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Production and evaluation of extruded snacks from Sourghum (*Sorghum bicolor* l. *Moench*), soybean (*Glycine max* (l.) *Merr*.) And carrot (*Daucus carota subsp. sativus*)

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Abstract
The nutritional qualities of extruded sorghum-soy snack fortified with carrot pulp were evaluated. Snacks were prepared by hot extrusion of sorghum-soybean-carrot blends (wheat (0.8kg), sorghum (0.16kg), soybean (0.04kg) and carrot pulp (0.1kg)) in a single screw extruder operated at standard processing conditions (barrel temperature, 150ºC). The samples were subjected to chemical, microbial, anti-nutritional and sensory analysis using standard methods. Results of chemical analysis showed that the incorporation of soy flour into the blends increased the nutrient content of the extrudates while fortification with carrot pulp increased the pro-vitamin A content to 116% of Required Dietary Allowance (RDI) (3478 International Units). Carrot fortification also increased the acceptability of the snacks by imparting desirable colour, taste and flavour to the product. The vitamin C, B_1, B_2, B_3, and iron contents were markedly retained after extrusion. The extrusion processing was effective in eliminating tannin, hydrogen cyanide, trypsin inhibitor and haemagglutinin activities and reduced phytate content of the final extrudate to a safe level. The preferred snack (sorghum-soy-carrot extruded snack) had a low fat content, high carbohydrate, ash, fibre and protein contents. The enhanced nutrients of the extrudate suggest that acceptable extruded snacks could be produced from blends of soy, sorghum and carrot.

Keywords: extrusion, snack food, protein-energy malnutrition, fortification

Introduction

In many developing countries such as Nigeria, malnutrition is an endemic dietary problem characterised by protein-energy malnutrition (PEM) and micronutrient deficiency (Bowley, 1995; Otegbayo *et al*., 2002) [7, 26]. The high cost and inadequate production of protein rich foods have resulted in increased protein-energy malnutrition among vulnerable groups (Bell & Reich,1989) [6] due to insufficient intake of energy, protein and micronutrients which predisposesthem to endemic related diseases such as kwashiorkor, marasmus and noma (Cancrumoris) (WHO, 2005) [35]. Overdependence on available carbohydrate based foods and near absence of cereal-legume ready to eat blends also aggravates the challenge, because even when available it may not be affordable to majority of the populace. It is therefore very important to develop ready-to-eat protein rich snacks from cheap locally available raw materials, which will contribute significantly in supplying adequate dietary requirement, needed to alleviate the challenges. In the past few years, efforts have been made to reduce or eliminate the challenge globally. Dietary diversification which involves the use of commonly available or consumed grains, legumes and other nutritious crops to prepare foods such as snacks to meet the nutritional/dietary need of the population has been suggested as the ultimate solution to malnutrition challenges (Gibsonin, 2011) [12]. Anton *et al* (2009) [4] recorded a significant improvement in the overall nutritional profile of corn-starch based extruded snacks fortified with common beans. Hence, the need to identify and explore the potentials of using locally available but under-utilized agricultural produce in formulation of nutrient dense snack food products.Snacks are classified as convenience foods that constitute important part of many consumer's daily nutrient and calorie intakes, and serves as useful adjunct to regular meals (AFGC, 2008) [2]. Snacks are high in calories, fat and low in proteins, vitamins, and other nutrients, emanating from the major ingredient blend such as cereals, legumes and other additives. Sorghum (*Sorghum bicolor* L. *Moench*), which is a cereal source of easily digestible carbohydrate, essential minerals and characteristic flavour that is a widely consumed staple in the tropics (Enwere, 1998) [9]. Sorghum species are important food crop in Africa, Central America, and South Asia and is the fifth most important cereal crop grown in the world (Ihekoronye & Ngoddy, 1985) [15].

