Quality Evaluation Of Extruded Full Fat Blend Of African Breadfruit-Soybean-Corn Snack

Samaila James, Titus Ugochukwu Nwabueze

Abstract: Quality evaluation of extrudates/snacks made from full fat blend of African breadfruit-soybean-corn was studied. The raw flour blend was extruded in a single screw extruder at 21% moisture content, 140^{o}C barrel temperature, 140rpm screw speed fitted with 2mm die nozzle diameter. Food extrusion significantly ($p<0.05$) reduced the moisture and crude protein from 21.00 to 9.70% and from 30.80 to 24.50% respectively. Extrusion cooking did not significantly ($p>0.05$) affect the fat, crude fibre and energy values of the extrudates. While ash and carbohydrate contents were significantly ($p<0.05$) increased from 2.85 to 5.15% and from 48.00 to 54.10% respectively upon extrusion. Extrusion cooking did not significantly ($p>0.05$) affect vitamins B_1, C and E of the extrudates; however, vitamin A was significantly ($p<0.05$) reduced. Extrusion cooking had no significant ($p>0.05$) effect on histidine, lysine, threonine and phenylalanine contents of the extrudates; while valine, metheonine, leucine, tryptophan, arginine and isoleucine contents of the extrudate was negatively affected. Food extrusion significantly ($p>0.05$) reduced the antinutrient contents of the extrudates with trypsin inhibitor having the highest reduction (69.77%) and tannin having the lowest reduction (34.78%).

Index Terms: African breadfruit, Corn, Extrusion cooking, Snack, Soybean, Quality evaluation

1 Introduction

Snack is a convenient food that provides calories satisfying short-term hunger and often eaten in a hurry (Tettweiler, 1993; Ocheme *et.al*., 2011). Snacks are high in calorie and fat and low in proteins, vitamins and micronutrients (Ranhotra and Vetter, 1991). Snacks often contain substantial amount of sweeteners, preservatives and aroma components providing tasty appeal to the consumer (Ocheme *et. al*., 2011). In developed countries snacks are eaten in between meals to check hunger, provide energy and tasty appeal; while in developing countries eaten as main meal because of their ready availability and affordability. The small nature of snacks makes them handy, easy to be managed and carried about. The process of snack production is largely a home art in most developing countries making the product differ considerably in terms of nutritional composition, microbiological safety and sensory attributes from one community to another. The extrusion technology has been employed in developing a wide range of raw materials from cereal flour, starch granules, tubers, legumes etc into semi-cooked or completely cooked acceptable food products such as breakfast cereals, snacks, flakes, quick cooking pasta products, texturised vegetable protein and breakfast gruel (Iwe and Ngoddy, 1998; Iwe, 2001; Nwabueze, et al., 2008; Leszek, 2011). African breadfruit (*Treculia africana*) is a wild tropical ever green tree that has immense potential as a nutritional source for man and other domestic animals. The seed is known as 'Afon' in the south-west of Nigeria and 'Ukwa' in the south-east of Nigeria. The tree grows wildly in the high rainforest zone of Nigeria and other African countries producing enormous seeds during its fruiting season (March to April); a mature tree produces approximately fifty fruits annually measuring five to ten kilograms after processing (Runsewe *et al.*, 2001; Nwabueze and Iwe, 2010). The seeds are traditionally consumed as porridge or sauce meal when cooked with other food ingredients; boiled or roasted and eaten as dessert snacks or the flour prepared as breadfruit cake (Runsewe *et al*., 2001; Nwabueze *et al.*, 2008; Nwabueze and Iwe, 2010). Research works on extruded African breadfruit-soybean-corn mixtures have been reported (Nwabueze *et al*., 2007 Nwabueze *et al*., 2008; Nwabueze and Iwe, 2010). The objective of this work was to evaluate the quality of full fat extruded blends of African breadfruit-soybean-corn snack.

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2 Materials and Methods

2.1 Source of Material

African breadfruit seeds were purchased from Umuahia main market; Corn (16DT-across pool) variety was obtained from the International Institute for Tropical Agriculture (IITA) Kano substation; while Soybean (TGX 1740-1 MJ) seeds were obtained at the National Cereal Research Institute, Badeggi, Niger State, Nigeria.

