Prospects for the utilization of *Senna obtusifolia* products as protein supplements for poultry

S. S. Diarra[1]

School of Agriculture, Geography, Environment, Ocean and Natural Sciences, The University of the South Pacific, Samoa Campus, Fiji

ABSTRACT The scarcity and high cost of conventional ingredients are major factors limiting the growth of the poultry industry globally. This has driven research into alternative ingredients for poultry feeding. *Senna obtusifolia* or cassia, a widely distributed shrub, is invasive in many regions of the world. The seeds and leaves of the plant are moderate protein sources with the protein having an acceptable amino acid profile, especially essential amino acids. This nutritional profile of *Senna obtusifolia* products (seeds and leaves), coupled with their availability make them potential protein supplements for poultry feeding; however, the presence of several antinutritional factors (**ANFs**) (Oxalate, phytate, saponins, tannins and haemagglutinins) hinders their fullest use in the diet. In recent years, there has been increasing research interest into processing techniques to reduce the ANFs content and make these products safe for poultry feeding. Depending on birds age, fermented *Senna* seed meal may be included in the diet of broilers and cockerels up to 200 g/kg without compromising birds' performance but raw meal as low as 50 g/kg exerts antinutritional effects. More research is needed into maximum utilization of *Senna* products to reduce cost of production on smallholder to medium scale poultry farms. Newer processing methods will need to be developed in response to the increasing market price of conventional protein sources.

Key words: antinutritional factors, nutritional composition, processing, underutilized crops

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INTRODUCTION

Senna obtusifolia also known as cassia, Sicklepod, Chinese *Senna*, coffee weed, Arsenic weed or java bean is an annual or perennial shrub, which may grow as high as 2 meters (ILDIS, 2005). *Senna obtusifolia* is an environmental weed seed native to tropical South America, now invasive in many parts of Africa, America, Asia, Australia, Europe, and Oceania (ILDIS, 2005; Witt et al., 2018). The weed, mainly spread through excreta of domestic livestock (Neldner et al., 1997), infests a wide range of crops including pastures (Webster and MacDonald, 2001) causing significant yield reduction (Buchanan et al., 1980).

Although invasive, *S. obtusifolia* has received attention as an important agroforestry plant in many countries and regions of the world. The leaves, seeds and stems have several foods, feed, and pharmaceutical uses. Kawal, from fermented green leaf of *S. obtusifolia*, is a high protein product eaten as substitute to meat in Sudan and the juice from this fermentation is a good ingredient in making a stew with okra (Dirar, 1984). The leaves are important food sources for rural populations during the lean period when grain reserves from the previous harvest have been exhausted (Pasternak et al., 2007). Because of these attributes, the International Crops Research Institute for the Semi-Arid Tropics (**ICRISAT**) conducted trials in 2006 to evaluate the potential of *S. obtusifolia* as a new rain-fed crop for the Sahel region of Africa (Pasternak et al., 2007). In Asia, the leaves, seeds and root are used for several therapeutic purposes including the treatment of diarrhea, stomachache, conjunctivitis, and also as anthelmintic (ILDIS, 2005). The gum from *Senna* seeds is a popular food thickener or roasted and boiled in water as a tea (ILDIS, 2005). Macerated cassia leaves and roots are used the production of dyes and the stems for making mats and fences (Lazarides et al., 1997).

Senna obtusifolia products (leaves and seeds) are moderate sources of protein (Ingweye et al., 2010; Ayssiwede et al., 2012; Augustine et al., 2017c, 2018a) with acceptable amino acid composition (Ingweye et al., 2010; Augustine et al., 2017c). These products have received some research interest for livestock and poultry

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[1]Corresponding author: diarra_s@usp.ac.fj

Table 1. Proximate composition and amino acid profile of *S. obtusifolia* seed, leaf, and soybean meal.