Soybean (*Glycine max* (L.) *Merr*.) is a source of high quality cheap protein that is often used to improve protein quantity and quality of most cereals and starch based foods. Carrot (*Daucus carota* subsp. *Sativus*) is one of the traditional root crops of Northern Nigeria (FAO, 1982) [10]. It is very rich in carotene, the precursor of vitamin A, and contains appreciable amount of thiamine, and riboflavin (Penderson, 1980). There is need to diversify and popularise other means of utilizing carrot to derive maximum health benefit from its nutrient particularly carotenoids (carotene/ß-carotene). A blend of these three cheap and culturally acceptable food crops may produce acceptable nutrient dense shelf-stable snacks, which could help in alleviating problems of protein-energy malnutrition and micronutrient deficiency that is prevalent in the developing countries. However, to get maximum nutrient benefit from these crops, they need to be processed to reduce or eliminate inherent anti-nutrients that may interfere with the biological availability of the nutrients. Among the methods used in removing inherent anti-nutrients include roasting, germination, cooking and recently extrusion cooking (Rajawat *et al*., 2000; Siegel &Fawcette, 1976) [30, 33].

Extrusion technology is not very popular in African food processing enterprises because its full potential as a processing technology has not been well recognised (Sefa-Dedeh & Saalia, 1997) [32]. Extrusion cooking has been reported to represent one of the fastest growing technologies that can be used to produce a wide variety of snacks, breakfast cereals, textured proteins at low cost and added advantage of requiring little technical ability to operate and maintain. It is considered a beneficial food processing techniques due to its effective destruction of growth inhibitors and contaminating microorganisms (Chung, *et al*., 2001) [8]. It has also been shown to improve the nutritional quality of food products like snacks (Pham & Del Rosario, 1984) [28]. Obatolu *et al*.,(2000) [23] reported that extrusion significantly increased the amino acid content of complementary food prepared from unmalted and malted maize fortified with cowpea. This research was aimed at producing acceptable extruded snacks from the blends of wheat, sorghum and soybean flours with carrot pulp as micronutrient fortificant.

Materials and Methods

Material procurement

The seeds of sorghum (*Sorghum bicolor* L. *Moench*), Soybean (*Glycine max*), and Carrot (*Daucus carota* subsp. *sativus*) were procured from Ogige market in Nsukka town, Nigeria, together with sugar, cooking fat and salt.

Preparation of raw materials and production of extruded snacks

Sorghum grains (10kg) were sorted manually to remove stones, spoilt seeds and washed thoroughly in a basin of water, to remove dust and other contaminants. The washed sorghum grains were soaked in water for 24 hours, after which they were dried in a Galenkamp oven, (300 series, Weiss Technic, UK), at a temperature of 60°C. The grains were cooled to room temperature and milled in Brabender attrition mill (Germany) twice in order to obtain fine flour, which was further sieved with cheese cloth of 1mm mess diameter. The resulting fine flour was stored in an air tight plastic container at room temperature (30 ± 2^0C) until used. Full fat soy flour was prepared according to the method reported by the National Agricultural Extension and Research Liaison Services (NAERLS, 1989) [22].The seeds were sorted and dehulled with Brabender attrition mill (Germany). The soybean seeds (10kg) were boiled for 20mins, drained with mesh tray and dried at 60ºC for 72hours using Galenkamp oven, (300 series, Weiss Technic, UK) and subsequently were milled with an attrition Brabender attrition mill (Germany)and then packaged in an airtight container and stored at a room temperature prior to use. The soybean and sorghum flour samples were blended with wheat flour in different proportions (Table 1). The blends were extruded using a single screw extruder FST 001 in the Department of Food Science and Technology, University of Nigeria, Nsukka, Nigeria, at standard barrel temperature of 100ºC and screw speed (rpm) of 150º fitted with 2mm cylindrical die at the metering section and feed moisture of 350gKg^{-1}. The obtained snacks were subjected to sensory analysis as described below, in order to isolate the best blend. Fresh carrots (6kg) were sorted, cleaned, and pulped using Conair laboratory blender,(model 90-7012G) and the pulp incorporated immediately into the best blend formulation in Table 2 at 10, 20, 40, 60, 80, 100, gKg^{-1} graded levels, and extruded using the same single screw extruder at similar conditions. Other ingredients, sugar (124 gKg^{-1}), salt (6.2 gKg^{-1}), Fat (75 gKg^{-1}), and water (350 gKg^{-1}) were also incorporated in the formulation.

