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Evaluation of different processing methods of soya beans (*Glycine max*) on its nutritive value and the performance of broilers: A qualitative selection approach for extension

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Several trials has been conducted by poultry nutritionist in evaluating effects of soybean processing on its nutritive value and the performance of broilers without clearly declaring the best processing method to be adopted by farmers that will give them on the average a cumulative best result output. A qualitative selection approach was thus adopted in the evaluation of different processing methods of soya beans (*Glycine max)* on its nutritive value and the performance of broilers using published results from the same authors who conducted an experiment using four thermal processing methods (extrusion, cooking, toasting and roasting -dry heating); four fermentation processing methods (fermentation with culture organisms, cooking and fermentation, daddawa, cooking and fermentation + potash) and four alkaline processes methods (soaking in water, sodium carbonate (Na_2CO_3), potassium carbonate (K_2CO_3) and sodium hydroxide -NaOH) A quantitative evaluation of both nutritive values and performance of experimental birds were undertaken as basis for selection of best means from each processing method after the selected best from each of the processing methods were compared to select the overall best. Cooking, cook and ferment and 1% potassium carbonate respectively emerged as the representative best for thermal, fermentation and alkaline processing. The comparative evaluation of the representative best processing methods showed that cook and ferment from fermentation group was the overall best. This processing method showed the best potentials for essential nutrients preservation, better performance of broilers and greater economic returns on investment. This confirmed the superiority of fermentation process in increasing the viability of soya beans utilization in broiler feeds resulting from microbial organisms activities.

Key words: Broilers, farmers, qualitative selection, soybeans, processing.

INTRODUCTION

Soybean utilization in the monogastric animals (poultry) Feed industry will continue to draw the attention of all

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actors in the feed supply chain. This is accountable by the nutritional benefits of this oil seed to the feed industry and thus, the reason for continues search for best ways of enhancing utilization of different forms (raw fullfat) are still a major research focus.

Several soybean processing techniques that are aimed at improving the nutritive values and removing anti nutritional factors (ANFs) have been documented. These includes: Drying, toasting, cooking, extraction, autoclaving, fermenting, alkaline treatment, use of enzyme (Asiedu, 1989; IITA, 1997; ASA, 1993; Kaankuka et al., 1996; Qin et al., 1996; Caine et al., 1998; Ayanwale, 1999; Mellor, 2002; Ayanwale and Kolo, 2011). These soyabean processing techniques uniquely present different opportunities and challenges in both the nutritional profile and nutrient availability of soya beans for utilization by animals.

Thermal processing of soyabean such as hydrothermal, autoclaving, extrusion, micronization is acknowledged for being very successful in enhancing the nutritional value of soyabean and in reducing ANFs. It is however affected by many and varied reports on the influence of temperature time combinations on the ANFs and amino acids profile of soya bean as well as high energy and technology cost requirement, lack of standardization of cooking time and temperature regimes and associated cost (Lovell, 1990; Kaankuka et al., 1996; Qin et al., 1996; Ebrahimi-Mahmoudabad and Taghinejad-Roudbaneh, 2011; Ari et al., 2012a) poses greater challenge in the nutritional status of thermally processed soya beans and its utilization by broilers.

The use of microbial cultures in the treatment of soya bean meal in order to achieve enhancement of total soluble mater, crude protein and reduced ANFs have been reported by Caine et al. (1998). This process however, required complex process of inoculation with microbial substrates. Other solid state fermentation processes adopted for soya beans include daddawa fermentation; cooking and fermentation (Campbel-Platt, 1980; Water-Bayer, 1998; Ayanwale and Kolo, 2001; Ari et al., 2012b); *in vitro* cytotoxicity of soybean agglutinin has also been demonstrated (Babot et al., 2016).

In spite of the associated benefits of fermentation, cooking time and prolong period of fermentation above 72 h is reported to have deleterious effects on the nutritive value of soya beans and consequently on the performance of broilers. Similarly, the use of enzymes in the improvement of the availability of nutrients from plant sources has resulted in the development of highly effective heat stable phytases that ensures maximum phosphorous release from plant phytase especially in soya beans (Mellor, 2002). However, the exogenous supply of enzymes significantly affects the ability of birds to produce endogenous phytase. A novel approach was also adopted in improving the potential utilization of raw soya bean (Erdaw et al., 2016; Iji et al., 2016) in poultry feeds using different dosing rates of cocktails of new generation enzymes with relatively good outcomes in terms of feed quality improvement and response of fed chickens to raw soya bean based diets. The justification for the use of enzymes must also be measured on the optimum enzyme dose rate required to maximize economic returns from enzyme use (Hruby, 2002).

The use of alkaline treatment of soya beans is dependent on the concentration levels and type of the alkaline used (Friedman and Master, 1984; Ayanwale, 1999; Ari et al., 2012c). The use of strong alkaline salts in the processing of soya beans often result in decreased protein quality, loss of amino acids and the formation of amino acids lysinoalanine complex. This leads to reduced nutrient availability especially lysine.

The small holder farmer/feed miller is faced with even greater challenge of selecting for adoption of any of these processing methods as each of these methods manifest differently in the nutritive value and performance parameters evaluated for broilers (Ari et al., 2012d, e, 2013).

It is envisaged that a comparative evaluation of these processing techniques on the performance of broilers, the nutritional value of the processed soya beans and the effectiveness of the systems should provide a base for the adoption of a more effective method of maintaining the quality, and providing the best economic returns to poultry farmers and the feed mill industry (Dudley-Cash, 2004)

This study is therefore aimed at undertaking a comparative evaluation of the effects of the best treatments of each of the soya beans processing methods and its utilization by broilers. Specifically a qualitative evaluation of each of the experimented soya beans processing methods was envisaged to support farmers and extension staff in decision making.