Constituents	*Senna* seed meal			*Senna* leaf meal		Soybean meal	
Proximate principles (% DM)							
Crude protein	29.5	19.6	23.4	22.4	19.5	45.1	46.3
Ether extract	2.3	4.0	8.7	4.7	3.2	6.6	1.55
Crude fiber	10.2	13.8	14.5	15.8	14.8	3.3	4.95
Ash	3.7	5.7	7.7	13.9	8.2	6.2	7.71
Amino acid (% protein)							
Lysine	4.02	4.2	3.9	n a	4.1	2.79[b]	6.17
Methionine	1.02	1.35	1.3	n a	1.9	0.60[b]	1.35
Threonine	2.2	n a	2.6	n a	3.5	1.73[b]	3.85
Arginine	4.7	2.3	4.5	n a	3.0	3.02[b]	7.29
Valine	4.4	2.1	4.4	n a	3.9	2.01[b]	4.78
Histidine	2.1	4.0	2.3	n a	2.5	1.14[b]	2.74
Phenylalanine	4.5	3.6	4.6	n a	4.9	2.15[b]	5.1
Isoleucine	3.0	2.8	3.4	n a	3.5	1.90[b]	4.56
Leucine	7.6	n a	8.1	n a	6.4	3.21[b]	7.63
Sources	Ingweye et al. (2010)	Augustine et al. (2016)	Augustine et al. (2017c)	Umar et al. (2017)	Augustine et al. (2018a)	NRC (NRC, 2012)	Ibáñez* et al. (2020)

Abbreviation: n a, not analyzed.
*Values are means for soybean from 4 different origins.
[b]Amino acids (% DM).

feeding in recent years, but the presence of several antinutritional factors limit their efficient utilization as feed ingredients, especially in monogastric diets. This paper reviews the composition, feeding experiments and feed technologies for optimum utilization of cassia products as alternative ingredients in poultry diets and makes recommendations for future research.

COMPOSITION OF *SENNA OBTUSIFOLIA* SEEDS AND LEAVES

Nutrient Composition

Results of proximate composition suggest that *S. obtusifolia* leaves and seeds are moderate protein sources (Ingweye et al., 2010; Ayssiwede et al., 2012; Augustine et al., 2016, 2017c, 2018b; Umar et al., 2017). The essential amino acid composition of *S. obtusifolia* seed (Ingweye et al., 2010) and leaf (Augustine et al., 2016) is comparable to most alternative plant protein sources for poultry (Table 2). The soluble carbohydrate content of *S. obtusifolia* products ranges from 410 to 500 g/kg in the seed (Ingweye et al., 2010; Augustine et al., 2018b) and 410 g/kg in the leaf (Bake et al., 2016; Augustine et al., 2017c, 2018a; Tarimbuka et al., 2017; Umar et al., 2017). *Senna* seeds and leaves are high in fiber (Ingweye et al., 2010; Augustine et al., 2017c, 2018a; Tarimbuka et al., 2017) and low in fat (Ingweye et al., 2010; Umar et al., 2017; Augustine et al., 2018a). Tarimbuka et al. (2017) reported an ME value of 12.8 MJ/kg in *S. obtusifolia* seed. Compositional differences in *Senna* products may be due to several factors including the growing conditions, age of plant and analytical procedures. Tables 1 summarizes the proximate composition and amino acid profile of *S. obtusifolia* seed and leaf.

Selected Antinutritional Factors in Senna obtusifolia *Seeds and Leaves*

Despite its acceptable nutritional profile, several antinutritional factors (**ANFs**) identified in *S. obtusifolia* products limit their full utilization as feed ingredients in monogastric diets. The major ANFs reported in the seeds and leaves include oxalic acid, phytic acid, tannin, saponins, and phytohemagglutinins (Ingweye et al., 2010; Sudi et al., 2011; Bake et al., 2016; Augustine et al., 2018b). Ingweye et al. (2010) and Bake et al. (2016) also reported traces (6.98–9.5 mg/kg DM) of hydrocyanic acid (**HCN**) in the *S. obtusifolia* seeds. These values are below the threshold of 25 mg HCN/kg DM for poultry (Diarra, 2014) suggesting that HCN should not be a major problem in *Senna*-based diets for poultry. The concentration of *S. obtusifolia* seeds and leaves in ANFs (Table 2) shows wide variations. Several factors including plant age, growing

Table 2. Concentration of major antinutritional factors in *S. obtusifolia* products.

Factors	Seed meal				Leaf meal	
Phytate (mg/100 g)	241	260	247.2	240	649	3700
Saponins (mg/100 g)	185	176	190	185	n a	3400
Oxalate (mg/100 g)	83	76	102	83	n a	1380
Tannin (mg/100 g)	389	359	378,5	191	2390	1850
Hemagglutinins (Hu/g)	1026	1241	n a	n a	n a	n a
Sources	Ingweye et al. (2010)	Bake et al. (2016)	Augustine et al. (2017c)	Tarimbuka et al. (2017)	Algadi and Yousif (2015)	Augustine et al. (2018a)

Abbreviation: n a, not analyzed.

conditions and analytical procedures may all be possible reasons for the variation.