The extrudates were collected on a wire mesh trays and dried at 150 ºC for 10min in Galenkamp oven (300 series, Weiss Technic, UK), prior to cooling and packaging in an airtight and moisture proof containers till sensory, chemical and microbial analysis were performed.

Table 1: Blends of soybean, sorghum and wheat flours (gKg^{-1})

Code	Sorghum	Soy bean	Wheat
Control	0	0	1000
XEG	80	20	900
PUV	160	40	800
TYU	240	60	700
XYZ	320	80	600
HGT	400	100	500
TYR	480	120	400
KLY	560	140	300
OQP	640	160	200

Table 2: Fortification of the best composite flour blend (PUV) with graded levels of carrot pulp

Code	Best composite flour blend (gKg^{-1})	Carrot pulp (gKg^{-1})
PUV	1000	0
VTC	980	20
KJC	960	40
DXF	940	60
EQZ	920	80
ALW	900	100

Analyses of raw materials and extruded snacks

Chemical, microbial and sensory analyses were performed on the raw materials and the products as described below.

Proximate Analysis

The proximate composition (fat, moisture content, crude fibre and protein, ash and carbohydrate content) were determined by the methods of Association of Official Analytical Chemist (AOAC, 2005) [5].

Total energy (calorific value)

Energy was calculated as described by Osborne and Voogt (1978) [25] using the Atwater factors: 1g of carbohydrates (C) provides (4 Kcalories), 1g of protein (P) provides (4 Kcalories) and 1g fat (F) provides (9 Kcalories).

Micronutrients determination

The biological method for assessment of vitamin A in form of β-carotene status was used for its determination (IVACG, 1982) [16] while determination of vitamins B_1,B_2,B_3 and B_6 were carried out using Snell and Snell methods (1953) [34]. The direct calorimetric method as described by Kalia (2002) [17] was used to determine the vitamin C content of the samples. Iron was determined using Phenanthroline method as described in AOAC (2005) [5].

Anti-nutritional factors determination

Trypsin inhibitor was determined by the method of Hammerstrand *et al*. (1981). Tannin was determined by the method of Hoff and Singleton (1977) [14]. The phytate content of the flour was determined by method of Maga (1982) [16- 19]. The method described by Pull *et al*., (1978) [29] was used for haemagglutinin determination.

Sensory evaluation of the extruded snack samples

A panel of 20 judges made up of staff and students of the Department of Food Science and Technology, University of Nigeria, Nsukka that are familiar with extruded snacks. They assessed the samples for appearance, flavour, texture, taste and overall acceptability using a 7-point categoryscale where 1 = dislike very much, 2 = dislike moderately, 3 = dislike slightly, 4 = neither like nor dislike, 5 = like slightly, 6 = like moderately and 7 = like very much. Coded samples of the extruded snacks, filtered water and napkin were presented on a tray for sensory evaluation by the panelists using the score sheet provided. A spit cup was provided to aid them in cleansing their palate after tasting each sample, to prevent carryover of taste.

Experimental design/ Statistical analysis

The experiment was designed using Completely Randomized Design (CRD). SPSS version 17 was used to analyse the data obtained statistically using analysis of variance (ANOVA), and mean separation was done by Duncan's New Multiple Range Test at 0.05 level of probability.

