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UTILIZATION OF CROTON SEED AS A POSSIBLE ANIMAL FEED: A REVIEW

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ABSTRACT: Croton is one of the largest genera in the Family Euphorbiaceae. Its species are distributed in a wide range of environmental and climatic conditions. The plants have for a long time been exploited for medicinal purposes but still hold the potential for nutritional purposes. The seeds of the plant have been exploited in oil extraction to produce biofuel but the residual seedcake has been less utilized. The use of croton seed and seedcake as feed has been in practice in Kenya and other countries but questions on its safety have been raised. Croton seeds are known to contain various phytochemicals and toxins such as crotin I, crotonic acid and tiglic acid that have deleterious health effects on animals. Notwithstanding the rich nutritional composition of the croton seeds, its safety concerns have limited their utilization as feeds. The croton seeds are rich in both essential fatty acids and protein whereas the residual seedcake is only rich in protein. However, the seedcake has toxic phytochemicals that include cardiac glycocides, alkaloids, phorbal esters and many others which are injurious to the animals and could result in death. Detoxification of the seedcakes poses a breakthrough for their use in poultry feeding. However, such techniques should not reduce the rich nutritional property of these seeds. This review focuses on the utilization of croton seedcake as a possible animal feed, documenting breakthroughs and limitations of the practice.

Keywords: Croton, Seed, Seedcake, Nutrient composition, Safety, Detoxification

INTRODUCTION

The Genus Croton is the second largest under the *Euphorbiaceae* Family and has approximately 1300 species which are largely trees, herbs and shrubs (Torres et al., 2008). The tree grows in the tropical and sub-tropical regions under varied environmental conditions. The stem, roots, leaves, seeds and the juice from the bark have been used for medicinal and nutritional purposes with varied utilization among different communities globally. Its traditional use as a medicinal plant has principally been exploited in Africa, Asia and Latin America (Sai Prassana and Karpaga, 2015). Croton *spp* have been utilized to treat gastrointestinal problems especially among the Asian communities (Ojo et al., 2017). In East Africa, Croton trees are mainly found in the mountainous regions (Aliyu et al., 2010). The species under this genus have heavily been exploited for their medicinal and nutritional property in Tanzania, Kenya and Uganda (Filho et al., 2017). Some of the species that have been used for either nutritional or medicinal purposes include *Croton heliotropiifolius* (Silva et al., 2017), *Croton tiglium* L (Ahmed et al., 2007), *Croton megalocarpus* (Wu et al., 2013), *Croton megalobotrys* (Maroyi, 2017b), *Croton bonplandianus* (Dutta et al., 2014) and *Croton macrostachyus* (Abebayehu et al., 2016) among others. *Croton megalocarpus* is the widely distributed species of the genera across African continent (Kivevele and Mbarawa, 2010).

Some species of croton has been utilized mainly for its oil and as animal feed in Kenya (Leakey et al., 1996). The Croton megalocarpus plant is locally known as *Mukinduri* (Kikuyu) or *Msuduzi* (Swahili) (Maroyi, 2017a). *C. megarlocapus is* the most widely distributed croton species in Kenya (Jacobson et al., 2018). Croton mainly grows in the areas with bimodal rainfall pattern including Central and Western regions in the country. In the Mount Kenya region, approximately 40% of the farms have croton though it is largely undomesticated (Jacobson et al., 2018). The plant is not a preferred browse by most of the animals for its seeds, bark and leaves have skin and mucosa irritating property that keeps most of the animals away (Diaz, 2011). The seeds of croton *spp.* have been exploited in oil extraction and the residual seedcake is exploited as feeds (Jacobson et al., 2018). However, toxicity concerns have been raised over the use of the seedcake as feed. This review focuses on the utilization of croton seedcake as animal feed and possible ways of reducing its toxic components while improving its nutritional benefits.

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METHODOLOGY OF REVIEW

A literature search for the keyword croton and its various species was conducted in major literature databases that included Google scholar, Springerlink, PubMed, Science Direct, BioMed Central, Elsevier, Hindawi publishers, Academic journal, Europe PMC and John Wiley and Sons that documented the historical uses, medicinal uses, nutritional composition, safety and toxins, oil extraction and uses of the seedcake. Additional literature was obtained from documented reports by government agencies in Kenya and other international bodies like FAO and EFSA and thesis that had been submitted to the University of Nairobi. Mendeley referencing software was used to collate relevant literature that had been selected and used in the review.

Varieties of croton

There is a diversity of species of croton distributed in different environmental and climatic conditions globally. Since the inception of the name of the genus Croton by Linnaues in 1753, 1250 species have been classified under it (Van Ee and Berry, 2010). Some of the species of croton that have been identified include *C. cajucara*, *C. celtidifolius* Baill., *C. eluteria* Bennett., *C. palanostigma*, *C. lechleri*, *C. urucurana*, *C. draconoides*, *C. malambo, C. nepetaefolius* Baill., *C. palanostigma* Klotzsch, *C. schiedeanus* Schlecht. and *C. zehntneri* Pax. majorly in South America; *C. arboreous* Millsp., *C. californicus* Mull. and *C. draco* Cham. & Schltdl. in the North and Central America; *C. macrostachys* Hochst., *C. megalocarpus* and *C. zambesicus* Mull. in Africa; *C. kongensis* Gagnep., *C. oblongifolius* Roxb., *C. sublyratus* Kurz, *C. tiglium* L. and *C. tonkinensis* Gagnep. in Asia (Salatino et al., 2007). All these species are known for their medicinal values to various communities. *C. megalocarpus* is the most common indeginous species to East Africa and can produce seeds up to 50kg per tree (Atabani et al., 2013).

