationary point. The interaction of the independent variables did not significantly (p>0.05) affected WSI. The optimal combination of low feed composition (14.76%), feed moisture (15.25%) and low screw speed (219.74) resulted in optimal WSI of (6.14%). The negative coefficients for feed composition (X_1), and screw speed (X_3) indicate that linear effect of these variables decreased VSCSITY. The positive coefficient for feed moisture indicates that linear effect increased VSCSITY. The quadratic and interaction of the independent variables did not significantly (P > 0.05) affect VSCSITY, while the lowest occurred at the highest feed composition and intermediate feed moisture. Optimal combinations are shown in Table 2.

The optimal combination of feed composition (21.21%), feed moisture (56.17%) and screw speed (178.7) resulted in optimal value of ER (1.68). The BD was influenced significantly ($P < 0.05$) by the feed composition and feed moisture. The positive coefficient indicates that increase in both feed composition and moisture linearly resulted in increase of BD. The optimal combination of feed composition (18.95%), feed moisture (41.12%) and screw speed (39.86) correspond to optimal value of 0.799 gcm^{-3} for BD.

The optimal combination of feed composition (102.68), feed moisture (34.19) and (204.85) correspond to optimal value of 17.82 cm^{3} for EQWS. The optimal combination of feed composition (15.18%), feed moisture (26.12%), and screw speed (291.61) correspond to optimal value of 18.53 for ART.

The response equation shows that quadratic effect influenced SME. Increasing screw speed increased SME. The quadratic effect showed a significant ($p<0.05$) influence on the SME. The optimum conditions of feed composition (19.15%), feed moisture (24.12%) and screw speed (250.33) translate to an optimum value of 406.8Kj Kg^{-1}. The optimum conditions of feed composition (8.46%), feed moisture (24.21%) and screw speed (107) translate to an optimum value of 1.41 gs^{-1} for MFR.

Table 2. Optimum levels of independent variables

Dependable variable	Feed composition (%)	Feed Moisture (%)	Screw Speed (rpm)	Optimum value
WAI	17.67	37.27	160.8	4.55($g_{H2O}\ g_{sample}^{-1}$)
WSI	17.67	15.23	219.75	6.15 %
VSCSTY	46.97	29.34	174.52	4.58Nsm^{-2}
ER	21.21	56.17	178.7	1.68
BD	18.95	41.13	39.89	0.8gcm^{-3}
ART	15.12	26.12	291.61	18.53 s
TORQUE	23.23	24.12	286	21.21Nm
PRESSURE	18.9	26.2	334	2.1x 10^{6} Nm^{2}
SME	19.16	24.12	250	406.81 KjKg^{-1}
MFR	8.465	24.22	106	1.41gs^{-1}

CONCLUSION

The RPM was effective in optimising the process condition for *fura* as influenced by feed composition, feed moisture and screw speed. Therefore the model could be used to navigate the design space. Results indicated that the independent variables were significant on the physicochemical properties of the extrudates. The importance of process variables on extrudate responses could be ranked in the following order: feed moisture (X_2), feed composition (X_1) and screw speed (X_3). The optimum conditions were identified and the response variables predicted with model equations under optimum conditions were in general agreement with experimental data.

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