Results and discusion

Proximate composition of sorghum-soy-carrot and wheat flour extrudates

The proximate composition of the extruded snacks is presented in Table 4. The result showed that the moisture content of the snack was 4.98±0.04g kg^{-1}, while crude protein, fat, fibre, ash, carbohydrate were 175.0, 20.6, 26.3, 75.8, 652.5 g kg^{-1}, respectively. The sorghum-soy-carrot extrudate had higher protein (175.0gKg^{-1}), fibre (26.3g kg^{-1}) and ash (20.6g kg^{-1}) with a lower composition of carbohydrate (652.5g kg^{-1}) and fat (75.8g kg^{-1}), compared to the control sample (wheat flour), which contained 91.0, 82.0, 1.0, 11.0, 754.9, g kg^{-1} crude protein, fat, fibre, ash and carbohydrates respectively. The high protein content of the sorghum-soy-carrot extrudate compared to the wheat snacks could be as a result of incorporation of soybean flour having high protein content (420.0 g kg^{-1}) compared to wheat flour (Table 3). The relatively high ash content when compared with the ash content of wheat snack (11.0g kg^{-1}) could be also as a result of soy substitution. This assertion is in line with the findings of Otegbayo *et al*. (2002) [26] on plantain flour substituted with soybean which increased the ash content of the extrudate. The high ash content of the extrudate is desirable, since it reflects high content of minerals necessary to alleviate micronutrient deficiency that is still a challenge in most developing countries. The high crude fibre content is attributed to the synergistic effect of addition of both sorghum (42.5g kg^{-1}crude fibre) and soybean (26.3g kg^{-1}crude fibre) (Table 3). This result agreed closely with the findings of Zasypkin *et al*., (1998) [36] on wheat flour substituted with soybean flour, which observed that crude fibre content increased with increasing soybean substitution in the extrudates. This result is an indication that the sorghum-soy-carrot extrudate could be a good source of dietary fibre. Therefore, this product has a potential for alleviating some dietary related diseases such as obesity, coronary heart diseases and arteriosclerosis, since the product can provide substantial quantity of the recommended dietary fibre intakes for children and adults (14 g/1000 kcal) (Aderson *et al*., 2009). The lower content of crude fat in sorghum-soy-carrot extruded snack is in line with the findings of Mercier *et al*., (1980) [20] on cassava starch substituted with soybean. They observed that monoglycerides and fatty acids form complexes with amylase during extrusion processing, thus reducing the fat content of the sorghum-soy-carrot extrudate. Also, the high fibre content of the sorghum-soy-carrot extrudates can interfere with effective extraction of fat from the product, since fibres are charged and can form enveloping matrixes (Mercier *et al*., 1980) [20]. The fat content and the water activity (a_w = 0.3) of the extrudate were optimal for maximum crispiness and low enough to discourage the onset of rancidity. The carbohydrate content of the sorghum-soy-carrot extrudate was 652.5g kg^{-1}which is lower than the carbohydrate content of wheat flour extrudates. This could be as a result of soy substitution and non-enzymatic maillard reaction between soy proteins and sorghum/wheat sugars.

Table 3: Proximate composition of major ingredients (g kg^{-1})

Parameters	Sorghum flour	Soybean flour	Wheat flour	Carrot pulp
Moisture	101.70±0.14 ^{c}	74.7±0.18 ^{d}	120.0±0.11^b	858.5±0.14^a
Protein	125.80±0.21^c	421.3±0.71 ^{a}	128.6±0.14 ^{b}	9.30±0.19^d
Fat	17.60±0.14^b	188.3±0.21^a	14.0±0.28^c	2.4±0.155^d
Fibre	42.50±0.05^a	26.30±0.08	8.2±0.05	28.00±0.18^b
Ash	16.5±0.08^b	55.3±0.07^a	4.6±0.02^d	6.0±0.08^c
Carbohydrate	695.9±0.07^b	234.1±0.19^c	724.6±0.16^a	95.8±0.21^d

Values are mean ± standard deviation (n=2). Different letters within each row indicate significant (P < 0.05) differences among treatments, based on Duncan's's post hoc* test. CHO=Carbohydrate

Tabel 4: Proximate composition of sorghum-soy-carrot snacks and wheat flour extrudate