Cultivation of croton *spp.*

Croton *spp.* often grows in areas with volcanic soils at an altitude of 200-1500m above sea level and mean annual rainfall of 150-1200mm (Maroyi, 2017a). The plant majorly grows as secondary forests along the edges of forests, rivers and lakes. They grow optimally under rainfall of 800-1900mm, temperature of 11-38°C, elevation of 1200-2450m and light deep well drained soil (Tenaw et al., 2017). The tree grows to a height of 35m with great variation among different species (Gichui, 2016). Dey et al. (2015) reported a height of 4-6m for *C. tiglium* whereas Nagireddy et al. (2017), Berry and Galdames (2013) and dosSantos et al. (2016) reported that *C. scabiosus* species had a height of 3-5m, *C. cerroazulensis* had a height of 7-7.5m and *C. sapiifolius* had a height of 14m respectively. Flowering on the tree starts after 3-4years of their growth with the fruits ripening at around 5 months after flowering (Jacobson et al., 2018). The plant can be propagated using seeds, cuttings, grafting or air layering. In East Africa, the trees are known to fruit twice a year; about five months after the rainy season. The seed yields of the tree average 25-40kg annually with a great variance on the weight of seeds from tree to tree (Aliyu et al., 2010), thus proper selection when breeding is needed. The plant largely grows in the mountainous regions as shrubs in East and South Africa (Sarin, 2012). In Tanzania, there are large scale plantations of *Croton spp.* that are utilized in biofuel production by a privately-owned company; whereas in Kenya, monoculture of croton trees is very minimal and just in small farms (Endelevu Energy, 2009).

Utilization of croton seeds

Croton has been exploited for various uses especially its nuts, much of which are non-nutritional as the seeds are inedible (Sharma et al., 2016). Croton seeds have been exploited for oil extraction which has multiple uses. Kim et al. (2014) in their study on croton oil, observed that it possesses a possible lipolytic property. In China, the oil has over time been exploited for its medicinal properties which include antimicrobial, insecticidal, purgative and analgesic (Dey et al., 2014).

The residual seedcake after oil extraction from croton seeds has been sold locally in Kenya as a poultry feed (Jacobson et al., 2018). Currently in Kenya, the croton seedcake are sold as ingredient of poultry feed in a process aimed at extending the value chain and importance of *C. megalocarpus* (Sharma et al. 2016). Croton seeds have also been exploited for their medicinal property just like the bark, leaves and its roots. Traditional health practioners from the Lower Eastern Region of Kenya reported the use of croton in the management of diabetes mellitus (Keter and Mutiso, 2012). Obey et al. (2018) reported an antimicrobial activity of up to 100% suppressive effect on plasmodium parasites by extracts of the bark of *C. macrostachycus.* There is evidence of use *C. tiglium* seeds for medicinal purposes as early as 450 BC in India (Dey et al., 2014). The seeds have been used as purgative and in wound healing, constipation and traditional dysentery and dyspepsia (Oyesola et al., 2009; Dey et al., 2014).

Croton has also been used in the production of biofuel with its commercial production currently being done in Kenya and Tanzania (Endelevu Energy, 2009; Jacobson et al., 2018). Seeds of croton *spp.* including *C. tiglium* have been recommended as possible sources of alternative fuel (Ariharan et al., 2015). Croton has been touted as an alternative fuel that is environmental friendly. In a study that evaluated a composite biofuel incorporating *C. megalocarpus* as a substitute to fossil fuel, Ruhul et al. (2016) reported a reduction of 5.21%, 8.38% and 20.71% in the carbon monoxide, hydrocarbon and smoke emission, respectively.

Extraction of croton oil from croton seeds

Croton is renowned for the oil extracted from its seeds for use as biodiesel. The oil in croton seed can either be extracted mechanically (pressing) or solvent (chemical) methods (Jiyane, Tumba and Musonge, 2018). The chemical extraction mainly explores the use of solvent, thus is also known as solvent extraction (Bhargavi et al., 2018). The solvent *n*-hexane has been proven to be effective in the soxhlet extraction of croton seed oils (Ojo et al., 2017). Saputera and Atikah (2014) recommended a raw material/solvent ratio of 1:5.18g ml^{-1} with an optimal maceration time 6.22 days for optimal extraction of croton oil. The mechanical extraction is often viewed as a cheaper technique and more convenient where mechanical pressers are often used. Osawa et al. (2014) obtained a yield of 38.42% (v/w) of croton oil using mechanical pressers. However, the solvent extraction has higher yields of up to 41% and consistent performance as noted in the extraction of oil from jatropha seeds (Atabani et al., 2013; Gonfa Keneni and Mario Marchetti, 2017). Solvent extraction has a reported higher efficiency of only 1% (w/w) residual fat in the cake (Kibazohi and Damson, 2013). Processing of the seeds has an impact on the nutritional composition of the croton oil. Ojo et al. (2017) reported a higher saturated to unsaturated fatty acid ratio in the dehulled seed oils as compared to the whole seed oils.

Nutritional Composition of Croton *spp* seeds

The proximate composition of seeds of various croton *spp.* are as shown in Table 1. The seeds of *Croton megalocarpus* have protein and oils contents of up to 50% and 30-32% respectively (Wu et al., 2013). However, some varieties of croton *spp.* seeds have lower oil and protein contents. A study by Bello et al. (2014) on *C. zambesicus* seeds found a lower crude protein and fat of 9.64% and 4.15% respectively as compared to other species. Variation in terms of nutritional composition of the seeds based on species calls for careful selection of species cultivated for a given purpose. The oil from croton seeds is largely inedible. A study by Adeyinka et al. (2013) reported high values of 4.10mg and 2.42 mg KOH/g for saponification values of *C. penduliflorus* seeds and seeds without seed coat respectively. The values are higher than those of known edible oils such as coconut oil (0.6 mg KOH/g) and cotton seed oil (0.6 mg KOH/g); proving they are inedible.

The croton seed oil is rich in saturated, monounsaturated and polyunsaturated fatty acids (Maroyi, 2017a). In his study, Bello et al. (2014) on *C. zambesicus* concluded that the seeds of this plant are a rich source of essential fatty acids beneficial to both animals and humans. Croton seed has a richer fatty acid profile as compared to other greatly utilized oilseed crops (Table 2), however concerns of its toxicity has limited its utilization for nutritional purposes. Ahmadi et al. (2017) reported linoleic and oleic acids as the major fatty acids in *C. tiglium* oil.