2.2 Preparation of raw Material

African breadfruit seeds were washed in cold potable water and drained through a local perforated basket. The drained seeds were partially cooked in boiling water for 15min to facilitate the separation of the seed coats from the endosperm. Partially cooked seeds were drained and allowed to stand for 20min to further soften the seed coat and effect cooling. Softened seeds were then decoated in an adjustable disc attrition mill and the fruits were manually separated from the coat on a tray. Dehulled seeds were oven dried at 60^{0}C for 17h and properly stored inside high density polyethene bag. Soybean seeds were sorted and winnowed manually in air current. The seeds were soaked in portable water for 18h at room temperature in a stainless steel container. Soaked seeds were gently mashed in a mortar to loosen the seed coat and the coats were separated from the cotyledon via water floatation. The cotyledons were drained dried in an air convection oven at 60^{0}C for 17h. Corn grains were sorted, dry-cleaned and stored in air-tight plastic container. The three processed seeds were stored under refrigeration prior to flour production.

2.3 Production of flour
Dry cleaned breadfruit seeds were milled in a disc attrition mill (7hp, China) and the flour passed through a screen of 75µm pore size. The resulting flour was stored at room temperature (28+2^{0}C) in a high density polyethene bag. Decoated soybean seeds were milled in a disc attrition mill (7hp, China) and screened through a 75µm pore opening. The resulting flour was stored in high density polyethene bag. While for corn flour, the seeds were further dried in an air convection oven (Gallenkamp, England) at 60^{0}C for 6h and pulverized in a disc attrition mill (7hp, China) and passed through a 75µm screen. The resulting flour was stored in an air tight plastic container.

2.4 Flour blending
The method reported by Nwabueze *et al*. (2008) was adopted for the blending. The blending was in ratio of 70:25:5 (African breadfruit-soybean-corn).

2.5 Sample preparation for extrusion
The flour blend was separately brought to 21% MC by water addition through material balance (Nwabueze and Iwe, 2010). The prepared samples were extruded at selected constant extrusion condition: screw speed of 140rpm and barrel temperature of 140^{0}C in a Brabender laboratory single-screw extruder (Duisburg DCE 330, New Jersey USA) fitted with 2mm die nozzle.

2.6 Extruder preparation
The extruder had grooved barrel length to diameter (L/D) ratio of 20:1 fitted with 2mm die nozzle diameter operated at a constant screw speed (ss) of 140rpm and 140^{0}C barrel temperature. A 4:1 compression ratio screw was employed (Nwabueze, 2007). The die nozzle diameter and length were 2mm and 40mm, respectively. Temperature settings were adjusted using thermostat, such that, feeding, compression, metering and die zone temperatures were 120, 150,170 and 150^{0}C. The extruder was allowed to run to stabilization at a screw speed of 40rpm using corn flour before the experimental runs commenced. The feed was introduced gradually but continuously in to feed hopper equipped with an auxiliary anger screw at 300g/min and received at the die end as strands of pellets.

2.7 Extrusion cooking
The portion for extrusion selected from the blend was extruded at a screw speed (ss) of 140rpm and 140^{0}C barrel temperature in a Brabender laboratory single-screw extruder (Duisburg DCE 330, New Jersey USA) fitted with 2mm die nozzle diameter.

2.8 Handling of extrudates
The emerging extrudates as pellets at the die nozzle were collected and spread under fan on the laboratory table at room temperature (28+2^{0}C) for 3h. The extrudates were later dried in an air convection oven (Gallenkamp, England) at 60^{0}C for 10h. The resulting dried extrudates were packaged inside coded high density polyethene bag. Few grammes needed for laboratory analysis were taken and milled in a Brabender roller mill and sieved through a 75µm opening. The resulting extrudates flour was packaged inside coded high density polyethene bag and stored under room temperature (28+2^{0}C) until needed for analysis.

2.9 Chemical analysis
Percent moisture, fat, ash, crude fibre and crude protein contents were determined using the methods of Association of Official Analytical Chemists (AOAC, 2006). Carbohydrate was calculated by difference. Gross energy value (Kcal/100g DM) was calculated as described by Ekanayake *et al*. (1990). Amino acid profile was determined as described by Spackman et al. (1958). Vitamins were evaluated in raw and extruded samples according to AOAC (2006). Samples were analyzed in triplicates.

2.11 Antinutritional agents
Trypsin inhibitor activity was quantified according to Arntified *et al*. (1985). Tannins, phytate and oxalate were determined using the method described by Nwosu (2010).