Sample Code	Moisture (g/kg^{-1})	Protein (g/kg^{-1})	Fat (g/kg^{-1})	Ash (g/kg^{-1})	Fibre (g/kg^{-1})	CHO (g/kg^{-1})
Sorghum-soy-carrot snack	49.8±0.04^a	175.0±0.21^a	75.8±0.22^a	20.6±0.25^a	26.3±0.08^a	652.5±0.19^a
Wheat snack	60.1±0.14^{ab}	91.0±0.04^b	82.0±0.21^{ab}	11.0±0.07^{ab}	1.0±0.07^{ab}	754.9±0.14^b

Values are mean ± standard deviation (n=2). Different letters within each column indicate significant (P < 0.05) differences among treatments, based on Duncan's's post hoc* test. CHO=Carbohydrate

Micronutrient composition of the Extrudates

The micronutrient composition (pro-vitamins A, B_1, B_2, B_3, C and iron) of both the sorghum-soy-carrot and wheat flour extrudates is presented in Table 5. From the result, pro-vitamin A content of the sorghum-soy-carrot extrudate was high (3478.1IU) and met the RDI for vitamin A by 116% RDI (3000IU), compared with the wheat counterpart that had zero detection for pro-vitamin A. The vitamin B_2 content of the sorghum-soy-carrot (6.3mgkg^{-1}) was higher than that of the wheat flour extruded snacks. This could be as a result of substitution of wheat flour (0.6mgkg^{-1}) with sorghum and soybean flour which had relatively high vitamin B_2 contents, 11.1 mg kg^{-1} and 11.5 mg kg^{-1} respectively. Also, the high content of Vitamin B_3 in the sorghum-soy-carrot extrudate (107.6 mg kg^{-1}) when compared to the wheat extrudate (60.0 mg kg^{-1}) could be as a result of substitution of wheat flour with sorghum flour (514.0 mgkg^{-1} Vitamin B_3).High temperature short time treatment (HTST) of the extrusion also ensured minimal destruction of the vitamins. The iron content of the sorghum-soy-extruded snack was 131.4 mg kg^{-1}, while that of the wheat flour extrudate was 27.0 mg kg^{-1}. This was also attributed to the substitution of wheat flour with sorghum (420.0mgkg^{-1}iron) (Fellow, 2000) [11]. Mineral content of extruded products are generally retained, and their bioavailability are enhanced by extrusion process.

Table 5: Micronutrient composition of the extruded snacks

Parameters	Wheat flour snacks	Sorghum-soy-carrot snacks
Pro-Vitamin A (IU)	0.0±0.01^b	3478.1±1.25^a
Vitamin B_1 (mgkg^{-1})	4.0±0.04^a	4.0±0.34^a
Vitamin B_2 (mgkg^{-1})	3.0±0.02^{ab}	6.3±0.23^a
Vitamin B_3 (mgkg^{-1})	60.0±0.39^b	107.6±0.10^a
Vitamin C (mgkg^{-1})	10.0±0.10^{ab}	29.5±0.92^a
Iron (mgkg^{-1})	27.0±0.30^b	131.4±01^a

*Values are mean ± standard deviation (n=2). Different letters within each row indicate significant ($P < 0.05$) differences among treatments, based Duncan's *post hoc* test. IU = international unit

Effects of Extrusion on the anti-nutritional factors

As shown in Table 6, Trypsin Inhibitor (TI), Tannin, Hydrogen cyanide and Haemagglutinin were reduced by the extrusion cooking to a level not detected by the analytical procedures employed, while phytate was reduced to a safe level of 0.10±0.0 mg/100g. This is because the extrusion cooking has been shown to be effective in reduction of the anti-nutritional level of the feed material to safe levels (Reddy *et al*., 2001) [31]. Also, the pre-processing of the raw materials which include boiling, drying, washing, milling amongst others, effectively decreased the anti-nutritional residues in the raw materials. The result agrees closely with the finding of Abd El-Hady, *et al* (2002) [1], which reported that the soaking and extrusion significantly decreased antinutrients such as phytic acid, tannins,phenols, a-amylase and trypsin inhibitors as well as phytic acid phosphorus of soaked and extruded legume beans.

