JOURNAL OF ANIMAL SCIENCE ADVANCES

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J Anim Sci Adv 2014, 4(11): 1101-1109

DOI: 10.5455/jasa.20141113124747

Online version is available on: www.grjournals.com

Original Article

Characterization of the Chemical Composition of Raw and Treated Jackfruit (*Artocarpus Heterophyllus)* and Java Plum (*Syzygium Cumini*) Beans for Poultry Feeding

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Abstract

The chemical composition of Jackfruit beans (JFB) and Java plum beans (JPB) was investigated to establish their nutritive value for poultry. The beans were soaked in water before subjecting them to the following treatments: fermented in presence of wood ash (SFWA); boiled (SB); roasted (SR); autoclaved (SA); fermented after boiling (SBF); roasted after fermentation (SFR); and a combination of boiling, fermentation and roasting (SBFR). Screening to identify phytochemical compounds and quantify anti-nutrients in the raw beans; determining the content of anti-nutrients in treated beans were conducted. Additionally, proximate composition, minerals, and metabolisable energy (ME) of raw and treated beans were determined. Most (>70%) phytochemical compounds in raw JFB and JPB were anti-nutrients and included sterols, triterpenes, courmarins, tannins, cardiac glycosides, alkaloids, saponins and steroid glycosides. Raw JFB and JPB had 1.11, 2.44% tannins; 1.00, 1.54 % oxalates; 0.754, 0.714% phytates respectively. Tannins in raw JFB were reduced by 88.7, 88.5, 85.9 and 84.5% in SFR, SBF, SB and SBFR treatments respectively. Oxalates in JFB were reduced by 85.3% and 81.2% in SBF and SBFR treatments respectively. Proximate composition, minerals, and ME of raw JFB and JPB was 92.5, 91.0% DM; 15.1, 4.42% CP; 0.983, 0.400% EE; 4.20, 3.44% CF; 3.78, 2.17% ash; 74.0, 88.6% NFE; 13.3, 13.2 MJ/kg ME; 0.456, 0.430% Na; 0.611, 0.481% Ca; 0.222, 0.088% P; 1.53, 0.895% K respectively. The method of treatment had no effect ($P>0.05$) on CF of JFB. Method of treatment had a significant ($P<0.05$) effect on CP, NFE, ME, DM, ash, P, K, Na, and Ca for JFB. Method of treatment had no significant ($P>0.05$) effect on CF and CP for JPB but DM, ash, EE, NFE, ME, P, K, Na, and Ca were affected ($P<0.05$). The SBF and SBFR reduced tannins and oxalates from raw JFB by more than 80%. The major nutrient in JFB and JPB is energy.

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Received on: 02 Oct 2014
Revised on: 17 Oct 2014
Accepted on: 13 Nov 2014
Online Published on: 30 Nov 2014

Keywords: Anti-nutrients, feed resources, livestock, nutritional value, treatment.

Abbreviations: Ca= calcium, CF= crude fibre, CP= crude protein, D= digestibility coefficient, DM= dry matter, EE= ether extract/crude fat, G= grams, JF= Jackfruit, JFB= Jackfruit beans, JP= Java plum, JPB= Java plum beans, JPF= Java plum fruit, ME= metabolisable energy, K= potassium, Na= sodium, NFE= nitrogen free extract, P= phosphorus/probability, PSI= pounds per square inch, SA= soaking-autoclaving, SB= soaking-boiling, SBF= soaking-boiling-fermentation, SBFR= soaking-boiling-fermentation-roasting, SFR= soaking-fermentation-roasting, SFWA= soaking-fermentation in presence of wood ash, SR= soaking-roasting.

Introduction

The JFB and JPB are produced by trees belonging to Moraceae and Myrtaceae plant families respectively. The structure of JF and JPF and their beans is shown in Figure 1. Each JF and JP tree produces 390kg and 140kg of beans annually respectively (Ndyomugyenyi *et al*., 2014). The total annual production of JFB and JPB in 50 villages of Kampala and Mbale districts, Uganda was reported to be 10.3 x 10^2 and 249 tonnes respectively (Ndyomugyenyi *et al*., 2014). In Uganda, the beans are unused feed resources and are readily available for livestock feed production (Ndyomugyenyi *et al*., 2014). The beans have potential as a feed resource for livestock. Flour of JFB contains 11% CP, 82% NFE and 78% starch (Tulyathan, 2001). Ravindran *et al*., (1996) reported that the CP and NFE of JFB are 12.4% and 74.0% respectively.