Table 1 - Proximate Composition of *Croton spp.* seeds

Proximate composition (% fresh weight)	*C. zambesicus*[a]	*C. penduliflorus*[b]	*C. tiglium*[c]
Moisture	7.94±0.02	6.12±0.44	6.2
Protein	4.15±0.01	0.06±0.01	26.69
Fat	9.64±0.14	34.01±0.14	40.01
Ash	15.45±0.21	3.26±0.43	3.14
Fibre	26.73±0.32	38.50±1.27	8.45
Carbohydrate	67.09±2.28	18.03±0.54	15.51

Adapted from [a]-Bello et al. (2014a), [b]-Adeyinka et al. (2013) and [c]-Saputera et al. (2006)

Table 2 - Fatty Acid composition of croton oil in comparison with other vegetable oils (wt %)

Fatty acid	Croton	Sunflower	Rapeseed
Lauric acid	0.11	0.11	0.04
Myristic acid	0.04	0.16	0.04
Palmitic acid	6.23	6.47	4.96
Palmitoleic acid	0.11	0.10	0.32
Stearic acid	4.37	4.34	1.73
Oleic acid	9.95	24.59	62.07
Linoleic acid	74.31	62.68	19.16
Linolenic acid	3.62	0.44	9.63
Arachidic acid	0.92	0.40	1.49
Erucic acid	0.33	0.71	0.53

Adopted from Wu et al. (2013)

The seeds of croton species are not only rich in macronutrients but also the micronutrients. Bello et al. (2014a) reported that the seed of *C. zambesicus* are richer in strontium (869.27 mg/100g), potassium (2.2 g/100g) and iron (467.53 mg/100g) than its leaves. Another study by Adeyinka et al. (2013) on seeds of *C. penduliflorus* found that they are rich in magnesium and calcium which are important micronutrients. Removal of the seed coats significantly reduces the mineral content by 8.1% while increasing the fat content by 16.02% (Adeyinka et al., 2013).

Extraction of oil from the seeds leaves a protein rich seedcake, whose utilization in animal feeding is highly recommended. A study on *Jatropha curcus* seedcake, a tree from the same sub-family with croton with similar toxicity concerns, reported a protein content of 43.48% (Sánchez-Arreola et al., 2015). Oil extraction bears the benefit of reducing the phorbol esters, but concerns of toxicity still remain with the presence of toxic proteins (Rajput and Gaur, 2015). Evaluation of amino acid profile of croton seedcakes in comparison with common animal feed seedcakes by Peoples et al. (1994), showed that seedcakes of *C. capitatus* are richer in essential amino acids as compared to the others (Table 3).

Table 3-Essential amino acid profile of *Croton capitatus* seedcakes in comparison with other common animal feed seeds (% DM)

Essential amino acid	Sunflower	Croton (*C. capitatus*)	Redwood amaranth
Arginine	0.61	1.29	0.53
Glycine (plus Serine)	0.96	1.01	0.73
Histidine	0.11	0.24	0.12
Isoleucine	0.31	0.42	0.23
Leucine	0.51	0.63	0.38
Lysine	0.47	0.61	0.41
Methionine (plus cysteine)	0.11	0.16	0.08
Phenylalanine	0.36	0.50	0.25
Phenylalanine (plus tyrosine)	0.55	0.80	0.45
Threonine	0.31	0.40	0.22
Valine	0.36	0.57	0.29

Adapted from Peoples et al. (1994).

Phyto-chemicals and antinutrients in Croton *spp.* seeds

Phytochemicals in croton seeds range from health promoting to compounds with deleterious effects to health. The phytochemicals that have been found in the seeds of different croton *spp.* include diterpines, phorbol ester, alkaloids, terpenoid, flavonoids, tannins, cardenolides and many others as shown in Table 4 (Parameswararao et al., 2016). The major phytochemical of concern in croton *spp.* seeds are the phorbol esters. This is majorly in the seed oil, with the most active phorbol ester being 12-O-tetradecanoylphorbol-13-acetate (TPA) (Nath et al., 2013). These compounds have tumour promoting properties. Seeds of similar species of croton from different regions also differ in their phyto-chemical composition. The proanthocyanodin and alkaloid property of croton induces a red sap property in croton seeds (Prassana and Karpaga, 2015).

Table 4 - Phyto-chemicals in different species of croton seeds

Croton *Spp*	Country of origin	Phyto-chemicals	Reference
C. tiglium	Far East	Alkaloids, flavonoids, terpenoids and phorbol esters	(Dey et al., 2014)
Croton bonplandianum Baill	India	Squalene, (9Z, 12Z)-octadeca-9, 12-dienoic acid, methyl 12-oxo-octadec-9-enoate, alkaloids, terpenoid, flavonoids, tannins, cardenolides and phytol.	(Parameswararao et al., 2016)
C. tiglium Linn.	India	Resin, resin, steroids, sugars, saponin	(Kishore et al., 2013)
C. tiglium	Pakistan	Alkaloids, steroids, terpenoids, glycosides and saponins.	(Abbas et al., 2011)
C. bonplandianum	India	Resins, alkaloids, saponins , phenols, flavonoids and steroids.	(Jeeshna et al., 2011)
C. megalocarpus	Kenya	Saponins, flavones, alkaloids, glycosides, terpenoids, steroids and flavonoids	(Waiganjo et al., 2013)

Safety of croton oil and seedcake

The croton oil is toxic to all living organisms, ranging from simple single cell organisms like bacteria to complex organisms such as the vertebrates (Pagani et al., 2017). The compounds that are known to be responsible for this toxic property include cardiac and cyanogenic glycosides, lectin, phorbol esters and alkaloids (Yumnamcha et al., 2014). Yumnamcha et al. (2014) in their study on *C. tiglium* found saponins and alkaloids in croton oils, which are known to possess DNA damaging property thus are genotoxic. Similar findings were reported by Aylate et al. (2017) in their study on the extracts from *C. macrostachycus*. Phorbol esters in the croton oil and seedcake has been associated with tumour-enhancing property (Dey et al., 2014). Phorbol esters occur to the tune of 3-5% in the fatty acids in croton seeds (Jain, Mangal and Kushwaha, 2015). Sharma et al. (2016) reported a skin-cancer inducing property in the croton seed oil. The most studied mechanism by which phobol esters causes cancer is its role in binding and activating protein kinase C (PKC) that plays a role in signal transduction (Goel et al., 2007). They hyperactivate the PKC thus causes a proliferation of cells thereby amplifying the efficacy of carcinogens in the body of an animal. These phobol-12,13-diesters are also responsible for the purgative and irritant property of ingested seeds. As it had been indicated earlier TPA is the most renowned toxic phobol-ester in croton seeds is the (EFSA CONTAM Panel, 2015).