MATERIALS AND METHODS

Experimental site

This study was conducted at the Livestock Complex of College of Agriculture, Doma Road, Lafia which is located between latitude 8 and 9× North and longitude 80 and 90° East. The minimum temperature is 21.9°C and maximum temperature of 37.6°C between January to June and the average annual rainfall is 823 mm.

Soya beans processing

Soya beans seeds *(Glycine max)* were procured from a local market in Lafia metropolis of Nasarawa State, Nigeria. The collected seeds were cleaned by winnowing and hand picking of stones and debris and were subjected to four thermal and hydrothermal processing methods (extrusion, cooking, toasting and roasting -dry heating); four (4) fermentation methods (fermentation with culture organisms, cooking and fermentation, daddawa and cooking and ferment + potash fermentation methods) and four alkaline treatments soaking in water (HOH) sodium carbonate

(Na_2CO_3), potassium carbonate (K_2CO_3) and sodium hydroxide (NaOH) according to the methods described by Ari et al. (2012a, b, c).

Chemical evaluation of processed soya beans

The proximate composition of each the processed soya beans were determined according to AOAC (2000); determination of amino acid profile using the methods described by Spackman et al. (1958); Trypsin Inhibitor Activity (TIA) determined according to the method described by Gupta and Deodhar (1975) and Hammerstrand et al. (1981); Phytic acid determination was done according to the modified method described by Wheeler and Ferrell (1971) and Stewart (1974); Protein Solubility Index method described by Araba and Dale (1990) was adopted and the determination of pH was done using urease assay as a measure of protein quality (Dudley-Cash, 2004).

Experimental treatment and diet preparation

A total of 240 day-old Anak broilers randomly divided into four (4) experimental groups of three replicate were used in each of the thermal and hydrothermal; fermentation methods; and alkaline treatments based experiments. Dietary treatments were as follows: Extrusion T1, cooking T2, toasting T3 and roasting - dry heating T4 for thermal and hydrothermal processing methods; fermentation with culture organisms F1, cooking and fermentation F2 , and daddawa F3 cooking and ferment + potash F4 for fermentation methods and soaking in water A1, sodium carbonate (Na_2CO_3) A2, potassium carbonate (K_2CO_3) A3 and sodium hydroxide (NaOH) A4 for alkaline treatments at both starter and finisher phases using completely randomized design having the test ingredients incorporation as the main source of variation.

The starter diets were formulated to give approximately 3000 Kcal of energy and 24% CP for all the experimental groups using a least cost feed formulation software *Feedwin* and were fed for five (5) weeks (1 to 35 days) brooding phase and the finisher diets were similarly formulated to give approximately 3000 Kcal of energy and 22% CP and were fed for four weeks (36-63 days). All management practices were similarly conducted.

Statistics

Quantitative evaluation

The data collected for the following parameters viz: Chemical composition of soya bean seed, amino acid profile of test soya beans, anti-nutritional factor analysis, chemical composition, performance traits, carcass characteristics, organ morphology, cooking yields and loss, serum profile and economics of each of the individual experiments were subjected to analysis of variance (ANOVA), means were separated where there were significant differences using Duncan's multiple range test (Duncan, 1955) using SPSS 16.0.

Qualitative evaluation

This experiment adopted qualitative evaluation techniques Likert scaling (Asika, 1991) was used to weigh the treatment means for each parameter measured in each of the experiment. The treatment group with the best cumulative means in each of the experiment (thermal, fermentation and alkaline treatment) was selected to represent the group in the comparative evaluation process.

Selection process for best means

The selection process was based on a four point score evaluation for the means of each of the parameters assessed in the three soya bean processing experiments. This four point score evaluation is irrespective of means similarities ($P<0.05$) within the same parameter and the cumulative average points score for each of the experimental treatment groups were ranked according to the methods described by Ajayi (2005) and Rahman and Ogungbile (2006). The scores were as follows: 1 = Fair; 2 = Good; 3 = Better and 4 = Best mean.

Selection process for processing methods

The selection process was based on a three point score evaluation for the overall means of each of the parameters assessed in the three soya bean processing experiments. The cumulative average points score for each of the experimental treatment groups were pooled and ranked according to the methods described by Ajayi (2005) and Rahman and Ogungbile (2006). The scores are as follows: 3 = Good; 2 = Better; and 1 = Best mean.

RESULTS AND DISCUSSION

Results of the quantitative evaluation are presented in Tables 1 to 4. The overall ranking for the selection of the best treatment group within the three experiments are presented in Tables 5 to 8 for thermal, fermentation and alkaline processing experiments, respectively.

The overall best performances recorded in the cooking, cook and ferment and 1% potassium carbonate (K_2CO_3) groups respectively confirmed these processes of soya beans as the best representatives of thermal, fermentation and alkaline processing methods that will guarantee the preservation of essential nutrients and remove ANFs for greater performance of broilers

This finding was in agreement with the findings of Balloun (1980) who reported better nutrient profile and better reduction values of TIA and other ANFs (Cheva-Isarakul and Tangtawaeewipat, 1995) of hydrothermaly processed soya beans as against the deleterious effects of excessive dry heating on the nutrient composition and bio-availability for utilization by broilers as observed by ASA (1993) and Tiamiyu (2001).