The ME of JPB was reported to be 13.4 MJ/kg (Ndyomugyenyi *et al*., 2008). The beans and leaves of JP are used as livestock feed while fruit pulp is used to make jelly, jam, squash, wine and vinegar (Pankaj, 2003). Pods of JP can be fermented to make beer (Chhotu, 2003). However, the major challenge affecting utilization of JFB and JPB as feed resources is the presence of anti-nutrients.

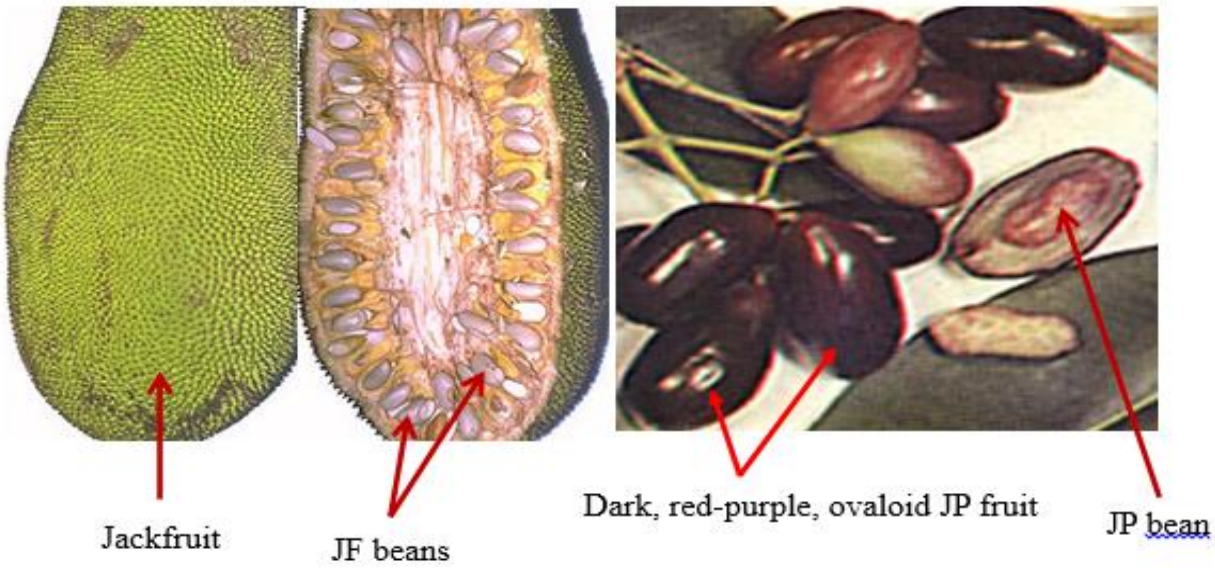

Figure 1: Structure of Jackfruit and Java plum beans

Presence of anti-nutrients in feedstuffs has been reported to cause growth depression, poor feed utilization and mortality in poultry (Francis *et al*., 2002; Ravindran *et al*., 1996; Akinmutimi, 1986). Anti-nutrients cause major limitations in the use of feedstuffs for livestock feeding when they are not adequately removed (Akande *et al*., 2010). Despite the limitations, the competition between humans and animals for conventional feedstuffs has stimulated the use of alternative feedstuffs because they are less costly and less exploited by humans (Boda, 1999; Mbugua, 1989). Thus, the search for alternative feed sources for livestock production continues for purposes of livestock sustainability, economic sustainability, and animal welfare (Preston, 1992). Although reports have been made on some anti-nutrients in JFB (Ravindran *et al*., 1996; Akinmutimi, 1986) and JPB (Ndyomugyenyi, 2008), little work has been done to remove these anti-nutrients from the beans. Wet heat treatment was reported to be effective in the biological inactivation of trypsin inhibitor from JFB (Ravindran *et al*., 1996; Bhat and Pattabiraman, 1989) but other treatment techniques should be evaluated for their efficacy. Use of one treatment method alone such as boiling, roasting, soaking or fermentation has often failed to substantially remove some anti-nutrients from feedstuffs. A combination of two or more treatment methods was proposed by Sadeghi *et al*., (2009) to remove most anti-nutrients from feedstuffs.