Role of Oxalate and Phytate as Antinutritional Factors Oxalate exerts adverse effects on animal performance (Rahman et al., 2013; Diarra et al., 2019) mainly by binding calcium, phosphorus, magnesium and many trace minerals including iron making these unavailable for assimilation (Rahman et al., 2013; Diarra et al., 2019). Several factors including the species of animal (McKenzie et al., 1988) and age (Diarra et al., 2019; Diarra, 2020) affect the threshold of calcium oxalate in the diet. Dietary oxalate concentrations of 20 g/kg and 5 g/kg diet caused toxicity in ruminant and monogastric animals, respectively (McKenzie et al., 1988). Phytic acid forms insoluble complexes with cations at neutral pH in the small intestine, reduces mineral absorption and increases excretion in poultry (Prattley et al., 1982; Ravindran et al., 2000; Diarra et al., 2010; Woyengo and Nyachoti, 2011). Woyengo and Nyachoti (2013) observed a 28 to 44% body weight losses in broilers and egg-type chickens fed diets containing 16.5 and 20 g phytate/kg, respectively compared to the control without phytate.

Role of Tannins as Antinutritional Factors. The harmful effects of tannins are through protein precipitation, inhibition of digestive enzyme and reduced starch, energy, mineral, and vitamin utilization (Tapiwa, 2019). Diets containing 5 g tannin/kg reduced feed intake in chickens (Vohra et al., 1966), reduced nitrogen retention and increased mortality in rats (Glick and Joslyn, 1970). Jansman et al. (1989) recommended a maximum of 3 g tannin/kg diet for young chicks. Diarra et al. (2011) also observed that young chicks are more sensitive to dietary total tannin than adult birds. However, the use of tannins as additives in poultry diets is increasing due to several beneficial effects on birds' performance, including antimicrobial properties. Recently, Perin et al. (2019) observed enhanced body weight gain in broiler chickens supplemented with dietary total tannin at 5 g/kg from 1 to 10-d and 10 g/kg from 11 to 42-day-old further supporting the observation of Diarra et al. (2011). In addition, tannins exist in 2 main forms: condensed and hydrolysable tannins with the former exerting more antinutritional effects than the latter (Bhat et al., 2013). This suggests that when considering tannin-containing ingredients for poultry feeding, emphasis should be on the form of the tannin.

Role of Saponins as Antinutritional Factors Saponins affect animal performance by encouraging lipid peroxidation and inhibiting the activities of trypsin and chymotrypsin (Savage, 2003). Species differences in saponin sensitivity have been reported with poultry being more sensitive (Savage, 2003). This author observed growth depression in chicks fed 3 g saponins/kg diet. Recently however, there has been increasing research interest in saponins as feed additive in poultry diets due to several benefits. Park et al. (2015) recommended 0.4% saponins from *Ginseng* leaves and stem for broiler growth. Dietary concentration of 0.1% saponins from *Quillaja sarponaria* maintained body weight gain in Eimeria challenged broilers (Scheurer et al., 2013). Therefore, the source of saponins and dietary concentration, performance criteria and age of poultry may all need consideration when including saponins containing ingredients in poultry diets.

Role of Hemagglutinins as Antinutritional Factors. Hemagglutinins cause toxicity in monogastric animals through reduction of cell membrane permeability to proteins and agglutination of red blood cells (Thompson et al., 1983). However, like tannins and saponins, there is growing research interest in hemagglutinins as feed additives in poultry diets (Gonmei et al., 2019).

EFFECT OF SELECTED PROCESSING METHODS ON ANTINUTRITIONAL FACTOR CONTENT IN *SENNA* PRODUCTS

Several physical and chemical processing methods may reduce the antinutritional factors (ANFs) content and explore the usefulness of *S. obtusifolia* products as feed ingredients for livestock and poultry. Toasting the seed at 80°C for one hour (Bake et al., 2016) or 30 min (Tarimbuka et al., 2017) significantly reduced hemagglutinins, phytate, oxalate, saponins, and tannin contents. Yusuf et al. (2016) also reported significant reduction of phytate, oxalate, saponins and tannin in *S. obtusifolia* seed boiled at 100°C for 40 min. Augustine et al. (2017d) soaked the seed for 6, 12 and 24 h and found a 52% reduction in tannin content after 6 h. Increasing the duration of soaking above 6 h did not further reduce tannin content but phytate, oxalate and saponins reduced with increasing soaking duration up to 24 h. This suggests the presence of both condensed and hydrolysable tannins in *S. obtusifolia* seed. These authors however, observed significant reduction in the crude protein above 6 h and most essential amino acids above 12 h soaking, probably due to leaching.