The chemical compositions, removal of anti-nutritional factors as well as the performance of broilers fed all the fermented soya beans were on the average, these are indicators that fermentation processes are advantageous processing methods when compared to thermal and alkaline treatments. This confirmed the reports of Ayanwale and Kolo (2001), Mellor (2002) and Kalavathy et al. (2003) among other workers.

Although all the fermentation process gave good performance especially in the removal of ANFs, the overall best performance recorded in the cooked and ferment group confirmed the potentials of the process as the best processing method that will guarantee the preservation of essential nutrients, better performance of broilers and yield of greater economic returns on

Table 1. Effect of different processing methods on the chemical and amino acid composition and anti-nutritional factors of soya bean.

Parameter	Thermal				Fermentation				Alkaline			
	T1	T2	T3	T4	F1	F2	F3	F4	A1	A2	A3	A4
Proximate composition												
DM	79.00	89.83	91.25	90.57	91.12	89.57	93.77	90.11	90.02	90.02	90.17	89.83
CP	40.20	39.27	35.47	37.53	40.35	32.91	37.90	37.86	39.7	38.34	40.27	39.64
CF	19.50	12.51	28.34	24.29	4.96	14.34	10.32	17.22	13.76	14.64	22.87	12.37
EE	9.72	19.27	18.03	16.92	9.32	19.41	16.82	20.22	21.85	18.58	6.72	21.31
T Ash	4.27	4.39	4.41	4.46	6.33	4.21	2.64	4.57	3.61	5.29	4.80	5.05
NFE	26.31	24.56	13.75	16.8	39.04	29.13	32.32	20.13	21.08	23.15	25.34	21.63
Ca	0.45	0.56	0.44	1.08	0.38	0.50	0.51	0.48	0.39	0.44	0.37	0.42
P	0.33	0.29	0.28	0.29	0.25	0.23	0.22	0.29	0.36	0.23	0.23	0.23
Amino acid composition (g/100 g protein)												
Lysine	2.40	5.30	3.60	5.71	5.25	5.60	3.99	5.09	5.23	5.5	5.78	4.79
Histidine	3.21	2.60	3.00	2.90	3.43	2.93	2.06	3.20	3.4	2.93	3	2.96
Arginine	4.52	4.95	4.48	4.72	5.58	5.73	4.01	5.19	5.5	5.82	5.82	4.8
Aspartic acid	11.80	11.57	10.49	10.60	11.46	10.72	10.03	11.00	11.23	12.03	12.08	12.15
Threonine	1.47	2.99	2.80	2.49	3.29	2.99	2.72	3.08	3.18	3.24	3.48	3.16
Serine	2.45	2.59	1.90	2.38	2.50	2.29	1.62	2.62	2.59	2.66	2.78	2.64
Glutamic acid	12.01	11.28	14.94	12.01	12.90	12.23	15.01	12.01	12.15	12.89	13.62	12.67
Proline	3.45	3.47	3.08	3.34	3.59	3.47	2.82	3.47	3.59	3.59	3.72	3.47
Glycine	2.71	3.21	3.35	2.84	3.21	2.86	2.10	2.91	3.00	3.45	3.49	2.68
Alanine	3.47	3.70	3.04	3.14	3.60	3.33	2.81	3.43	3.50	3.93	3.99	3.33
Cystine	0.71	0.64	0.70	0.88	1.12	0.88	1.04	0.96	1.07	0.80	0.88	0.96
Valine	1.69	2.65	2.85	3.05	3.53	3.20	3.39	3.32	3.37	2.75	2.8	3.69
Methionine	0.52	1.01	0.88	1.14	1.34	1.16	0.70	1.10	1.23	0.90	0.99	1.30
Isoleucine	1.81	2.41	2.32	2.89	3.32	2.99	2.81	2.97	3.10	2.53	2.65	2.78
Leucine	2.94	6.80	6.00	6.73	7.44	6.74	5.79	7.00	7.44	5.99	6.19	7.01
Tyrosine	1.69	2.90	2.63	2.49	3.46	2.91	2.49	3.04	3.18	2.91	2.77	2.63
Phenylalanine	3.31	3.60	3.06	4.26	4.50	4.34	3.30	4.42	4.42	3.78	3.79	4.26
Anti-nutritional factors												
TIA (mg/k)	6.05	2.30	7.30	7.10	Trace	Trace	Trace	Trace	9.40	0.90	1.20	1.15
Reduction in TIA (%)	60.59	85.02	52.44	53.75	100	100	100	100	38.76	94.14	92.18	92.51
PA (mg/100 g)	102.00	113.90	178.90	97.61	126.98	276.60	113.90	146.40	325	66	48.8	48.6
Reduction in PA (%)	70.73	67.25	48.12	71.71	63.19	19.83	66.99	57.57	5.80	80.87	85.86	85.86
UA (ΔpH)	0.06	0.09	0.02	0.06	0.06	0.18	0.04	0.16	0.07	0.09	0.03	0.04
PSI (%)	76.20	83.40	77.40	64.80	84.85	78.12	84.81	75.43	81.95	76.44	76.65	74.6

Table 1. Contd.

*Thermal	T1-Extrusion; T2-Cooking;T3-Toasting;T4-Roasting
Fermentation	F1- Lactobaccillus; F2- Cook and ferment; F3- daddawa; F4-Cook and ferment+ potash
Alkaline	A1-0 % Alkaline; A2-1% Na_2CO_3;A3-1% K_2CO_3; A4-1%NaOH

**TIA: Trypsin inhibitor factor; PA: Phytic acid; UA: Urase assay; PSI: Protein solubility index.

Table 2. Effect of different processing methods on the chemical composition of diets and nutrient digestibility in broilers.