3 Discussion
The result for the proximate composition and the energy values of raw flour blend and the corresponding extrudate is shown in Table 1. Crude protein, ash, carbohydrate and moisture contents were significantly ($p<0.05$) affected; while fat, crude fibre and energy values were not significantly ($p>0.05$) affected. The protein content of the extrudate decreased significantly ($p<0.05$) from 30.80 to 24.50%. During extrusion cooking, the chemical constituents of the feed material are exposed to high temperature, high shear and high pressure and these improve or damage the nutritional quality of the protein in the extruded material by various mechanisms (Leszek, 2011). During extrusion, peptides of proteins massively undergo unfolding and/or aggregation and this releases low molecular weight peptides thereby enhancing their digestibility. Extrusion cooking, generally randomly disrupt the disulphide and linear linkages of peptides, hence increasing the cleavage sites of the amino acids in the molecule by proteases. This is highly important in legume based food materials. However, production of an extensive isopeptides cross linked net works with carbohydrates and lipids alter the active sites of protease interfering with their catalytic activities with resultant decrease in their digestibility (Phillips, 1989). Extrusion cooking did not significantly ($p>0.05$) affect fat content. However, there was reduction in the fat content of the extrudate from 8.20 to 7.60%. Extrusion cooking has been reported to aid oil extraction since oil is freed during cooking and shearing operations which break fat globules (Nelson *et al*., 1978). Leszek, (2011) stated that lost of lipids during extrusion was first used to explain a mass balance dilemma. The loss in lipid can also be attributed to starch-lipid and protein-lipid complex formations which confer resistant to some lipid extraction techniques. However, in certain extruded foods high in bran than starch tend to contain high free lipid due to non interaction of lipids with starch (Guzman *et al.*, 1992). The chance for lipid oxidation that significantly affect product sensory attributes and nutritional quality is reduced during extrusion. This could be attributed to high temperature that inactivates lipolytic enzymes; low residence time of the feed material in the barrel and the formation of starch-lipid complex. However, air cells in expanded products and the release of pro-oxidants by screw wear favour lipid oxidation (Leszek, 2011). Extrusion cooking did not significantly ($p>0.05$) affect the crude fibre content.