Table 6: Effect of extrusion cooking on inactivation of some anti-nutritional factors in the sorghum-soy-carrot blend

Period	Trypsin Inhibitor (mg/100g)	Tannin (g/100g)	Phytate (mg/100g)	Hydrogen Cyanide (mg/kg)	Haemagglutinin (HU/mg protein)
Pre-Extrusion	0.64±0.14	0.26±0.28	1.24±0.3^a	0.67±0.45	4.30±0.02
Post-Extrusion	*NAD	*NAD	0.10±0.0^b	*NAD	*NAD

*Values are mean ± standard deviation (n=2). Different letters within each column indicate significant ($P < 0.05$) differences among treatments.
*NAD: No Activity Detected

Total viable counts of the extruded snacks

The total viable count (TVC) of the sorghum-soy-carrot snacks is presented in Table 7. It revealed that only aerobic mesophilic bacteria were detected in the product, which could be due to post-extrusion contamination. The extrusion cooking process may have inactivated contaminating microorganisms prior to extrusion. However, the level detected will not endanger the health of consumers, because the value is within the limit specified in the microbiological standards of the National Agency for Food and Drug Administration (NAFDAC, 2005) [21]which states that baked and flaked products should contain no more than 10^3 CFU/g aerobic mesophilic bacteria or TVC.

Table 7: Total viable counts of the extruded snacks

	DF	Average	CFU/g
Sorghum-soy-carrot snacks	10^{-1}	5.0±0.50	0.5x10^1

*DF= Dilution Factor; CFU/g = Colony forming unit per gram of snack sample

Energy value of the extruded snacks

The energy values of the extrudates are presented in Figure 1. The calorific value of the sorghum-soybean-carrot extrudate (409Kcal per 100g) was higher than the calorific value of wheat flour extrudate (362kcal per 100g). This implies that blending significantly improved the nutritional quality of sorghum-soy-carrot extruded snack, which could serve as a good source of energy owing to the carbohydrate, protein and fat content of the principal raw materials. The value was within the range recorded for breakfast cereals made from treated and untreated sorghum and pigeon pea (316.46–420 Kcal) (Kent, 1983) [18]and above the value reported for ready-to-eat breakfast cereals (327.54 -347.72 Kcal). (Okafor & Usman, 2013) [24].

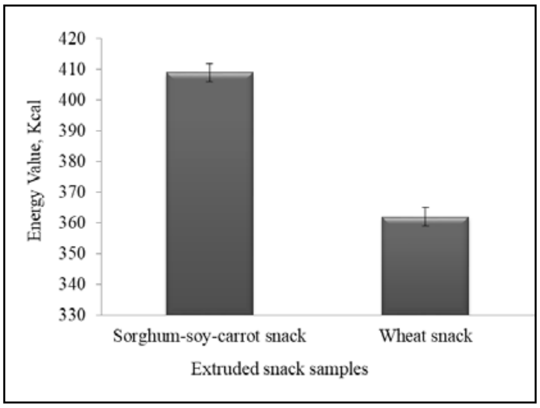

Fig 1: Energy values of the extruded snacks. Result of mean of two independent experiments

Sensory profile of the extruded snacks

The sensory properties of the sorghum-soy extruded snacks fortified with 10% carrot pulp, wheat flour snacks and sorghum-soy unfortified extruded snacks is presented in Table 8. The result shows that the extrudate fortified with 10% carrot (sorghum-soy-carrot extrudate) was the most acceptable, followed by the unfortified sorghum-soy extrudate while wheat flour extrudate was least acceptable. The higher acceptance of the $10gKg^{-1}$ carrot pulp fortified extrudate over the unfortified ones could be as result of the influence of β-carotene (pigment) on the colour of the sorghum-soy-carrot extrudate. The overall acceptability of the extrudates was mainly affected by the colour, flavour and taste. All the samples were equally accepted by the panellists, however, sorghum-soy-carrot extrudate scored highest in terms of colour, taste, flavour, texture and overall acceptability.