Natural fermentation of *S. occidentalis* seeds in earthenware buried to the neck for 3 d also reduced all ANFs (phytate, oxalate, saponins and tannin) and increasing the duration of fermenting to 5 d increased crude protein and amino acid and reduced crude fiber contents (Augustine et al., 2016). The increase protein content may not be an absolute but a relative change due to loss of dry matter and the utilization of carbohydrates and fats by microorganisms as source of energy. Possible increased hydrolysis of complex protein to amino acids by bacterial cells during fermentation and subsequent release of peptides and amino acids (Pranoto et al., 2013; Igbabul et al., 2014) may explain the higher amino acid profile of the fermented seed. The reduced fiber content may be due to breakdown of complex structures by acidity during fermentation. Algadi and Yusuf (2015) also reported significant reduction of tannin, phytic acid and total polyphenols in kawal, a fermented and dried *S. obtusifolia* leaf product, compared to the raw leaf. Augustine et al. (2018b) found that boiling for 30 min followed by fermentation for 7 d most efficiently reduced ANFs and increased amino acid profile of *S. obtusifolia* leaves. These authors also found that ensiling can reduce

Table 3. Effects of selected processing methods on the antinutritional factors of *S. obtusifolia* products.

Processing methods	Percentage reduction of antinutritional factors Oxalate	Phytate	Saponins	Tannin	Haemagglutinins	Sources
Boiled seeds (100°C for 40 min)	90.2	77	54.2	92	n a	Yusuf et al. (2016)
Boiled seeds (100°C for 1 h)	84.9	n a	54.3	57	58.9	Bake et al. (2016)
Toasted seeds for 30 min	74	89	54.3	7.3	n a	Tarimbuka et al. (2017)
Soaked seeds (6−24 h)	91	41	59	52	n a	Augustine et al. (2020)
Air-dried and ensiled leaves	80	74	75	85	n a	Augustine et al. (2018a)
Boiled leaves (30 min) + fermentation (7 d)	85	83	78	85	n a	Augustine et al. (2018b)

Abbreviation: n a, not analyzed.

the ANF content of the leaves below toxic levels and increased amino acid content. The mode of action of boiling on amino acids is not clear but probably due to a relative increase through reduction of ANFs and subsequent release of bound nutrients.

From the forgoing discussion, several processing methods will reduce the ANFs content of *Senna* products and improve their utilization as animal feed. Factors including, cost and ease of application will guide the choice of particular a processing method. Table 3 summarizes the effect of processing on the ANFs content of *Senna* products.

EFFECTS OF *SENNA* SEED MEAL ON POULTRY PERFORMANCE

Although a number of studies have evaluated the nutritional composition of *S. obtusifolia* products, its use in practical poultry diets is still limited. Few available studies suggest that with adequate processing, *Senna* seeds could be included in poultry diets without adverse effects on performance. Kwari et al. (2019) included 200 g/kg of differently processed seeds (boiled, toasted, soaked, sprouted and fermented) in diets of broiler chickens and observed that with the exception of the fermented seed fed group, feed intake, weight gain, dressing percentage and hematological indices were reduced on the *Senna* seed-based diets, probably due to maximum reduction in ANFs and improvement in nutrient utilization. Earlier, Augustine et al. (2016) found that fermentation was most efficient in reducing the ANFs content and improving the protein content and quality of the seed. Feeding the raw seed meal up to 250 g/kg did not affect hematological parameters in broilers but even as low as 50 g/kg increased serum aspartate amino transferase (**AST**), alanine transferase (**ALT**), alkaline phosphatase (**ALP**) compared to the control group (Augustine et al., 2017b). An important function of the liver is the conversion of toxic substances into forms readily excreted. The increased ALT, AST and ALP may suggest a liver dysfunction probably due to toxicity of the raw seed. Augustine et al (2018c) reported depressed weight gain, feed conversion ratio (**FCR**), and nutrient digestibility in broiler chickens fed 50 g raw *S. obtusifolia* seed meal/kg diet. The adverse effects of residual ANFs in the seed as earlier reported (Savage, 2003; Amarowicz, 2007; Tapiwa, 2019) could be possible reasons for elevation of the serum indices. Augustine et al. (2017a) found that feeding 200 g/kg processed seed (roasting, boiling, soaking, sprouting and fermentation) significantly reduced growth and dressing percentage of growing cockerels compared to the control group without *Senna* seed meal. As earlier discussed, the ANFs in *Senna* affect poultry performance by different mechanisms including nutrient binding, digestive enzyme inhibition, lipid peroxidation and agglutination of red blood cells.