Concerns have been raised with regard to the safety of the croton oil and seedcake as animal feed. Apart from croton oil inducing gastrointentinal discomfort, the proteins in the seedcake have been shown to possess proinflammatory effects on the gastrointestinal system in clinical trials (Liu et al., 2017). EFSA has raised concerns on the safety of *C. tiglium* or its seed cake as an animal feed as it contains crotin I which is a ribosome inactivating protein (RIP II) thus causes acute death of animal (Alexander et al., 2008). The compound has a LD_{50} of 20mg/kg body weight in mice.

Other health concerns have also been raised on oils from some species of croton. Ojokuku, et al. (2011) posits that in as much as *C. penduliflorus* seed oil has the positive hypocholesteremic health effect, it also poses the risk of inducing anemia. Crotonic acid, a compound in croton *spp.* seed oil, induces hemagluttination and hemolytic activity in animals (El-Kamali et al., 2015). *Croton tiglium* L. seed oils also possess piscicidal properties that some communities have exploited in fishing especially in India (Rajput and Gaur, 2015; Saha et al., 2015). Acute toxicity studies on the *C. penduliflorus* seed oils also showed deleterious effects on some internal organs at doses of 200, 600 and 800 mg/kg of feed in mice (Ashafa et al., 2012). *C. penduliflorus* seed oils have been shown to cause adverse effects on the kidney and nervous systems of animals (Ojokuku et al., 2011). Extracting oil is not an automatic procedure for removal of toxins from the seedcake in as much as the most toxic compounds, phorbol esters, are in the oil (Sadubthummarak et al., 2013).

CROTON SEEDCAKE AS ANIMAL FEED

There are only few documented studies of the exploitation of croton seeds and seedcakes as animal feed. Most documented feeding trials have exploited whole seeds of croton *spp* with varied efficacy as shown in Table 5. However, care is advised as these seeds have toxins that have deleterious effects on the health of the animal. Feeding trials by Gadir et al. (2003) on goats using *C. macrostachycus* whole seeds at 1g/kg and 0.25g/kg showed 100% mortality for all animals and weight loss of 21.6% and 26.3% respectively within 21 days. On the other hand, Thijssen (1998) reported satisfactory feeding efficiency, weight gain, feed intake and growth rate of the chicks fed on feeds with *C. megalocarpus* seedcake incorporated at the proportions of 10-25%. *C. macrostachycus* based feeds were found to be some of the high proteins feeds suitable for use in aquaculture (Kassahun et al., 2012). Feeding trials for croton have also been done on fishes. Dada and Adeparusi (2012) reported an increased fecundity index of 21,987.16 for catfish that were fed on 200g/kg body weight of *C. zambesiscus* seeds. A study by El-Kamali et al. (2015) established that croton seeds incorporated into feed for rats in experimental diets induced no deleterious hematological effects.

Table 5 - Performance of animals in feeding trials utilizing croton seeds

Croton *spp.*	Test animal	Type of seed	Amount incorporated	Performance of the animal
C. macrostachys	7 month-old Nubian kids	Whole	1 g/kg body weight	Mortality within 7-21 days
C. macrostachys	6 month-old Nubian kids	Whole	0.25 g/kg body weight	Mortality within 7-21 days
C. zambesiscus	Catfish (*Clarias gariepinus*)	Powdered seed	50 g/kg body weight	Increased fish weight and increased fecundity
C. zambesiscus	Catfish (*Clarias gariepinus*)	Powdered seed	100 g/kg body weight	Increased fish weight and increased fecundity
C. zambesiscus	Catfish (*Clarias gariepinus*)	Powdered seed	200 g/kg body weight	Increased fish weight and increased fecundity
C. zambesicus	Wistar rats	Aqueous extract of powdered seed	75 mg/kg body weight	0.07 g/day weight gain
C. zambesicus	Wistar rats	Aqueous extract of powdered seed	300 mg/kg body weight	0.68 g/day weight loss
C. zambesicus	Wistar rats	Methanol extract of powdered seed	75 mg/kg body weight	0.71 g/day weight loss
C. zambesicus	Wistar rats	Methanol extract of powdered seed	300 mg/kg body weight	0.28 g/day weight loss
C. tiglium	One-week old Chicks	Seedcake	10-25 % incorporated in commercial chick mash	Increased growth rate of up to 117.5 g

There are other plants that are similar to Croton *spp.* that have had their seedcakes exploited as animal feeds. *Jatropha curcas* (belongs to the same sub-Family with croton) seedcake were incorporated into soybean meal at 25% both as raw Jatropha seedcake and detoxified Jatropha seedcake, where 33.3% mortalities was noted in each case

(Elangovan et al., 2013). Detoxification in this study employed addition of 3% sodium bicarbonate as similar to croton *spp.* seeds, toxicity concerns have been raised for Jatropha seeds. Another study by Barros et al. (2015) noted more deleterious effects as increasing the Jatropha seedcake in the diet of broiler chicken, resulted into decreased body weight and diminishing size of spleen and kidneys; chicken fed on 100g jatropha seedcake per kg of diet lost up to 21.6g/day. This was attributed to the phorbol esters in the seedcake. Thus, detoxification of these seedcakes is necessary before their utilization as feeds.

Research has delved further into making croton seeds safe for use as animal feeds. Solvent extraction accompanied with heat treatment of the seed cakes has successfully been employed as a way of producing feeds free of toxic levels of phorbol esters (Goel et al., 2007). Phorbol esters are mainly in the croton oil rather than the seedcake (Pagani et al., 2017). However, oil extraction is not an assurance of total removal of the phorbol esters from the seedcake (Sadubthummarak et al., 2013), thus other efficient detoxification methods are necessary.