Therefore, this study was conducted to: remove anti-nutrients from raw JFB and JPB using two or more treatment methods; identify and quantify anti-nutrients in raw JFB and JPB; quantify anti-nutrients in treated JFB and JPB; evaluate the effect of treatments on the nutrient composition of JFB and JPB.

Materials and Methods

Source of Jackfruit and Java Plum Beans

The JFB and JPB were obtained from Wakiso district, Uganda. Wakiso district (00^{o}24$'$N 32^{o}29$'$E) lies in central Uganda in the Lake Victoria basin.

Treatment of Jackfruit and Java Plum Beans

Seven treatment methods were used to remove anti-nutrients from JFB and JPB. In the first method, the beans were mixed with wood ash (10 parts of beans: 1 part of ash) and tied within gunny bags; soaked in water for 12 hours, drained under shade for 9 hours; well covered and fermented for one week (SFWA). From second to seventh method, the beans were first soaked in water for 12 hours, drained, rinsed once with fresh water before subjecting them to further treatment (s). In the second method, the beans were cooked in water at 100^{o}C using charcoal stove for 2 hours (SB), while the third method involved roasting the beans on a hot pan using charcoal stove for 30 minutes (SR). The beans were sun-dried before autoclaving at 121°C, pressure of 15 PSI for 20 minutes in the fourth method (SA). The fifth method involved cooking the beans in water at 100^{o}C for 2 hours followed by sun-drying the beans under the shade for 12 hours, mixing the beans with fresh water (1kg of beans: 65mls of water), and fermenting for one week (SBF). The sixth method had the beans fermented for one week before they were roasted for 30 minutes (SFR). In the seventh method (SBFR), the beans were cooked in water at 100^{o}C for 2 hours, sun-dried in a shed for 12 hours, mixed with fresh water (1kg of beans: 65mls of water), fermented for one week before roasting for 30 minutes (Figure 2).

Chemical Analysis of Raw and Treated Jackfruit and Java Plum Beans

Three anti-nutrients; tannins, phytates and total oxalates in the beans were quantified. Tannins were determined using modified Vanillin assay method (Price *et al*., 1978); phytates (Reddy and Love, 1999); total oxalates (Day and Underwood, 1986). Phytochemical composition was determined using the methods of Ciulei (1964). Solvents used to extract phytochemical compounds from beans were water, hexane, ethanol, and diethyl ether. Proximate composition and minerals were determined using procedures of AOAC (1990). The ME was estimated using the following formula developed by ARC (1977):

ME (Kcal/kg) = 4.31 x g.dCP + 9.28 x g.dEE + 4.14 x g.dNFE

Digestibility coefficients (d) of 90% for CP, 90% for EE and 80% for NFE were assumed.

Statistical Analysis

Data were analyzed using General Linear Model (GLM) procedures of Statistical Analysis System (SAS, 2001). The means generated were separated using Least Significant Difference at 5% significant level.