However, there was a reduction in the fibre contents of the extrudates from 6.00 to 5.50%. As with starch, larger fragments of fibre molecules may be sheared off during extrusion (Leszek, 2011). The author further stated that, fragments could unite to form large insoluble complexes or Maillard compounds generally termed as lignin. This physicochemical rearrangement may influence profoundly the health benefits of the extruded foods. This phenomenon is utilized in the production of resistant starch (RS) for specific group of people such as the diabetics. Insoluble dietary fibre offers lubrication to anal linings which tremendously helps in minimizing inter luminal pressure, reduced food transient time in the stomach, reduced rise in blood glycemic index among others. Extrusion cooking significantly ($p<0.05$) increased the ash content of the extrudates from 2.85 to 5.15%. This could be attributed to high barrel temperature and high shear rate involved during the cooking process. The low moisture content in the extrudates (9.70%) as against 21% in the flour blend prior to extrusion shows that, extrusion cooking reduced the moisture by 53.81%. The low moisture content will give the product good shelf stability as reported by Aremu *et al.* (2006). Extrusion cooking significantly ($p<0.05$) increased the carbohydrate content of the extruded flour blend from 48.00 to 54.10%. Conditions that increase temperature, share and pressure tend to increase the rate of gelatinization. Complete gelatinization may not occur but, digestibility is improved nonetheless (Wang *et al.,* 1993a). In essence extrusion may predigest starch depending on the composition of the feed material and operating conditions. The energy value of the flour blend and the extrudate were not significantly ($p<0.05$) different from each other. However, the energy values of the extrudates were higher compared to the flour blend numerically. This can be attributed to gelatinization of starch during extrusion. The result of the vitamin content of the raw flour blend and the corresponding extrudate is shown in Table 2. Extrusion cooking did not significantly ($p>0.05$) affect vitamins B_1, C and E of the extrudate; however, vitamin A was significantly ($p<0.05$) affected. The retention of vitamins in extrusion cooking generally decreases with increasing temperature, increasing screw speed, decreasing moisture, decreasing throughput, decreasing die diameter and increasing specific energy input (Killeit, 1994). Mustakas *et al*. (1964) showed that, different barrel temperatures, feed moisture content and residence time of 1min. did not affect riboflavin and niacin contents of the extrudates. In this work, moisture content of 21^0C, barrel temperature of 140^0C, screw speed of 140rpm and 2mm die diameter gave 85.71% niacin retention. The retention of niacin was fairly low compared 92% reported by Beetner *et al*. (1974) in extruded maize grit. There was high retention in the vitamin E content 81.25%. This shows that the product will be a good source of antioxidant which will help in scavenging the activities of free radicals in the body thereby inducing cell apoptosis and reducing cell necrosis. High temperature short time cooking provides an excellent way of vitamins retention most especially vitamin C during food processing. In this work, there was 63.64% vitamin C retention. High retention of vitamins C and E shows that the product is a potential source of antioxidant which provides physiological benefits besides nutrients supply. Although extrusion systems can be successfully used for higher retention of vitamins, food manufacturers often carry out vitamin fortification post extrusion by dusting, enrobing, spraying or coating (Leszek, 2011). Table 3 shows the result of amino acid composition of the flour blend and the corresponding extrudate. Extrusion cooking significantly ($p<0.05$) reduced valine, metheonine, leucine, tryptophan, arginine and isoleucine contents of the extrudates. However, histidine, lysine, leucine, threonine and phenylalanine were not significantly ($p>0.05$) affected. Effects of extrusion cooking on some amino acids analyzed in this work is in agreement with other findings reported for extruded flour (Bjorck, *et al*., 1984); extruded maize meal (Beaufrand, et al., 1978). In this work isoleucine, tryptophan and valine had low retentions compared with others. Reaction between free amino acids of proteins and aldehyde clusters of sugars results in to the formation of enzyme-resistant bonds and dark colored melanoids. This reaction considerably reduces free amino acid content of extruded products (Leszek, 2011). Lysine the limiting amino acid in cereals was substantially retained in the extrudate (71.43%). The retention is fairly low compared to 25 and 37g/Kg (99.75 and 99.63%) in extruded wheat flour at 150 and 200rpm, applying 171^0C and 15g/Kg moisture in a twin extruder (Bjorck *et al*., 1984). Table 4 shows some antinutrient content of the raw flour blend and the extrudate. Extrusion cooking significantly ($p<0.05$) reduced the oxalate, phytate and trypsin inhibitor; while tannin was not significantly ($p>0.05$) affected. However, tannin content was reduced by 34.78%. Reduced tannin content in the extrudate means increased bioavailability of macromolecules notably, proteins; increased palatability; reduced pathogenesis of cancer development and reduced damage to intestinal tract (Makker and Becker, 1996; Uzoechina, 2007). Extrusion cooking significantly ($p<0.05$) reduced oxalate content by 50.00%. However, this reduction falls below the reduction (94.44%) reported by Anounye et al. (2012) in extruded pigeon pea and unripe plantain blends. Oxalate in the body combines with divalent cations Ca++, Fe++, forming their insoluble salts. These insoluble salts obstruct kidney tubules leading to kidney stones (Coe, 2005). Extrusion cooking significantly ($p<0.05$) reduced the phytate content of the extrudates by 66.67%. Phytic acid forms insoluble complex with certain trace elements zinc, iron and copper reducing their bioavailability with resultant effects of reduced tune over of heamoglobin production and impaired metabolic process. Certain types of proteins e.g. trypsin inhibitor, lectins inhibit enzymes thereby interfering with normal food digestion process. Extrusion cooking significantly reduced trypsin inhibitor by 69.77%. The percentage reduction is high compared to 61.22% reduction in extruded pigeon pea and unripe plantain (Anounye *et al*., 2012).

4 CONCLUSION

The results of the work showed that, food extrusion significantly influenced the proximate composition; vitamins; amino acid profile and antinutrient contents of the extrudates. Increased ash and carbohydrate contents and high retentions of all the vitamins (A, B_1, C and E) determined in the extrudates implied that, the product is a good source of food minerals and energy rich in antioxidants which will help in mopping out the activities of free radicals in the body system thereby extending life expectancy. Extrusion cooking significantly ($p<0.05$) reduced the antinutrient contents of the extrudates. The reduction means increased food digestibility and bioavailability of certain minerals in the body. Extrusion cooking significantly ($p<0.05$) reduced some of the analyzed indispensible amino acids of the extrudates. However, histidine, lysine, threonine and phenylalanine were not negatively affected. Nutrients deficiency of extruded product is corrected through post extrusion fortification.

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Reference

[1]. Anounye , J. C., Jigam, A. A. and Ndaako, G. M. (2012). Effects of extrusion cooking on the nutrients and anitnutrients composition of pigeon pea and unripe plantain blends. *Journal of Applied Pharmaceutical Science,* 2(5):58-162.