In India, milk is employed as a detoxicant of croton seeds but this has only been evaluated in its medicinal use but not as a feed (Maurya et al., 2015). A study by Pal et al. (2014) found that the use of milk in detoxifying *C. tiglium* seeds reduced the phorbol esters and crotonic acids by 65.4% and to undetectable levels respectively. Kishore et al. (2013) reported that the method has no significant impact on the phytochemical components such as alkaloids, saponins, resin and saponins. However, it reduces the fat content thus would reduce the phorbol esters (Jain et al., 2015). The effect of such treatment on the nutritional composition of these seedcakes has also not been studied. Phorbol esters that have been traced in seedcakes in plants with the same toxicity as croton have been shown to degrade after 21 days of storage at moisture content of 130g/kg (Fujiki et al., 2017). This, points to a possible way of detoxification of the seedcakes to free them of these tumour-enhancing compounds thus making them safe as feeds. In the detoxification procedure, it is necessary not to induce any deleterious effects in the nutritional composition. Another study on Jatropha seedcake found that thermal treatment at 120ºC and 220ºC, followed by addition of 10% adsorbing bentonites (nanoparticle of zinc oxide) and 4% $NaHCO_3$ and incubation for four weeks, reduced phorbol esters to non-toxic levels of 0.04-0.05 mg/g with no cytotoxicity while on other hand not affecting the proximate composition (Sadubthummarak et al., 2013). Absence of cytotoxicity is an indication of absence of the toxic lectin proteins.

In croton *spp.* seedcakes, the most injurious proteinous compounds are the crotins, a lectin class of proteins (Vasconcelos and Oliveira, 2004). Crotins are hemolytic proteins that exhibit hematological adverse effects in animals. Crotin I and II exhibited toxicity in mice at acute LD_{50} of 1.33 and 4.38 mg/mouse respectively (at 72 hours), and delayed LD_{50} of 0.92 and 1.68 mg/mouse respectively (at 7 days) (Stirpe et al., 1976). The *C. tiglium* seeds have an acute LD_{50} of 2000mg/kg body weight (Harshavardhan et al., 2016). For these seedcakes to be exploited for feeds, it would be necessary to detoxify them of these proteins. In the detoxification of jatropha seeds, it was found that samples that were deshelled followed by defatting, enzyme hydrolysis (pectinase and cellulase) and treatment with 60% methanol and 65% ethanol; lowered toxic lectin proteins by 52.8% and other antinutrients such as saponins, phytic acid, total phenolics and trypsin inhibitor activity by 65.1%, 31.8%, 71.9% and 21.5% respectively (Xiao et al., 2011). The treatment also improved the protein digestibility corrected amino acid scores by 47.1% and crude protein content by to 15.22%.

CONCLUSION

There is increasing utilization of seeds croton *spp.* for oil extraction expanding the use of croton, but the possibility of extending the value chain by using the seedcake as a feed remains less explored. The nutritional composition of the croton seedcakes make them viable for possible exploitation as poultry feed. However, the toxicity of these seeds induced by various phytochemicals still remains the greatest challenge to this venture. Croton has been shown to pose various toxic effects to various animals ranging from simple organisms to complex ones including poultry. A possible way for detoxification of these seeds serves to ameliorate their quality as feeds. Practical ways for detoxification have been tried but not possibly for its utilization for feed for poultry or any other animal. The effect of such technique to the nutritional composition has also not been explained. For its possible use as a feed, it would be important for the safety of croton seedcakes to be evaluated to provide scientific justification for its use. Future research should evaluate the use of these identified detoxification technique and their influence on nutritional composition of the croton seeds.

DECLARATION

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Authors' contribution
All the three authors reviewed the paper and contributed in developing the content.

Availability of data
The data can be availed to the journal upon request.

Consent to publish
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REFERENCES

Abbas A, Murtaza S, Aslam F, Khawar A, Rafique S, & Naheed S. (2011). Effect of Processing on Nutritional Value of Rice (Oryza sativa). *World Journal of Medical Sciences*, *6*(2): 68–73.

Abebayehu A, Mammo F, & Kibret B. (2016). Isolation and characterization of terpene from leaves of Croton macrostachyus (Bissana). *Journal of Medicinal Plants Research*, *10*(19) : 256–260. http://doi.org/10.5897/JMPR2016.6082

Adeyinka MA, Owolabi JB, & Isiaka AA. (2013). Effects of seed coat absence on the chemical composition of croton (Croton penduliflorus) seed and its oil. *International Journal of Science and Research*, *2*(11): 132–136.

Ahmadi NR, Mangunwidjaja D, Suparno O, & Pradono DI. (2017). Extraction process optimization of kamandrah (Croton tiglium l.) seed with expression and identification of active ingredient as botanical larvacide of dengue fever preventive. *J. Tek. Ind. Pert. Vol.*, *21*(3), 154–162.

Ahmed S, Riaz MA, Malik AH, & Shahid M. (2007). Effect of seed extracts of Withania somnifera, Croton tiglium and Hygrophila auriculata on behavior and physiology of Odontotermes obesus (Isoptera, Termitidae). *Biologia - Section Botany*, *62*(6), 770–773. http://doi.org/10.2478/s11756-007-0134-0

Alexander J, Benford D, Cockburn A, Cravedi J, Dogliotti E, Domenico ADi, … Peteghem C. Van. (2008). Ricin (from Ricinus communis) as undesirable substances in animal feed, Scientific Opinion of the Panel on Contaminants in the Food Chain. *The EFSA Journal*, *2008*(June): 1–38. http://doi.org/10.2903/j.efsa.2008.726

Aliyu B, Agnew B, & Douglas S. (2010). Croton megalocarpus (Musine) seeds as a potential source of bio-diesel. *Biomass and Bioenergy*, *34*(10), 1495–1499. http://doi.org/10.1016/j.biombioe.2010.04.026

Ariharan VN, Meena Devi VN, Parameswaran NK, & Nagendra Prasad P. (2015). Physico-chemical analysis on croton tiglium oil for potential use as biodiesel. *International Journal of Pharma and Bio Sciences*, *6*(2): B231–B236.