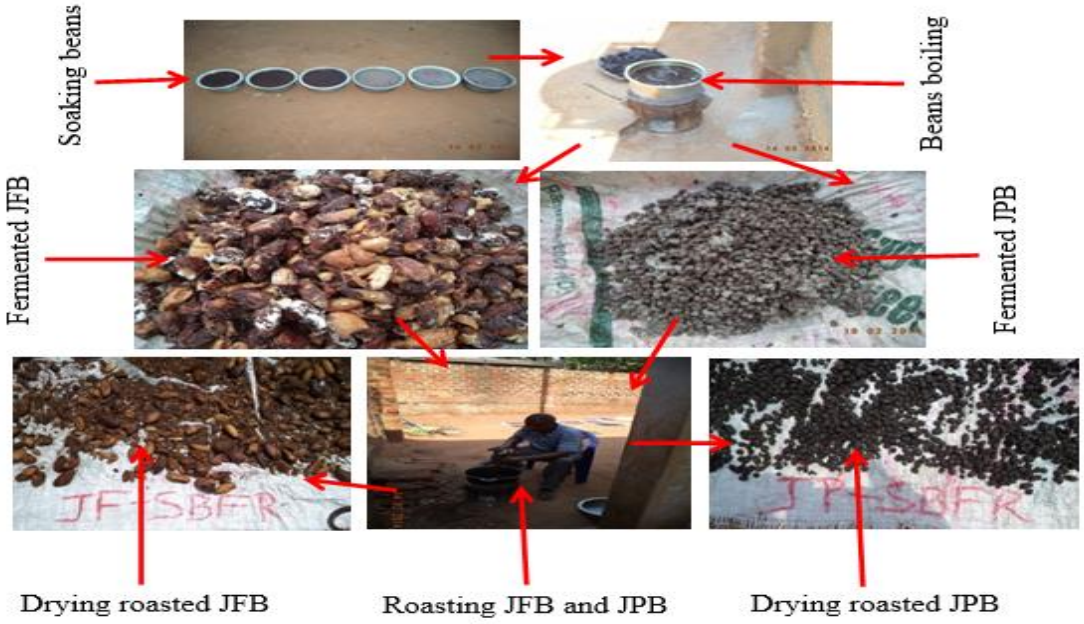

Figure 2: Soaking-boiling-fermentation-roasting (SBFR) treatment method

Results

Identification of Anti-Nutrients in Raw Jackfruit and Java Plum Beans

Majority of phytochemical compounds identified in JFB (77.8%) and JPB (75%) were anti-nutrients and included sterols, triterpenes, courmarins, tannins, cardiac glycosides, alkaloids, saponins, and steroid glycosides (Table 1). Small portions of phytochemical constituents in JFB (22.2%) and JPB (25%) were not anti-nutrients and included reducing compounds and fatty acids. Water and ethanol had more (52.4%) active phytochemical constituents of JFB and JPB extracts than hexane and diethyl ether (47.6%).

Table 1: Phytochemical constituents of raw Jackfruit and Java plum beans.

Solvent	Water		Hexane		Ethanol		Diethyl ether	
Raw beans	**JFB**	**JPB**	**JFB**	**JPB**	**JFB**	**JPB**	**JFB**	**JPB**
Alkaloid salts	-	-	-	-	-	-	-	-
Anthocyanin pigments	-	+	-	+	-	+	-	+
Anthracenosides	-	-	-	-	-	-	-	-
Basic alkaloids	+	+	+	-	+	+	+	-
Caffeine	-	-	-	-	-	-	-	-
Cardiac glycosides	+	+	+	+	+	+	+	+
Courmarins	+	+	+	+	+	+	+	+
Fatty acids	+	+	+	+	+	+	+	+
Flavonosides	-	-	-	-	-	-	-	-
Reducing compounds	+	+	+	+	+	+	+	+

Saponins	+	+	+	+	+	+	+	+
Steroid glycosides	+	+	+	+	+	+	+	+
Sterols	+	+	+	+	+	+	+	+
Tannins	+	+	-	+	+	+	-	+
Triterpenes	+	+	+	+	+	+	+	+

+ Sign indicates presence of phytochemical compound
- Sign indicates absence of phytochemical compound.

Concentration of Anti-Nutrients in Raw and Treated Jackfruit and Java Plum Beans

There was reduction in content of anti-nutrients from raw JFB and JPB as result of treatments (Tables 2 and 3). The SFR, SBF, SB, and SBFR treatments removed more (>84%) tannins from raw JFB (Table 2). The SBF and SBFR treatments removed more (>80%) oxalates from raw JFB. Phytate reduction from raw JFB was minimal (<32%) in all treatments. A reduction by over 70% of tannins from raw JPB was recorded for the SBFR treatment method (Table 3). Oxalate and phytate reduction from JPB was minimal (<45%) in all treatments.

Table 2: Anti-nutritive compounds in raw and treated Jackfruit beans (%DM).

Composition, %	Raw	SFWA	SB	SR	SA	SBF	SFR	SBFR
Dry matter	92.5	87.5	90.0	90.5	89.9	87.8	90.1	90.1
Condensed tannins[1]	1.11	0.337	0.156	0.419	0.953	0.128	0.125	0.172
% Tannin reduction	0.00	69.6	85.9	62.3	14.1	88.5	88.7	84.5
Total oxalates	1.00	0.589	0.823	0.492	0.564	0.147	0.387	0.188
% Oxalate reduction	0.00	41.1	17.7	50.8	43.6	85.3	61.3	81.2
Phytates	0.754	0.639	0.517	0.565	0.569	0.636	0.620	0.516
% Phytate reduction	0.00	15.3	31.4	25.1	24.5	15.6	17.8	31.6

[1]Catechin Equivalent (% CE).

Table 3: Anti-nutritive compounds in raw and treated Java plum beans (%DM).