[2]. Beaufrand, M.J., de la Gu_eriviere, J.F., Monnier, C., and Poullain, B. (1978). Influence du procede decuisson extrusion sur la disponibilite des proteines. *Ann. Nut. Aliment*., 32, 353–364.

[3]. Beetner, G., Tsao, T., Frey, A. and Harper, J.M. (1974) Degradation of thiamine and riboflavin during extrusion processing, *J. Food Sci*., 39, 207–208.

[4]. Bjorck I, Asp N-G, Birkhed, D. and Lundquist, I. (1984). 'Effects of processing on availability of starch for digestion in vitro and in vivo; I. esxtrusion cooking of wheat flours and starch', *J. Cereal Sci*., 2(2), 91–103.

[5]. Coe, F. L., Evan, A., and Worcester, E. (2005). "Kidney stone disease". *J Clin Invest*. 115 (10): 2598–608.

[6]. Guzman, L. B., Lee, T. C. and Chichester, C. O. (1992). 'Lipid binding during extrusion cooking'Food Extrusion Science and Technology, New York, Marcel Dekker, Inc.

[7]. Iwe, M. O. (2001). Organoleptic assesment of extruded blends of soy and sweet potatoe flour by response surface analysis. *Plants Foods for Human Nutrition*, 60:1-14.

[8]. Iwe, M. O. and Ngoddy, P. O. (1998). Proximate composition and some functional properties of extrusion cooked soybean and sweet potatoe blends. *Plants Foods for Human Nutrition*, 53:121-132.

[9]. Killeit, U. (1994). Vitamin Retention in Extrusion Cooking, *Food Chem*. 49, 149–155.

[10]. Leszek Moscicki (2011). Extrusion-Cooking Techniques Applications, Theory and Sustainability. WILEY-VCH Verlag & Co. KGaA, Weinheim, Germany.

[11]. Makkar, H.P.S., Becker, K. Effects of pH, temperature and time on inactivation of tannin and possible implication in detanification studies. *J Agr and Food Chem*. 1996; 44: 1291-1295.

[12]. Mustakas, G.C., Griffin, E. L., Alien, L. E. and Smith, O.B. (1964). Production and Nutritional Evaluation of Extrusion Cooked Full Fat Soybean Flour, J *Am. Oil Chem. Soc*. 41, 607–615.

[13]. Nelson, A. I., Wijeratne, W. B., Yeh, S. W., Wei, T. M. and Wei, L. S. (1987). 'Dry extrusion as an aid to mechanical expelling of oil from soybeans', *J Am Oil Chem Soc*, 64(9), 1341–7.

[14]. Nwabueze, T. U. (2007). Effects of process variables on trypsin inhibitor activity(TIA), phytic acid and tannin content of extruded african breadfruit-soy-corn mixtures: A response surface analysis. *Journal of Food Science and Technology*, 40(1):21-29.

[15]. Nwabueze, T. U. and Iwe, M. O. (2010). Residence time distribution (RTD) in a single screw extrusion of African breadfruit mixtures. *Food Bioprocess Technology*, 3:135-145.

[16]. Nwabueze, T. U., Iwe, M. O. and Akobundu, E. N.T. (2008). Physical characteristics and acceptability of extruded African breadfruit-based snacks. *Journal of Food Quality*, 31(2):142-155.

[17]. Ocheme, O. B., Ariahu, C.C., and Igyor, M. O. (2011). Assesment of traditionally produced Dakuwa (A cereal/legume based Nigerian snack) in Niger state, Nigeria. *Nigerian Food Journal,* 29(1):63-69.

[18]. Phillips, R.D. (1989). Effect of extrusion cooking on the nutritional quality of plant proteins, in Protein Quality and the Effect of Processing, ed. R. D. Phillips, J.W. Finley, Marcel Dekker, New York, pp 219–246.

[19]. Politz, M. L., Timpa, J. D., and Wasserman, B. P. (1994b). 'Quantitative measurement of extrusion-induced starch fragmentation products in maize flour using nonaqueous automatic gel-permeation chromatography', *Cereal Chem*, 71(6), 532–6.

[20]. Ranhotra. G. S., and Vetter, J. L. (1991). Foods considered for nutrient addition: Snacks and confectionaries. Pp 208–213.

[21]. Bauernfeind JC, Lachance PA, editors. Nutrient addition to food. CT: Food and Nutrition Press. P 319-15.