Parameter	T1	T2	T3	T4	F1	F2	F3	F4	A1	A2	A3	A4
Chemical composition (starter Diets)												
DM	92.69	92.87	92.73	92.72	90.47	92.78	91.40	92.05	92.10	92.10	91.30	92.42
CP	22.00	21.77	23.47	20.53	22.91	22.30	22.47	20.13	21.14	21.86	23.36	23.36
CF	4.75	6.40	7.36	7.60	6.78	6.06	6.74	6.82	7.15	6.58	6.88	6.24
EE	10.48	13.40	12.72	12.11	9.88	12.01	13.50	9.48	11.75	9.52	10.32	8.86
Ash	14.75	15.19	15.10	12.55	12.79	17.25	17.76	17.21	11.49	10.55	11.20	11.25
NFE	40.71	36.11	34.08	39.93	45.60	35.08	38.53	46.36	37.57	43.59	39.49	42.71
Ca	2.24	2.48	1.76	2.94	5.39	2.26	1.35	2.89	2.23	2.93	1.70	1.35
P	1.35	1.26	1.26	1.43	2.68	1.35	0.72	1.36	0.69	0.90	0.64	0.63
Chemical composition (finisher Diets)												
DM	93.43	92.95	92.83	92.62	92.93	92.43	94.19	92.57	91.81	92.12	92.73	91.99
CP	20.83	22.99	20.12	20.41	21.23	21.66	21.06	23.24	20.44	23.63	20.56	20.62
CF	7.15	5.19	6.94	7.26	5.67	6.90	6.93	5.91	7.06	7.01	7.41	6.80
EE	12.42	10.59	14.47	13.44	11.50	11.23	13.30	11.53	12.45	11.16	13.52	11.93
Ash	9.31	9.96	9.68	9.44	15.03	12.11	8.76	11.19	5.72	6.80	14.03	7.76
NFE	43.72	44.22	41.62	42.07	38.50	47.47	44.14	40.70	46.14	43.52	37.21	44.88
Ca	0.80	2.24	1.72	1.92	2.69	2.09	1.49	1.22	1.20	1.74	2.00	1.52
P	0.54	1.68	0.74	0.74	0.74	1.35	0.73	0.68	0.61	0.54	1.22	0.72
Nutrient digestibility (Starter)												
DM	71.10^{b}	77.01^{a}	73.42^{ab}	57.50^{c}	83.57^{ab}	81.94^{b}	84.58^{a}	82.28^{b}	69.22^{b}	83.46^{a}	69.77^{b}	74.52^{b}
CP	89.11	85.94	86.07	81.24	92.91	90.73	92.51	88.84	80.63	80.96	82.50	81.39
CF	60.52^{c}	87.93^{a}	88.06^{a}	83.80^{b}	71.10	85.70	87.66	86.49	89.98	72.30	75.37	82.81
EE	89.42	88.83	90.25	76.71	91.81	92.11	90.38	94.84	82.79	80.27	79.15	76.30
Ash	71.72	86.04	67.75	77.67	76.05	81.56	86.74	83.12	79.58	71.25	73.41	71.49
NFE	95.90	87.23	93.50	95.89	96.62	95.20	92.83	95.33	84.45	93.78	94.18	92.17
Ca	87.63	74.98	60.11	83.31	87.56	79.81	82.12	92.43	82.30a	79.45a	59.81b	58.28b
P	84.27	84.29	80.48	87.24	82.50	85.87	88.13	89.94	54.78c	75.73a	61.24b	43.30c

Table 2. Contd.

Nutrient digestibility (Finisher)												
DM	85..01	84.91	85.00	85.10	86.91	87.08	87.11	87.08	82.29	82.44	82.38	82.43
CP	83.03	83.62	81.86	81.72	85.91	87.07	86.55	85.91	80.62	79.26	80.96	75.10
CF	67.88	70.00	69.87	78.63	72.12	77.25	72.04	68.14	72.16	83.19	65.52	74.17
EE	92.80	95.70	95.82	95.36	95.58	95.64	95.35	95.73	94.62	93.32	95.06	94.63
Ash	65.53	58.83	34.07	58.49	68.30	67.01	60.66	67.32	18.90	44.50	67.55	40.34
NFE	93.14	93.16	92.45	88.28	91.77	97.18	96.53	96.35	85.97	85.49	88.54	94.83
Ca	97.52	78.41	62.67	78.58	76.54	79.63	84.12	69.57	40.20	73.56	73.60	56.54
P	68.40	70.68	68.69	75.81	76.84	89.93	79.13	65.80	55.56	46.50	80.85	67.03

^{abc}Means with the same superscripts on the same row are not significantly different (p>0.05); SEM: Standard error of mean.

Table 3. Effect of different processing methods on the performance parameters and cost implications of broilers.