Conclusion

Acceptable nutrient dense snacks could be successfully produced from blends of soybean, sorghum and carrot. The protein content of the most preferred snack was $175.0g\ kg^{-1}$and would meet the protein requirement per day of adults and children if they consume 330g and 120g of the product, respectively. Inclusion of soy flour into sorghum and wheat flours led to improvement of in nutrient content of the sorghum-soy-carrot snack. Also, the inclusion of carrot pulp in the formulation significantly ($P <0.05$) increased the pro-vitamin A content of the snack and enhanced the overall acceptability of the product. Addition of sorghum reduced wheat flour demand by 20% which increased the fibre, ash, vitamin and iron contents of the extrudate. Extrusion process improved the nutritional quality of the extrudates by reducing the anti-nutritional factors to safe levels. Since nutritional problems in the developing countries have frequently been identified as protein energy malnutrition and micronutrient deficiency, this snack produced from blend of soy flour, sorghum flour and carrot pulp will help to alleviate the challenges.

References

1. Abd El-Hady, EA, Habiba RA. Effect of soakingand extrusion conditions on antinutrients and protein digestibility of legume seeds / Lebensm.-Wiss. U.-Technol,2003:36:285-293.
2. AFGC. Nutrition and health: the facts and the figures. Australian Food and Grocery Council, Kingston, Australia, 2008,
3. Anderson JW, Baird P, Davis Jr RH, Ferreri S, Knudtson M, Koraym A *et al*. 2009, Health benefits of dietary fiber. Nutrition Reviews, 67: 188–205. doi: 10.1111/j.1753-4887.2009.00189.x
4. Anton, AA, Fulcher RG, Arntfield SD. Physical and nutritional impact of fortification of corn starch-basedextruded snacks with common bean (Phaseolus vulgaris L.) flour: Effects of bean addition and extrusion cooking. Food Chem.,2009:113:989-996.
5. AOAC, Official Methods of Analysis 18th ed. Association of Official Chemists, Gaitherburg, MD, USA, 2005,
6. Bell DE, Reich MR. Health, Nutrition and Economic Crisis: Approaches to Policy in the Third World. Dover Massachusetts, Auburn House, 1989, 20-25.
7. Bowley A. Micronutrient Deficiencies: A Global Health Problem. Nutriview,1995:3:1-3.
8. Chung, S, Bechtel, Villota P, R Production of Meat – Based Intermediate Moisture Snack Food by Twin Screw Extrusion. Paper No. 696, presented at 50th Annual Meeting of Inst. of Food Technologist, Chicago, IL, June 25 – 29.
9. Enwere, NJ Foods of Plant Origin. Afro-Orbis Publications Ltd, Nigeria, 1998, 20-109.
10. FAO, Legumes in Human nutrition, FAO and Food Nutrition Paper, 20. Food and Agricultural Organisation of the United Nations, Rome, 1982, 37-126.
11. Fellows P. Food Processing Technology: Principle and Practice. Woodhead Publishing Ltd., Cambridge, 2000, 177-182.
12. Gibsonin, RS Strategies for Preventing Multi-micronutrient Deficiencies: a Review of Experiences with Food-based Approaches in Developing Countries, in Combating micronutrient deficiencies: food-based approaches, ed. by Thompson B and Amoroso L. FAO/CABI International, 2011, 7-27.
13. Hammestrand, GE, Black LT, Glover JD. Trypsin inhibitors in soy products: Modification of the standard analysis procedure. Cereal Chem,1981:58:42-45.
14. Hoff JE, Singleton KE. A method for the determination of tannin. J of Food Sci,1977:42:1566-1568.
15. Ihekoronye AI, Ngoddy PO. Integrated Food Science and Technology for the Tropics. Macmillan Education Ltd., London, 1985, 50-198.
16. International Vitamin A Consultative Group, IVACG Biochemical Methodology for Assessment of Vitamin A Status. Nutrition Foundation, Washington DC, USA, 1982, 24-29.
17. Kalia M. Food Analysis and Quality Control. Kalyani Pub., New Delhi, 2002, 167.
18. Kent, NL Technology of Cereals, Pergamon Press, Oxford, UK, 1983, 221.
19. Maga JA. Phytates: Its chemistry, occurrence, food interactions, nutritional significance and method of analysis. J Agric Food Chem,1982:3:1-7.
20. Mercier C, Charbonnure R, de la Gueriviere, TF Formation of Amylose–Lipid Complexes by Twin Screw Extrusion Cooking of Manioc Starch. Cerealchem,1980:57:4.
21. NAFDAC, Analytical Standards and Expected Limits for Food and Food Products.National Agency for Food and Drug Administration and Control, Lagos, Nigeria, 2005, 20-98.
22. National Agriculture Extension Liaison Services, NAERLS, Soybean in the Nigerian Diet.Extension Bulletins No 21. Zaria, Nigeria, NAERLS, 1989, 12-15.
23. Obatolu, VA, Cole, AH, Maziya-Dixon BB. Nutritional quality of complementary food prepared from unmalted and malted maize fortified with cowpea using extrusion cooking. J. Sci. Food Agric,2000:80:646-650. doi: 10.1002/(SICI)1097 010(20000501) 80:6<646:: AIDJSFA509>3.0.CO;2-L
24. Okafor GI, Usman. OG Production and evaluation of breakfast cereals from blends of African yam bean (Sphenostylisstenocarpa), maize (Zea mays) and defatted coconut (Cocusnucifera). J of Food Proc and Pres, 2013. DOI/10.1111/jfpp.12060.
25. Osborne DP, Voogt P. Calculation of calorific value. In: The Analysis of nutrients in foods. Academic Press, New York, 1978.