However, Augustine et al. (2017c) found that inclusion of 200 g/kg fermented *Senna* seed maintained broiler growth. Differences in the concentration of ANFs and processing methods could be possible reasons for inconsistencies in performance among studies. Table 4 summarizes the recommendations of *Senna* seed meal in poultry diets by different authors.

FUTURE RESEARCH FOCUS

Senna seeds and leaves have acceptable nutrient contents but the presence of several ANFs (oxalate, phytate, saponins, tannins and hemagglutinins) may limit

Table 4. Summary of main findings of *Senna obtusifolia* seed meal in poultry diets.

Processing methods	Dietary inclusion	Remarks	Sources
Raw seed meal	50 g/kg − broilers	Maintained weight gain and improved feed: gain.	Assam et al. (2017)
	50 g/kg − broilers	Depressed growth, feed: gain and nutrient digestibility.	Augustine et al. (2017b)
	75 g/kg	Depressed weight gain, feed intake and feed: gain.	Assam et al. (2017)
	250 g/kg	No effect on hematology but increased serum AST and ALT.	Augustine et al. (2017c)
Fermented seed meal	200 g/kg diet - broilers	Maximum reduction of ANFs, Broiler performance (weight gain, FCR and dressing percentage) maintained	Kwari et al. (2019)
Roasting, boiling, soaking, sprouting + fermentation	200 g/kg − cockerels	Reduced body weight gains in cockerels	Augustine et al. (2017c)
Soaking + drying + toasting	75 g/kg − broilers	Maintained growth performance and reduced cost	Augustine et al. (2010)

their use as ingredients in poultry diets. Beside their antinutritional properties however, moderate concentrations of saponins, tannins, and hemagglutinins may also improve animal performance (Scheurer et al., 2013; Park et al., 2015; Perin et al., 2019). Research efforts in processing *Senna* products for poultry feeding should therefore aim at reducing the ANFs content below toxic levels without adverse effects on its nutrients. Common processing methods of *Senna* products including thermal treatment and soaking are more adapted to small and medium scale conditions but these may result in loss of heat labile and water-soluble nutrients. Supplementation of diets with the correct nutrients and several commercial additives has shown to reduce the adverse effects of many ANFs and improve animal performance. Supplementation of diets with phytase (Rutherfurd et al., 2012; Amerah et al., 2014) and additional inorganic calcium (Ravindran et al., 1996; Diarra et al., 2019) improved the ability of poultry to utilize diets containing phytate and oxalate, respectively. DL-methionine supplementation has been found to hydrolyze tannins into gallic acid, which is excreted via urine as 4-O- methyl gallic acid (Elkin et al. 1978 cited by Diarra, 2014). Treatment with acids and alkali has also been found effective in reducing ANFs content in feeds. Breeding for lower ANFs content would also be an alternative measure to increase the inclusion level of plant products in diets. Currently however, reports on the use of these processing technologies or breeding *Senna* are still limited probably due to its underutilization and low value. There is need for more research into these and more processing methods to make the fullest use of products from this underutilized plant as feed ingredient and reduce poultry production cost.

Based on availability and nutritional composition, *S. obtusifolia* products (seeds and leaves) have potential as protein supplements in poultry diets but antinutritional factors (oxalate, phytate, saponins, tannins and hemagglutinins) hinder its fullest use in the diet. Several processing techniques, which can reduce the ANFs content and improve the utilization of these products by poultry, are available. Depending on the class of birds, adequately processed *Senna* seeds can be included in the diet up to 200 g/kg but raw seeds are not recommended even as low as 50 g/kg feed. Newer processing methods will likely developed in response to the increasing market price of conventional protein sources. Although the use of *Senna* products for large scale feed production may not be warranted, it could be used to reduce cost on small to medium scale farms. There is need for more research into processing methods for maximum utilization of *Senna* products by poultry.

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