Performance parameter	T1	T2	T3	T4	F1	F2	F3	F4	A1	A2	A3	A4
Starter phase												
IBW	47.67	40.67	44.33	45.00	42.67	40.33	40.00	40.33	42.67	40.33	40	39
ABW	537.6	642.37	582.8	514.67	535.20^{c}	749.30^{a}	709.33^{b}	710.80^{b}	423.13	429.2	494.67	501.33
FI (g)	374.00^{a}	490.67^{a}	415.67^{b}	260.67^{c}	693.00^{ab}	607.67^{c}	730.00^{a}	629.00^{bc}	373.00^{b}	661.33^{a}	371.00^{b}	425.00^{b}
ABWG(g)	210.33^{b}	285.33^{a}	279.67^{a}	186.67^{b}	244.00^{b}	264.33^{b}	370^{a}	255.33^{b}	121.33	144.33	153	120.33
FCR	1.78^{c}	1.72^{bc}	1.49^{ab}	1.41^{a}	2.84^{b}	2.31^{a}	2.04^{a}	2.48^{ab}	3.06^{ab}	4.63^{c}	2.45^{a}	3.55^{b}
PER	2.56^{a}	2.67^{a}	2.87^{a}	3.50^{b}	1.54^{a}	1.95^{ab}	2.27^{b}	2.03^{ab}	1.55^{bc}	1.00^{a}	1.76^{c}	1.22^{ab}
EER	17.77^{a}	19.24^{a}	19.57^{a}	24.31^{b}	10.29^{b}	13.84^{ab}	15.93^{a}	12.71^{ab}	11.32^{a}	6.41^{b}	12.48^{a}	8.78^{b}
Survl (%)	95.33	95.33	94.00	94.00	97.00	96.67	97.00	95.33	97.00	97.67	97.00	98.00
P Index	112.88^{b}	158.58^{a}	177.07^{a}	125.89^{b}	81.91^{b}	111.25^{b}	188.96^{a}	100.29^{b}	38.17^{b}	31.03^{b}	61.59^{a}	33.55^{b}
Finisher phase												
IBW	537.6	642.37	582.8	514.67	535.20^{c}	749.30^{a}	709.33^{b}	710.80^{b}	423.13	429.2	494.67	501.33
ABW	1853.33^{b}	2127.50^{a}	2197.50^{a}	1645.00^{c}	2029.17^{ab}	2220,83^{ab}	2425.00^{a}	1526.67^{c}	1366.67^{b}	1529.33^{ab}	1614.33^{a}	1422.10^{ab}
FI (g)	844.00^{a}	902.33^{a}	894.00^{a}	648.33^{ab}	1315.33^{ab}	1257.33^{b}	1451.67^{a}	1314.33^{ab}	984.33^{ab}	928.00^{b}	1140.67	1144.67^{a}
ABWG(g)	466.67^{a}	424.33^{a}	436.67^{a}	337.33^{b}	383.33^{b}	438.67^{b}	661.00^{a}	422.33^{b}	285.00^{bc}	329.67^{a}	303.33^{ab}	249.67^{c}
FCR	1.81	2.13	2.05	1.97	3.44^{b}	2.90^{ab}	2.20^{a}	3.24^{b}	3.46^{a}	2.83^{a}	3.75^{ab}	4.62^{b}
PER	2.66^{c}	2.05^{a}	2.43^{ab}	2.55^{ab}	1.37^{c}	1.62^{ab}	2.17^{b}	1.39a^{b}	1.43^{b}	1.51^{b}	1.30^{ab}	1.07^{a}
EER	18.64^{a}	20.72^{a}	13.88^{b}	14.09^{b}	9.74^{b}	11.5^{ab}	13.24^{a}	9.4^{b}	8.40^{b}	10.73^{a}	7.79^{b}	6.79^{b}
Survl (%)	98.93^{a}	98.67^{a}	99.00^{a}	97.33^{b}	95.00^{ab}	96.00^{a}	93.33^{b}	96.00^{a}	97.67	97	98.67	98.33
P Index	255.86^{a}	196.39^{ab}	211.48^{a}	175.02^{b}	106.60^{b}	149.16^{b}	282.68^{a}	135.79^{b}	81.63^{b}	114.04^{a}	80.00^{b}	54.08^{b}

Table 3. Contd.

					Cost implication							
feed cost	71.10^{b}	77.01^{a}	73.42^{ab}	57.50^{c}	21,393.00	21,538.20	24,739.20	21,858.00	69.22^{b}	83.46^{a}	69.77^{b}	74.52^{b}
Income	89.11	85.94	86.07	81.24	92.91	50,853.00	57,387.00	60,142.50	38,709.0	80.96	82.50	81.39
Cost/benefit ratio	60.52c	87.93a	88.06a	83.80b	71.10	85.70	87.66	86.49	89.98	72.30	75.37	82.81

^{abc}Means with the same superscripts on the same row are not significantly different (p>0.05); SEM: Standard error of mean; IBW: Initial body weight; ABW: Average body weight; FI- Feed intake; ABWG: Average body weight gain; FCR: Feed conversion ratio; PER: Protein efficiency ratio; EER: Energy efficiency ratio; Survl (%): Survival percentage; P Index: Performance index

Table 4. Effect of different processing methods on carcass characteristics, organ morphology, cooking yield and serum profile.