Ashafa AOT, Yakubu MT, Ogbe AAA, & Abass AA. (2012). Effect of ethanolic seed extract of croton penduliflorous hutch. On loperamide-induced constipated male rats. *Bangladesh Journal of Pharmacology*, *7*(1): 42–46. http://doi.org/10.3329/bjp.v7i1.10120

Atabani AE, Silitonga AS, Ong HC, Mahlia TMI, Masjuki HH, Badruddin, IA, & Fayaz H. (2013). Non-edible vegetable oils: A critical evaluation of oil extraction, fatty acid compositions, biodiesel production, characteristics, engine performance and emissions production. *Renewable and Sustainable Energy Reviews*, 18: 211–245. http://doi.org/10.1016/j.rser.2012.10.013

Aylate A, Agize M, Ekero D, Kiros A, Ayledo G, & Gendiche K. (2017). In-Vitro and in-Vivo antibacterial activities of Croton macrostachyus methanol extract against E. coli and S. aureus. *Advances in Animal and Veterinary Sciences*, *5*(3): 107–114. http://doi.org/10.14737/journal.aavs/2017/5.3.107.114

Barros CR, Rodrigues MAM, Nunes FM, Kasuya MCM, Luz JMR da, Alves A, … Mourão JL. (2015). The Effect of Jatropha Curcas Seed Meal on Growth Performance and Internal Organs Development and Lesions in Broiler Chickens. *Revista Brasileira de Ciência Avícola*, (1992): 1–6. http://doi.org/10.1590/1516-635xSpecialIssue

Bello MO, Abdul-Hammed M, Adekunle AS, & Fasogbon OT. (2014a). Nutrient contents and fatty acids profiles of leaves and seeds of Croton zambesicus. *Advance Journal of Food Science and Technology*, *6*(3): 398–402.

Berry PE, & Galdames C. (2013). *Croton cerroazulensis* (Euphorbiaceae), a new species from Cerro Azul (Panama). *Webbia*, *68*(1): 17–19. http://doi.org/10.1080/00837792.2013.816824

Bhargavi G, Nageswara Rao P, & Renganathan S. (2018). Review on the Extraction Methods of Crude oil from all Generation Biofuels in last few Decades. *IOP Conference Series: Materials Science and Engineering*, *330*(1). http://doi.org/10.1088/1757-899X/330/1/012024

Dada AA, & Adeparusi EO. (2012). Dietary effects of two medicinal plants (Sesamum indicum) and (Croton zambesicus) on the reproductive indices in female African catfish (Clarias gariepinus) broodstock. *Egyptian Journal of Aquatic Research*, *38*(4): 269–273. http://doi.org/10.1016/j.ejar.2012.12.012

Dey T, Saha S, Adhikari S, & Ghosh PD. (2014). A Comprehensive Review on Medicinally Important Plant, Croton tiglium L. *International Journal of Current Research in Biosciences and Plant Biology*, *1*(3): 41–49.

Diaz GJ. (2011). Toxic Plants of Veterinary and Agricultural Interest in Colombia. *International Journal of Poisonous Plant Research*, *1*(ISSN 2154-3216): 1–19.

dos Santos RF, Riina R, & Caruzo MBR. (2016). Croton sapiifolius Müll . Arg .: A new occurrence for the State of Espírito Santo, Brazil. *Hoehnea*, *43*(4): 529–531.

Dutta S, Dey P, & Chaudhuri TK. (2014). Phytochemical investigation and correlation study of Croton bonplandianus Baill . stem. *Journal of Pharmacognosy and Phytochemistry*, *3*(1): 142–148.

EFSA CONTAM Panel. (2015). Risks for human and animal health related to the presence of phorbol esters in Jatropha kernel meal. *EFSA Journal*, *13*(12)" 1–80. http://doi.org/10.2903/j.efsa.2015.4321

Elangovan AV, Gowda NKS, Satyanarayana ML, Suganthi RU, Rao SBN, & Sridhar M. (2013). Jatropha (Jatropha curcas) seed cake as a feed ingredient in the rations of sheep. *Animal Nutrition and Feed Technology*: *13*(1), 57–67.

El-Kamali H, Omran A, & Abdalla M. (2015). Biochemical and haematological assessment of Croton tiglium seeds mixed with animal diet in male albino rats. *Annual Research & Review in Biology*, *8*(4): 1–7. http://doi.org/10.9734/ARRB/2015/19801

Endelevu Energy. (2009). *Jatropha Reality Check - A field assessment of the agronomic and economic viability of Jatropha and other oilseed crops in Kenya*. *Sustainable Management of Resources in Agriculture*. Nairobi, Kenya: Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH. http://doi.org/10.1063/1.1402155

Filho JMT. de A, Araújo L. da C, Oliveira AP, Guimarães AL, Pacheco AG. M, Silva FS, … Araújo EC. da C. (2017). Chemical composition and antibacterial activity of essential oil from leaves of Croton heliotropiifolius in different seasons of the year. *Revista Brasileira de Farmacognosia*, *27*(4): 440–444. http://doi.org/10.1016/j.bjp.2017.02.004

Fujiki, H., Suttajit, M., Rawangkan, A., Iida, K., Limtrakul, P., Umsumarng, S., & Suganuma, M. (2017). Phorbol esters in seed oil of Jatropha curcas L. (saboodam in Thai) and their association with cancer prevention: from the initial investigation to the present topics. *Journal of Cancer Research and Clinical Oncology*, *143*(8): 1359–1369. http://doi.org/10.1007/s00432-017-2341-6

Gadir, W. S. A., Onsa, T. O., Ali, W. E. M., El Badwi, S. M. A., & Adam, S. E. I. (2003). Comparative toxicity of Croton macrostachys, Jatropha curcas and Piper abyssinica seeds in Nubian goats. *Small Ruminant Research*, *48*(1), 61–67. http://doi.org/10.1016/S0921-4488(02)00181-5

Gichui, W. G. (2016). *Antinociceptive activities of extracts of Croton megalocarpus hutch (Eurphobiaceae) using animal models*. University of Nairobi.

Goel, G., Makkar, H. P. S., Francis, G., & Becker, K. (2007). Phorbol esters: Structure, biological activity, and toxicity in animals. *International Journal of Toxicology*, *26*(4): 279–288. http://doi.org/10.1080/10915810701464641

Gonfa Keneni, Y., & Mario Marchetti, J. (2017). Oil extraction from plant seeds for biodiesel production. *AIMS Energy*, *5*(2), 316–340. http://doi.org/10.3934/energy.2017.2.316

Harshavardhan, B., Sb, A. K., Ravishankar, B., Chaturvedi, A., & Ravi, M. (2016). An experimental study to assess toxic potential of jayapala (Croton Tiglium) beeja in relation to gastrointestinal tract. *International Journal of Health Sciences and Research*, *5*(9): 346–351.