[22]. Runsewe, A., Olowu, A. O., Olanrewaju, D. M., Akesode, F. A., (2001). Efficacy of the African breadfruit (*Treculia africana*) in the nutritional rehabilitation of children with protein energy malnutrition. *Nigerian Journal of Paediatrics,* 28(4):128-34.

[23]. Tettweller, P. (1991). Snack food worldwide. Food

Technol., 4558-61.

[24]. Uzeochina, O.B. Evaluation of the effect of processing techniques on the nutrient and antinutrients contents of Pigeon pea (Cajanus cajan) Seed flours. *J. Food Sci*. 2007; 28:76-77.

[25]. Wang, S., Casulli, J. and Bouvier, J. M. (1993a). 'Effect of dough ingredients on apparent viscosity and properties of extrudates in twin-screw extrusion cooking', *Intl J Food Sci Technol,* 28(5), 465–79.

Table 1
Proximate and energy value of raw flour blend and the corresponding extrudate

Proximate (%)	Raw	Extruded
Crude protein	$30.80^{a} \pm 0.20$	$24.50^{b} \pm 1.00$
Fat	$8.20^{a} \pm 1.00$	$7.60^{a} \pm 1.00$
Crude fibre	$6.00^{a} \pm 1.00$	$4.50^{a} \pm 1.00$
Ash	$2.85^{b} \pm 1.00$	$5.15^{a} \pm 1.00$
Moisture	$21.00^{b} \pm 0.58$	$9.70^{a} \pm 0.58$
Carbohydrate	$48.00^{b} \pm 1.00$	$54.10^{a} \pm 1.00$
Energy (Kcal/100g)	$389.00^{a} \pm 10.00$	$382.80^{a} \pm 5.77$

Values are means and standard deviations of three determinations. Values not followed by the same superscript in the same row are not significantly

Table 2
Vitamin content of raw flour blend and the corresponding extrudate

Vitamin (mg/100g)	Raw	Extruded	% Retention
A (IU/100g)	$18.50^{a} \pm 1.00$	$12.20^{b} \pm 1.00$	65.95
B_1	$0.07^{a} \pm 0.10$	$0.06^{a} \pm 0.10$	85.71
C	$2.20^{a} \pm 1.00$	$1.40^{a} \pm 0.10$	63.64
E	$3.20^{a} \pm 1.00$	$2.60^{a} \pm 0.10$	81.25

Values are means and standard deviations of three determinations. Values not followed by the same superscript in the same row are not significantly different ($p>0.05$).

Table 3
Amino acid profile of raw flour blend and the corresponding extrudate

Amino acid (%)	Raw	Extruded	% Retention
Histidine	$0.41^{a} \pm 0.10$	$0.28^{a} \pm 0.10$	68.29
Valine	$0.60^{a} \pm 0.10$	$0.30^{b} \pm 0.10$	50.00
Metheonine	$0.60^{a} \pm 0.10$	$0.40^{b} \pm 0.10$	66.67
Leucine	$1.60^{a} \pm 0.10$	$1.00^{b} \pm 0.20$	62.50
Lysine	$0.35^{a} \pm 0.10$	$0.25^{a} \pm 0.10$	71.43
Threonine	$0.42^{a} \pm 0.10$	$0.25^{a} \pm 0.10$	59.52
Tryptophan	$0.11^{a} \pm 0.01$	$0.05^{b} \pm 0.01$	45.45
Arginine	$0.80^{a} \pm 0.10$	$0.55^{b} \pm 0.10$	68.75
Phenylalanine	$0.80^{a} \pm 0.10$	$0.60^{a} \pm 0.10$	75.00
Isoleucine	$0.56^{a} \pm 0.10$	$0.25^{b} \pm 0.10$	44.64

Values are means and standard deviations of three determinations. Values not followed by the same superscript in the same row are not significantly different ($p>0.05$).

Table 4
Antinutrient content of raw and extruded blend

Antinutrient	Raw	Extruded	% Reduction
Tannin	$2.30^{a} \pm 1.00$	$1.50^{a} \pm 1.00$	34.78
Oxalate	$1.00^{a} \pm 0.20$	$0.50^{b} \pm 0.10$	50.00
Phytate	$0.90^{a} \pm 0.10$	$0.06^{b} \pm 0.10$	66.67
Trypsin Inhibitor	$4.30^{a} \pm 1.00$	$1.30^{b} \pm 1.00$	69.77

Values are means and standard deviations of three determinations. Values not followed by the same superscript in the same row are not significantly different ($p>0.05$).