Carcass characteristics	Thermal				Fermentation				Alkaline			
	T1	**T2**	**T3**	**T4**	**F1**	**F2**	**F3**	**F4**	**A1**	**A2**	**A3**	**A4**
Live weight (g)	1853.3^{b}	2400.0^{a}	2462.7^{a}	1933.3^{b}	2776.0	2833.0	2833.0	2500.0	160.0^{c}	195.0^{b}	226.67^{a}	190.00^{b}
Pluck weight (g)	2162.7^{a}	2172.70^{a}	2263.30^{a}	1810.00^{b}	262.30	267.03	271.00	228.30	189.67^{b}	156.00^{c}	220.67^{a}	185.0^{bc}
Pluck percentage (g)	94.19	90.77	91.81	93.75	94.43	94.25	95.72	91.61	97.20	97.57	97.23	97.36
Eviscerated weight (g)	210.00^{a}	187.67^{ab}	203.33^{a}	158.67^{b}	165.67^{b}	209.00^{a}	213.33^{a}	171.67^{b}	163.7^{ab}	125.0^{bc}	186.67^{a}	116.67^{c}
Head (%)	0.98	1.01	1.01	1.10	0.81	0.90	0.85	0.86	1.50	0.96	1.02	0.93
Neck (%)	1.87^{b}	1.48^{b}	2.34^{a}	2.22^{ab}	1.38^{b}	2.03^{a}	1.44^{b}	1.50^{b}	2.01^{a}	1.67^{ab}	1.80^{ab}	1.38^{b}
Wing (%)	3.05	1.77	2.56	2.99	2.87^{b}	2.99^{ab}	2.67^{b}	3.37^{a}	3.35^{a}	3.17^{a}	3.29^{a}	2.10^{b}
Breast (%)	6.92^{ab}	3.71^{b}	8.64^{ab}	9.54^{a}	7.04^{c}	9.34^{a}	8.81^{ab}	8.41^{b}	9.17^{a}	9.17^{a}	9.20^{a}	7.00^{b}
Organ morphology												
Intestine (g)	1.99	1.48	1.43	2.21	1.64^{a}	1.67^{a}	1.39^{b}	0.86^{c}	2.22^{b}	3.15^{a}	2.55^{b}	2.29^{b}
Lungs (g)	0.28^{ab}	0.81^{a}	0.43^{ab}	0.11^{b}	0.14	0.20	0.13	0.20	0.11^{b}	0.11^{b}	0.18^{a}	0.10^{b}
Liver (g)	0.74^{ab}	1.02^{a}	0.86^{ab}	0.65^{b}	0.78^{a}	0.66^{b}	0.53^{c}	0.66^{b}	0.92^{a}	0.65^{b}	0.73^{b}	0.63^{b}
Hearts (g)	0.44^{ab}	0.82^{a}	0.37^{ab}	0.21^{b}	0.20	0.23	0.08	0.22	0.27^{a}	0.15^{b}	0.23^{ab}	0.18^{ab}
Kidney (g)	0.02^{b}	0.64^{a}	0.01^{b}	0.01^{b}	0.03	0.13	0.03	0.03	0.03	0.01	0.02	0.02
Spleen (g)	0.18	0.35	0.35	0.04	0.04	0.14	0.02	0.03	0.03	0.01	0.02	0.02
Gizzard (g)	1.38^{a}	1.12^{b}	1.04^{b}	1.10^{b}	1.13^{a}	0.92^{ab}	0.62^{b}	0.79^{b}	1.94^{a}	0.01^{b}	1.21^{a}	0.88^{a}
Gall bladder (g)	1.16	0.33	0.18	0.04	0.04	0.13	0.01	0.10	0.11^{b}	0.90^{a}	0.19^{b}	0.04^{b}
Abdominal fat (g)	0.51^{a}	0.85^{b}	0.91^{b}	0.81^{b}	0.39	0.41	0.15	0.44	0.96^{a}	0.25^{b}	0.85^{a}	0.36^{b}
Crop oesophagus (g)	10.33^{a}	4.93^{b}	14.00^{a}	10.00^{ab}	12.33^{b}	5.17^{c}	16.67^{a}	4.50^{c}	12.30^{a}	7.83^{d}	10.67^{b}	9.43^{c}
Proventiculus (g)	0.60^{ab}	1.63^{a}	0.61^{ab}	0.30^{b}	0.50	0.50	0.23	0.45	0.50^{a}	0.17^{c}	0.39^{ab}	0.30^{bc}
Duodenum fold length (cm)	12.17^{b}	23.33^{a}	14.73^{ab}	10.00^{b}	14.50^{b}	16.00^{b}	17.67^{a}	16.00^{b}	14.67^{a}	9.17^{c}	13.67^{b}	13.67^{b}
Duodenum width (cm)	4.13^{b}	18.67^{a}	4.40^{b}	1.99^{b}	2.97^{a}	2.92^{a}	1.50^{b}	2.68^{a}	3.50	2.63	2.97	5.90
Jejunum width (cm)	12.65^{ab}	24.00^{a}	3.20^{b}	0.99^{b}	2.57^{a}	2.15^{ab}	1.68^{b}	2.04^{ab}	3.40^{a}	2.13^{b}	2.73^{ab}	2.30^{b}
Ileum length (cm)	2.16	7.80	1.74	1.47	2.11^{a}	1.90^{ab}	1.08^{c}	1.68^{b}	1.09^{d}	1.76^{b}	1.63^{c}	1.91^{a}
Ceacum Length (cm)	18.67	15.03	18.50	15.27	23.17	26.17	21.00	24.00	21.00	19.00	18.67	21.00
Ceacum width (cm)	4.34	2.13	5.50	2.67	3.83	3.33	6.67	3.33	4.33^{a}	1.73^{c}	3.38^{b}	2.43^{c}

Table 4. Contd.