Composition, %	Raw	SFWA	SB	SR	SA	SBF	SFR	SBFR
DM	91.0	89.2	91.4	92.9	92.3	88.8	92.8	90.3
Condensed tannins[1]	2.44	2.31	0.922	1.39	2.41	0.917	1.29	0.716
% Tannin reduction	0.00	5.33	62.2	43.0	1.23	62.4	47.1	70.7
Total oxalates	1.54	0.949	1.12	1.16	0.910	1.23	1.31	0.955
% Oxalate reduction	0.00	38.4	27.3	24.7	40.9	20.1	14.9	38.0
Phytates	0.714	0.525	0.407	0.501	0.506	0.578	0.403	0.567
% Phytate reduction	0.00	26.5	43.0	30.3	29.8	19.0	43.6	20.6

[1]Catechin Equivalent (% CE).

Proximate Composition and Metabolisable Energy of Raw and Treated Jackfruit and Java Plum Beans

With exception of CF, proximate composition and ME of JFB varied significantly (P<0.05) with treatment method (Table 4). Most treatments (55%) decreased proximate composition and ME of raw JFB. The highest reduction of 11.9% CP was recorded in both SFWA and SB. However, an increase of 3.6% in NFE was observed in SB treatment. Also, EE and ash contents of raw JFB increased by 30.8% and 25.3% in SA and SFWA treatments respectively. Except for CF and CP, proximate composition and ME of JPB were significantly (P<0.05) altered by treatment methods (Table 5). The bulk of treatments (63.3%) increased proximate composition and ME of raw JPB. The CP increased in SR (10.3%), SBF (8.1%), SFWA (8.1%), and SFR (6.8%); EE increased in SA (75.8%), SB (64.3%), and SR (51.9%); ash content

increased in SFWA (41.8%); CF (9.2%) in SBF; ME (2.94%) in SA.

Mineral Composition of Raw and Processed Jackfruit and Java Plum Beans

The method of treatment had a significant ($P<0.05$) effect on mineral content of JFB and JPB (Tables 6 and 7). Above 50% treatment methods decreased mineral composition of raw JFB while an increase in mineral content of the beans was observed in a quarter of the methods (Table 6). The highest reduction of 38.3% P and 43.8% K was recorded in SB and SR treatment methods respectively. The highest increment of 49.5% Ca and 5.59% Na was observed in SFWA and SBF respectively. Above 70% treatment decreased mineral content of raw JPB (Table 7). The highest decrease of 51.2% Na was recorded in SA method; and 28.5% Ca, 52.3% P, 52.4% K in SB treatment alone. However, an increment of 51.0% Ca, 17.8% P, and 1.65% K was observed in SFWA treatment only.

Table 4: Proximate and ME compositions of raw and treated Jackfruit beans (%DM).

Composition, %	Raw	SFWA	SB	SR	SA	SBF	SFR	SBFR	LSD	P
DM	92.5^{a}	87.5^{f}	90.0^{cd}	90.5^{b}	89.9^{d}	87.8^{e}	90.1^{c}	90.1^{c}	0.153	<.0001
CP	15.1^{a}	13.3^{c}	13.3^{c}	14.4^{ab}	13.5^{bc}	14.0^{bc}	13.4^{bc}	14.3^{abc}	0.958	0.0188
EE	0.983^{b}	0.655^{d}	0.591^{d}	0.852^{c}	1.01^{b}	1.42^{a}	0.966^{b}	0.392^{e}	0.085	<.0001
CF	4.20^{a}	4.76^{a}	4.83^{a}	4.35^{a}	4.69^{a}	4.63^{a}	4.80^{a}	4.80^{a}	1.05	0.793
Ash	3.78^{b}	5.06^{a}	2.17^{e}	2.98^{c}	3.01^{c}	2.25^{d}	2.98^{c}	2.28^{d}	0.079	<.0001
NFE	74.0^{cd}	72.9^{d}	76.8^{a}	75.0^{bc}	75.3^{bc}	74.7^{bc}	75.4^{ab}	75.9^{ab}	1.32	0.0034
ME, MJ/kg[1]	13.3^{b}	12.9^{c}	13.3^{b}	13.4^{b}	13.3^{b}	13.5^{a}	13.3^{b}	13.3^{b}	0.150	0.0010

[1] Calculated from chemical composition.
[a, b, c, d, e, f] Means within a row with different superscript differ significantly ($P<0.05$).