Jacobson, M., Shr, Y. H., Dalemans, F., Magaju, C., & Ciannella, R. (2018). Using a choice experiment approach to assess production tradeoffs for developing the croton value chain in Kenya. *Forest Policy and Economics*, *86*(November 2017), 76–85. http://doi.org/10.1016/j.forpol.2017.09.015

Jain, P. K., Mangal, G. P., & Kushwaha, R. (2015). Pharmaceutical study of Jayapala seed (Croton tiglium Linn). *International Ayurvedic Medical Journal*, *3*(3): 773–777.

Jeeshna, M. V, Paulsamy, S., & Mallikadevi, T. (2011). Phytochemical constituents and antimicrobial studies of the exotic plant species , Croton bonplandianum Baill. *Journal of Life Sciences*, *3*(1): 23–27. http://doi.org/10.1080/09751270.2011.11885165

Jiyane, P. C., Tumba, K., & Musonge, P. (2018). Optimisation of *Croton gratissimus* Oil Extraction by *n*-Hexane and Ethyl Acetate Using Response Surface Methodology. *Journal of Oleo Science*, *67*(4): 369–377. http://doi.org/10.5650/jos.ess17197

Kassahun, D. A., Waidbacher, H., Munguti, J. M., & Zollitsch, W. J. (2012). Locally available feedstuff's for small-scale aquaculture in Ethiopia - A review. *Bodenkultur*, *63*(2–3): 51–62.

Keter, L. K., & Mutiso, P. C. (2012). Ethnobotanical studies of medicinal plants used by Traditional Health Practitioners in the management of diabetes in Lower Eastern Province, Kenya. *Journal of Ethnopharmacology*, *139*(1): 74–80. http://doi.org/10.1016/j.jep.2011.10.014

Kibazohi, O., & Damson, L. (2013). Improvement of Hydraulic Press for Vegetable Oil Expression in Rural Areas. *Tanzania Journal of Engineering and Technology*, *4*(1): 55–62.

Kim, M. S., Kim, H. R., So, H. S., Lee, Y. R., Moon, H. C., Ryu, D. G., Kwon, K. B. (2014). Crotonis fructus and its constituent, croton oil, stimulate lipolysis in op9 adipocytes. *Evidence-Based Complementary and Alternative Medicine*, *2014*: 10–15. http://doi.org/10.1155/2014/780385

Kishore, K. R., Shantha, T. R., Venkatesharlu, V. R. R., & Sridhar, B. N. (2013). Evaluation of shodhana [ayurveda (Indian traditional medicine) detoxifying method on jayapala (Croton tiglium Linn.) seed: A preliminary physico-phyto-chemical analysis. *Journal of Herabl Medicine and Toxicology*, *7*(1): 79–87.

Kivevele, T. T., & Mbarawa, M. M. (2010). Comprehensive analysis of fuel properties of biodiesel from croton megalocarpus oil. *Energy and Fuels*, *24*(11): 6151–6155. http://doi.org/10.1021/ef100880g

Leakey, R. R. B., Temu, A. B., Melnyk, M., & Vantomme, P. (1996). *Inventory and future management strategies of multipurpose tree and herb species for non-timber forest products in Nepal*. *Domestication of valuable tree species in agroforestry systems: evolutionary stages from gathering to breeding* (Vol. 9). Retrieved from http://www.fao.org/docrep/w3735e/w3735e18.htm

Liu, L., Yu, H., Wu, H., Yang, X., Pan, Y., Chen, Y., … Xia, C. (2017). Toxic proteins from Croton tiglium L. exert a proinflammatory effect by inducing release of proinflammatory cytokines and activating the p38-MAPK signaling pathway. *Molecular Medicine Reports*, *16*(1): 631–638. http://doi.org/10.3892/mmr.2017.6617

Maroyi, A. (2017a). Croton megalocarpus Hutch. in Tropical Africa: Phytochemistry, Pharmacology and Medicinal Potential. *Research Journal of Medicinal Plants*, *11*(4): 124–133. http://doi.org/10.3923/rjmp.2017.124.133

Maroyi, A. (2017b). Ethnomedicinal uses and pharmacological activities of Croton megalobotrys Müll Arg: A systematic review. *Tropical Journal of Pharmaceutical Research*, *16*(10): 2535–2543. http://doi.org/10.4314/tjpr.v16i10.30

Maurya, S., Seth, A., Laloo, D., Singh, N., Singh, A., & Gautam, D. S. (2015). Śodhana: An Ayurvedic process for detoxification and modification of therapeutic activities of poisonous medicinal plants. *Ancient Science of Life*, *34*(4): 188–197. http://doi.org/10.4103/0257-7941.160862

Nagireddy, L., Parveen, S., & Pullaiah, T. (2017). Population Structure and Regeneration of Croton scabiosus Bedd. (Euphorbiaceae) in Dry Forests of South Eastern Ghats of YSR Kadapa District, Andhra Pradesh, India. *Journal of Experimental Agriculture International*, *15*(6): 1–9. http://doi.org/10.9734/JEAI/2017/31498

Nath, R., Roy, S., De, B., & Dutta Choudhury, M. (2013). Anticancer and antioxidant activity of Croton: A review. *International Journal of Pharmacy and Pharmaceutical Sciences*, *5*(SUPPL. 2), 63–70. http://doi.org/10.1016/S0040-4020(01)98737-X

Obey, J. K., Ngeiywa, M. M., Kiprono, P., Omar, S., von Wright, A., Kauhanen, J., & Tikkanen-Kaukanen, C. (2018). Antimalarial Activity of *Croton macrostachyus* Stem Bark Extracts against *Plasmodium berghei In Vivo*. *Journal of Pathogens*, *2018*: 1–6. http://doi.org/10.1155/2018/2393854

Ojo, M., Amoo, A., Ayoade, W., & Ojo, C. (2017). Physicochemical properties, fatty acid composition and antimicrobial potential of Turk's cap (Croton penduliflorus) seed oil. *Chemical Science International Journal*, *20*(4): 1–7. http://doi.org/10.9734/CSJI/2017/35835

Ojokuku, S. A., Odesanmi, O. S., & Magbabeola, O. A. (2011). Haematology for Pregnant Rabbit.Pdf. *International Journal of Tropical Medicine*, *6*(2): 35–38.