Small intestine (cm)	61.67^{a}	43.73^{ab}	44.33^{ab}	18.60^{b}	70.00	86.67	66.67	70.00	25.00^{a}	9.50^{b}	11.83^{b}	10.00^{b}
Colo-recticulum length (cm)	11.67^{a}	4.57^{b}	14.93^{a}	10.67^{ab}	12.43	13.00	16.00	12.50	11.00^{a}	7.33^{d}	13.00^{a}	9.33^{c}
Colo-recticulum width (cm)	2.10^{b}	1.47^{b}	3.23^{a}	1.93^{b}	2.70^{a}	1.57^{b}	2.90^{a}	2.07^{ab}	2.33^{b}	10.20^{ab}	2.17^{b}	12.67^{d}
Colo-gizzard length (cm)	27.60^{a}	18.97^{c}	21.10^{b}	19.77^{bc}	25.10^{a}	24.33^{ab}	19.83^{c}	20.53^{bc}	22.37^{b}	20.50^{c}	19.07^{d}	23.50^{a}
Intestine (g)	1.99	1.48	1.43	2.21	1.64^{a}	1.67^{a}	1.39^{b}	0.86^{c}	2.22^{b}	3.15^{a}	2.55^{b}	2.29^{b}
Cooking yield and loss												
Cooking yield	55.98^{a}	55.53^{ab}	53.33^{b}	53.02^{b}	63.25^{a}	64.77^{a}	63.57^{a}	60.25^{b}	53.63^{a}	53.59^{a}	53.05^{a}	51.32^{b}
Cooking loss	44.02^{a}	44.47^{ab}	46.67^{b}	46.98	36.75^{a}	35.23^{a}	36.43^{a}	39.75^{b}	46.37^{a}	46.41^{a}	46.95^{a}	48.68^{b}
Serum profile												
Urea (mmn/1)	3.55^{a}	3.33^{a}	3.43^{a}	2.13^{b}	2.83^{b}	2.83^{b}	2.07^{c}	3.00^{a}	3.0^{a}	2.17^{c}	2.73^{b}	2.27^{c}
Cholesterol (mmn/1)	2.57^{b}	2.27^{c}	2.83^{a}	2.27^{c}	2.70	2.80	2.97	2.87	2.17^{d}	3.13^{b}	3.47^{a}	2.43^{c}
Creatine (mn/1)	122.67^{a}	111.33^{b}	122.67^{a}	97.33^{c}	85.33^{a}	98.67^{b}	85.33^{a}	115.33^{a}	102.00^{a}	83.33^{b}	82.33^{b}	89.00^{ab}
Packed Cell Volume (PCV)	32.67^{a}	31.33^{a}	32.33^{a}	28.33^{b}	29.33^{b}	32.33^{a}	25.33^{a}	27.33^{c}	30.67	30.33	31.00	25.67

^{abc}Means with the same superscripts on the same row are not significantly different ($p>0.05$) SEM: Standard error of mean.

Table 5. Overall scoring of parameters measured in the different thermal processing methods of soyabeans.

Parameter	Thermal processing methods			
	Extrusion	**Cooking**	**Toasting**	**Roasting**
Chemical composition of soyabean seed	3	1	4	2
Amino acid profile of test soya beans	3	1	4	2
Anti-nutritional factor analysis	2	1	4	3
Chemical composition of starter diets	1	2	3	4
Chemical composition of finisher diets	3	1	2	1
Nutrient digestibility starter	1	2	3	4
Nutrient digestibility finisher	3	1	4	2
Performance traits starter	2	1	3	4
Performance traits finisher	2	3	1	4
Carcass characteristics	1	4	3	2
Organ morphology	4	1	3	2
Cooking yields and loss	1	2	3	4
Serum profile	1	3	2	4
Economics	3	2	2	4
Means	2.1	1.8	2.93	3.0
Score	2	1	3	4

1 = Fair; 2 = Good; 3 = Better; 4 = Best mean.

Table 6. Overall scoring of parameters measured in the different fermentation methods of soyabeans.

Parameter	Fermentation method			
	Lactobacillus	Cook and ferment	Daddawa	Cook + potash and ferment
Chemical composition of soyabean seed	2	1	3	4
Amino acid profile of test soya beans	1	3	4	2
Anti-nutritional factor analysis	1	3	2	4
Chemical composition of starter diets	1	2	3	3
Chemical composition of finisher diets	2	3	1	1
Nutrient digestibility starter	3	4	1	2
Nutrient digestibility finisher	3	1	2	4
Performance traits starter	2	3	1	4
Performance traits finisher	4	3	1	2
Carcass characteristics	4	1	2	3
Organ morphology	2	1	3	4
Cooking yields and loss	3	1	2	4
Serum profile	1	1	3	2
Economics	3	1	2	4
Means	2.3	2.0	2.1	3.1
Score	3	1	2	4

1 = Fair; 2 = Good; 3 = Better; 4 = Best mean.

Table 7. Overall scoring of parameters measured in the different alkaline treatment of soyabeans.

Parameter	Alkaline treatment			
	0 % Alkaline	1% Na_2CO_3	1% K_2CO_3	1%NaOH
Chemical composition of soyabean seed	2	1	3	1
Amino acid profile of test soya beans	2	4	1	3
Anti-nutritional factor analysis	4	1	3	2
Chemical composition of starter diets	4	1	2	3
Chemical composition of finisher diets	2	3	1	4
Nutrient digestibility starter	2	3	1	3
Nutrient digestibility finisher	4	3	1	2
Performance traits starter	4	1	3	2
Performance traits finisher	3	3	1	2
Carcass characteristics	1	3	2	4
Organ morphology	3	2	1	4
Cooking yields and loss	1	2	3	4
Serum profile	1	2	1	2
Economics	3	2	1	4
Means	2.6	2.2	1.7	2.9
Score	3	2	1	4

1 = Fair; 2 = Good; 3 = Better; 4 = Best mean.

investment.