Table 5: Proximate and ME compositions of raw and treated Java plum beans (%DM).

Composition, %	Raw	SFWA	SB	SR	SA	SBF	SFR	SBFR	LSD	P
DM	91.0^{d}	89.2^{f}	91.4^{c}	92.9^{a}	92.3^{b}	88.8^{g}	92.8^{a}	90.3^{e}	0.291	<.0001
CP	4.42^{ab}	4.78^{a}	3.99^{b}	4.93^{a}	4.40^{ab}	4.81^{a}	4.74^{a}	4.60^{a}	0.569	0.0612
EE	0.400^{e}	0.444^{d}	1.12^{b}	0.832^{c}	1.65^{a}	0.434^{de}	0.050^{f}	0.418^{de}	0.040	<.0001
CF	3.44^{ab}	3.22^{b}	3.47^{ab}	3.31^{ab}	3.54^{ab}	3.79^{a}	3.20^{b}	3.42^{ab}	0.523	0.312
Ash	2.17^{b}	3.73^{a}	0.910^{e}	1.27^{d}	1.41^{c}	0.881^{e}	1.41^{c}	0.874^{e}	0.084	<.0001
NFE	88.6^{c}	86.4^{d}	89.6^{ab}	88.9^{bc}	88.1^{c}	88.8^{bc}	89.9^{a}	89.7^{a}	0.767	<.0001
ME, MJ/kg[1]	13.2^{d}	13.0^{e}	13.5^{ab}	13.5^{ab}	13.6^{a}	13.3^{c}	13.3^{cd}	13.4^{bc}	0.095	<.0001

[1] Calculated from chemical composition.
[a, b, c, d, e, f, g] Means within a row with different superscript differ significantly ($p<0.05$).

Table 6: Mineral composition of raw and processed Jackfruit beans (%DM).

Composition, %	Raw	SFWA	SB	SR	SA	SBF	SFR	SBFR	LSD	P
DM	92.5^{a}	87.5^{f}	90.0^{cd}	90.5^{b}	89.9^{d}	87.8^{e}	90.1^{c}	90.1^{c}	0.153	<.0001
Na	0.456^{b}	0.448^{c}	0.325^{e}	0.358^{d}	0.327^{e}	0.483^{a}	0.324^{e}	0.254^{f}	0.004	<.0001
Ca	0.611^{f}	1.21^{a}	0.489^{g}	0.692^{c}	0.693^{c}	0.640^{d}	0.626^{e}	0.904^{b}	0.006	<.0001
P	0.222^{a}	0.195^{b}	0.137^{d}	0.141^{d}	0.188^{b}	0.196^{b}	0.190^{b}	0.153^{c}	0.010	<.0001
K	1.53^{a}	1.23^{b}	0.869^{f}	0.860^{f}	1.24^{b}	1.12^{d}	1.19^{c}	0.905^{e}	0.021	<.0001

[a, b, c, d, e, f, g] Means within a row with different superscript differ significantly ($p<0.05$).

Table 7: Mineral composition of raw and processed Java plum beans (%DM).

Composition, %	Raw	SFWA	SB	SR	SA	SBF	SFR	SBFR	LSD	P
DM	91.0^{d}	89.2^{f}	91.4^{c}	92.9^{a}	92.3^{b}	88.8^{g}	92.8^{a}	90.3^{e}	0.291	<.0001
Na	0.430^{a}	0.257^{c}	0.249^{c}	0.314^{b}	0.210^{e}	0.330^{b}	0.247^{cd}	0.231^{d}	0.017	<.0001
Ca	0.481^{d}	0.982^{a}	0.344^{f}	0.534^{c}	0.473^{d}	0.421^{e}	0.550^{b}	0.477^{d}	0.014	<.0001
P	0.088^{b}	0.107^{a}	0.042^{e}	0.060^{c}	0.059^{c}	0.045^{e}	0.060^{c}	0.053^{d}	0.005	<.0001
K	0.895^{b}	0.910^{a}	0.426^{f}	0.629^{d}	0.668^{c}	0.438^{e}	0.666^{c}	0.434^{e}	0.006	<.0001

$^{a, b, c, d, e, f, g}$ Means within a row with different superscript differ significantly ($p< 0.05$).