26. Otegbayo, BO, Sobande FO, Aina JO. Nutritional quality of soy-plantain extruded snacks. Ecology of Food and Nutrition,2002:41:463-474.
27. Pederson CS. Vegetable Juices. In: Fruit and Vegetable Juice Processing Technology 3rd Ed. ed by Nelson, P. E. &Tressler, D.K. AVI Publishing Co. Inc., Westport Connecticut, 1980, 460-482.
28. Pham CB, Del Rosario RR. Study on the development of texturized vegetable products by the extrusion process. J of Food Tech,1984:21:569-576.
29. Pull SP, Puekke SG, Hymowitz T, Orf JH. Soybean lines lacking the 120,000-Dalton seed lectin. Science,1978:200:1277-1279.
30. Rajawat P, kushwah A, Kushwah S. Effect of extrusion cooking on some functional properties of Fababean.Jof Food Sci and Tech,2000:32:667-670.
31. Reddy NR, Sathe C, Shridhar K. Food Phytates. Boca Raton: CRC Publishers, 2001.
32. Sefa-Dedeh S, Saalia FK. Extrusion of maize–cowpea blends in a modified oil expeller. J. Sci. Food Agric,1997:73:160-168. Doi: 10.1002/(SICI)1097-0010(199702)73:2<160::AID-JSFA683>3.0.CO;2-Uv
33. Siegel A, Fawcett B. Food Legume Processing and Utilization (with Special Emphasis on Application in Developing Countries). International Development Research Centre, Ottawa, Canada, 1976, 10.
34. Snell FD, Snell CT. Colometric Method of Analysis, 3rd Ed, Dvan Ostrand Company. Inc., New York, 1953, 31-50.
35. World Health Organization Global Prevalence of Vitamin A DeficiencyWHO/NUT/95.3., Geneva, 2005, 49.
36. Zasypkin DV, Lee TC. Extrusion of soybean and wheat flour as affected by moisture content. J of Food Sci,1998:63:1058-1061.doi: 10.1111/j.1365 2621.1998.