The results obtained from the use of different alkaline salts in this experiment confirmed the advantages associated with alkaline treatment in the nutritional improvement of soya beans for broiler utilization (Omoeti et al., 1992; Ayanwale, 1999; Aregheore et al., 2003).

Although the results of the various chemical analysis performed on both the alkaline treated soya beans seeds and alkaline treated soya beans based diets and other performance parameters were better in the sodium carbonate treated group, biological assay using performance traits measurements of the broilers and other indices like economic benefit and cost analysis cumulatively placed the 1% potassium carbonate (K_2CO_3)

Table 8. Overall scoring of parameters measured in the comparative evaluation of the best processing methods in thermal, fermentation and alkaline processing of soyabeans.

Parameter	Processing methods		
	Thermal- cooking	Fermentation-cook and ferment	Alkaline-1% potash
Chemical composition of soyabean seed	1	3	2
Amino acid profile of test soya beans	3	2	1
Anti-nutritional factor analysis	2	1	2
Chemical composition of starter diets	2	1	2
Chemical composition of finisher diets	2	3	1
Nutrient digestibility starter	2	1	3
Nutrient digestibility finisher	2	1	3
Performance traits starter	2	1	3
Performance traits finisher	2	1	3
Carcass characteristics	3	2	1
Organ morphology	1	3	2
Cooking yields and loss	2	1	3
Serum profile	3	2	3
Economics	3	2	1
Means	2.1	1.7	2.1
Score	2	1	2

1 = Fair; 2 = Good; 3 = Better; 4 = Best mean.

group as the overall best in the alkaline processing experiment.

The relative poor results associated with the sodium hydroxide treatment of soya beans may be associated with the type and possibly the strength of the alkaline salt which led to mineral and nutrient chelating as earlier reported by Ayanwale (1999) and leaching of nutrients (Ku et al., 1976) as well as reduction in nutritional value and bioavailability.

The overall ranking for the selection of the best processing method among the different processing methods experimented on is presented in Table 4. The ranking in this table summarized the pooled ranks of best means of the three selected experimental bests (cooking for thermal processing, cook and ferment for fermentation methods and 1% potassium carbonate (K_2CO_3) for the alkaline treatment) as described in the research methodology.

Although the three selected processes presented good nutrient profile, 1% potassium carbonate (K_2CO_3) was scored best in terms of nutrient composition as indicated in Table 1. This confirmed that biological assay rather than chemical analysis was the best assessor of nutrient quality in any feed ingredient required for broilers, since nutrient mobilization and utilization was found to be best in the cook and ferment group.

The outstanding score of the cook and ferment group in the removal of anti-nutritional factors especially trypsin inhibitor activity confirmed the superiority of fermentation in the removal of ANFs as earlier documented by Fagbemi et al. (2005) who stated that fermentation was the most effective processing method that drastically reduced phytic acid and trypsin inhibitor activity in oilseeds. This view was also shared by Doell et al. (1981) whose examination of some traditional oriental soya foods revealed that most of the TIA had been removed or inactivated during fermentation processing and the rest were further removed through cooking. Phytic acid reduction has also been reported in fermented soya beans by Sudarmadji and Markakis (1977) and Sutardi and Buckle (1985).

The best scores observed in the cook and ferment group when compared with the other groups in nutrient digestibility, performance parameters such as average weight gain, feed conversion ratio, protein efficiency ratio and performance index among others in both the starter and finisher phases observed in this comparative evaluation was supported by Roozen and De Groot (1985), Matsui (1996), Caine et al. (1998), Ayanwale and Kolo (2001) and Barde and Ari (2004) who reported that fermentation provided a major means of nutritional improvement of feedstuff for utilization by farm animals.

The emergence of the cook and ferment group as the overall best in spite of similarities or even better performance in some trails measured confirmed that fermentation process converts food compounds into structurally related but financially more viable food through the activities of microbial cells as reported by Stanbury and Whitaker (1984).

Conclusions

The findings of this study revealed that significant variations in the effect of different thermal, fermentation and alkaline processing methods on the chemical composition, amino acid profile, ANFs removal and the performance of broilers. The best performance recorded in the cooking group confirmed hydrothermal processing of soya beans as the best thermal processing method that will guarantee the preservation of essential nutrients and removal of ANFs for greater performance of broilers, while the poor performance recorded in the roasting group confirmed the process as not an ideal soya bean processing method for broiler feeds. The cook and ferment group presented the best performance recorded under fermentation process. However, controlled fermentation using selected culture organisms (*Lactobacilus bulgricus, Saccharomyces cerevisiae* and *Streptococcus lactis*) helps in the improvement and preservation of nutrient quality without necessarily impacting better performance of broilers than uncontrolled fermentation processes. The use of potassium carbonate (1% K_2CO_3) and sodium carbonate (1% Na_2CO_3) in the processing of soya bean recorded greater improvement in the removal of ANFs and preservation of nutrient quality, gave better performance traits, serum profile and economic returns. These factors accounted for the best performance recorded in 1% K_2CO_3 treatment of soya beans when compared with other alkaline treatment methods investigated in this study.

The comparative evaluation of all the processing methods showed that cook and ferment group was the overall best in spite of similarities or even better performance in some traits measured when compared with the other methods. The potentials of this processing method in the preservation of essential nutrients, better performance of broilers and yield of greater economic returns on investment observed in this comparative evaluation has confirmed that fermentation process converts food compounds into structurally related but financially more viable food through the activities of microbial organisms. Thus, the qualitative tool used to arrive at this decision has provided the farmer an aggregated selection criterion for choosing the right processing method to adopt for optimum benefit.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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