Discussion

Identification of Anti-Nutrients in Raw Jackfruit and Java Plum Beans

Some anti-nutrients identified in JFB and JPB in the current study agree with what other researchers reported. Ravindran *et al*., (1996) and Morton (1987) reported that JFB contained saponins, while JPB had tannins (Pankaj, 2003).

Concentration of Anti-Nutrients in Raw and Treated Jackfruit and Java Plum Beans

Concentration of oxalates and phytates in raw JFB in the study was higher than the 0.66% and 0.597% respectively reported by Akinmutimi (2006). The variation in oxalate and phytate concentrations could be attributed to differences in locations from where the beans were obtained. However, phytates in raw JFB and JPB were within the range (0.5- 1.58%) reported in Phaseolus vulgaris L. by Lolas and Markakis (1975). Reduction of the anti-nutrients observed as a result of treatments involving boiling agree with what Akinmutimi (2006) reported. A combination of boiling and fermentation in the current study reduced the anti-nutrients even further. Anti-nutrients function by forming strong bonds with carbohydrates or proteins in the feed, making them unavailable for digestion. During microbial fermentation, as complex polysaccharides get broken into simple sugars, strong bonds are equally broken thereby releasing anti-nutrients. Anti-nutrients were probably inactivated by other micro-organisms in the fermentation environment, hence reducing their concentration. The practice of fermentation has long been used by local communities in the South-western region of Uganda to treat high tannin sorghum prior to production of local drinks.

Proximate Composition and Metabolisable Energy of Raw and Treated Jackfruit and Java Plum Beans

The CP of raw and treated JFB was higher than the 11.0% reported by Tulyathan (2001) and 12.4% reported by Ravindran *et al*., (1996). However, CP of raw and treated JPB was less than the 6.3-8.5% reported by Morton (1987). The CP of raw and treated JFB was higher than that of non-conventional feedstuffs such as bakery cracker residues (9.41%), cassava with hulls (2.9%), passion fruit pulp (13.7%), sugar cane juice (1.61%) and sweet potato (4.39%) (Rostagno *et al*., 2005). The NFE of raw JFB was lower than the 82% reported by Tulyathan (2001) but close to the 74.0% reported by Ravindran *et al*., (1996). Although ME of raw and treated JFB and JPB was lower than that of conventional energy sources such as cassava meal (14.9 MJ/kg) and wheat (15.1 MJ/kg) (Ewing, 1997), it was higher than barley (12.7 MJ/kg), rice (12.3 MJ/kg), oats (12.0 MJ/kg), and millet (11.8 MJ/kg) (Göhl, 1975). However, the ME of the beans was higher than that of non-conventional feedstuffs such as coconut meal (8.1 MJ/kg), sweet potato (11.4 MJ/kg) and yeast brewery (10.9 MJ/kg) (Rostagno *et al*., 2005). The ME of JP beans was comparable to the 13.4 MJ/kg reported by Ndyomugyenyi *et al*., (2008). Despite ME of raw and treated JFB and JPB being lower than that of some conventional energy sources, they are still within an acceptable level for use as energy feeds.

Mineral Composition of Raw and Processed Jackfruit and Java Plum Beans

The Na in raw and treated JFB and JPB was

higher than that of oats (0.1%), rice (0.1%), barley (0.02%), and sorghum (0.1%); Ca was higher than that of oats (0.12%), rice (0.11%), barley (0.07%), sorghum (0.19%), and wheat (0.05%); K was higher than that of oats (0.41%), barley (0.42%), sorghum (0.41%) and 0.2% rice (Göhl, 1975). However, P in raw and treated JFB and JPB was lower than that of maize (0.34%), millet (0.41%), oats (0.37%), barley (2.2%), wheat (0.48%), and 0.29% rice (Göhl, 1975). The Ca content of raw and treated JPB in the current study was higher than the 0.41% reported by Morton (1987). With exception of SFWA treatment method, the P content of raw and treated JPB was lower than the 0.17% reported by Morton (1987).

Conclusions

Anti-nutrients identified in raw JFB and JPB included sterols, triterpenes, courmarins, tannins, cardiac glycosides, alkaloids, saponins, and steroid glycosides. The SBF and SBFR reduced tannins and oxalates from raw JFB by more than 80%. The JFB and JPB could be best used as energy sources for poultry and other livestock species.

Acknowledgements

The authors thank Gulu University for funding the study. Authors are also very grateful to Mr. I Katongole and Mr. D Asizua for their contribution towards the success of the study.

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