Ojokuku, S. A., Odesanmi, O. S., & Magbagbeola, O. A. (2011). The effects of oral administration of Croton penduliflorus seed oil and edroxy progesterone acetate on fasting blood sugar, lipid and haematology of pregnant rabbits. *International Journal of Tropical Medicine*, *6*(2): 35–38. http://doi.org/10.3923/ijtmed.2011.35.38

Osawa, W. O., Onyari, J. M., Sahoo, P. K., & Mulaa, F. J. (2014). Process optimization for production of biodiesel from croton oil using two-stage process. *IOSR Journal of Environmental Science Ver. III*, *8*(11): 2319–2399. Retrieved from www.iosrjournals.org

Oyesola, T. O., Oluwole, F. S., & Oyesola, O. A. (2009). Effects of Croton penduliflorus methanolic extract on intestinal enzymes and protein content in pregnant rats. *Research Journal of Medicinal Plants*, 3: 141–145. http://doi.org/10.3923/rjmp.2009.141.145

Pagani, A., Gaeta, S., Savchenko, A. I., Williams, C. M., & Appendino, G. (2017). An improved preparation of phorbol from croton oil. *Beilstein Journal of Organic Chemistry*, *13*: 1361–1367. http://doi.org/10.3762/bjoc.13.133

Pal, P. K., Nandi, M. K., & Singh, N. K. (2014). Detoxification of Croton tiglium L. seeds by Ayurvedic process of Śodhana. *Anc Sci Life*, *33*(3), 157–161. http://doi.org/10.4103/0257-7941.144619

Parameswararao, K., Ramesh, B. V, Prasad, C. S., & Rao, M. C. (2016). GC-MS Screening of Bioactive Compounds from Seeds of Croton Bonplandianum baill (Euphorbiaceae). *Der Pharmacia Lettre*, *8*(9): 341–348.

Peoples, A. D., Lochmiller, R. L., Leslie, D. M., Boren, J. C., & Engle, D. M. (1994). Essential Amino Acids in Northern Bobwhite Foods Published by : Wiley on behalf of the Wildlife Society Stable URL : http://www.jstor.org/stable/3809564 Accessed : 28-06-2016 02 : 38 UTC. *The Journal of Wildlife Management*, *58*(1): 167–175.

Rajput, V., & Gaur, R. (2015). Toxicological study on Clarias batrachus caused by Croton and Mahua extract. *Journal of Pharmacognosy and Phytochemistry*, *3*(5): 32–34.

Ruhul, A. M., Kalam, M. A., Masjuki, H. H., Alabdulkarem, A., Atabani, A. E., Fattah, I. M. R., & Abedin, M. J. (2016). Production, characterization, engine performance and emission characteristics of Croton megalocarpus and Ceiba pentandra complementary blends in a single-cylinder diesel engine. *RSC Advances*, *6*(29): 24584–24595. http://doi.org/10.1039/c5ra21750d

Sadubthummarak, U., Parkpian, P., Ruchirawat, M., Kongchum, M., & Delaune, R. D. (2013). Potential treatments to reduce phorbol esters levels in jatropha seed cake for improving the value added product. *Journal of Environmental Science and Health - Part B Pesticides, Food Contaminants, and Agricultural Wastes*, *48*(11): 974–982. http://doi.org/10.1080/03601234.2013.816606

Saha, P., Talukdar, A. Das, Ningthoujam, S. S., Choudhury, M. D., Nath, D., Nahar, L., … Basar, N. (2015). Chemical composition, antimicrobial and antioxidant properties of seed oil plants of North-East India: A review. *Tang [Humanitas Medicine]*, *5*(3): 17.1-17.22. http://doi.org/10.5667/tang.2015.0010

Sai Prassana, C. G., & Karpaga, S. (2015). Comparative studies on the morphology of the stomach in the Insectivora. *Acta Theriologica*, *12*(13–38): 223–244.

Salatino, A., Salatino, M. L. F., & Negri, G. (2007). Traditional uses, chemistry and pharmacology of Croton species (Euphorbiaceae). *Journal of the Brazilian Chemical Society*, *18*(1), 11–33. http://doi.org/10.1590/S0103-50532007000100002

Sánchez-Arreola, E., Martin-Torres, G., Lozada-Ramírez, J. D., Hernández, L. R., Bandala-González, E. R., & Bach, H. (2015). Biodiesel production and de-oiled seed cake nutritional values of a mexican edible jatropha curcas. *Renewable Energy*, *76*: 143–147. http://doi.org/10.1016/j.renene.2014.11.017

Saputera, M., & Atikah, T. A. (2014). Extraction and transesterification of Croton tiglium oil seeds from Central Kalimantan, Indonesia as an alternative biodiesel raw material. *Asian Journal of Applied Sciences*, *7*: 140–149. http://doi.org/10.3923/ajaps.2014.140.149

Saputera, Mangunwidjaja, D., Raharja, S., Kardono, L. B. S., & Iswantini, D. (2006). Cas chromatography and gas chromatography-mass spectrometry analysis of Indonesian Croton tiglium seeds. *Journal of Applied Sciences*, *6*(7): 1576–1580.

Sarin, A. (2012). *Biodiesel*. Amritsar, India: RSC publishing. http://doi.org/10.1039/9781849734721

Shama, I. Y. A., & Ebtiha, A. S. (2013). Investigations on the effects of various oral doses of Croton zambesicus seeds' in wistar rats. *Journal of Pharmacology and Toxicology*, *8*(1): 19–27. http://doi.org/10.3923/jpt.2013.19.27

Sharma, J., Singh, R., & Goyal, P. K. (2016). Chemomodulatory potential of flaxseed oil against DMBA/croton oil-induced skin carcinogenesis in mice. *Integrative Cancer Therapies*, *15*(3): 358–367. http://doi.org/10.1177/1534735415608944

Sharma, N., Bohra, B., Pragya, N., Ciannella, R., Dobie, P., & Lehmann, S. (2016). Bioenergy from agroforestry can lead to improved food security, climate change, soil quality, and rural development. *Food and Energy Security*, *5*(3): 165–183. http://doi.org/10.1002/fes3.87

Silva, J. de A. G., da Silva, G. C., Silva, M. G. de F., da Silva, V. F., Aguiar, J. dos S., da Silva, T. G., & Leite, S. P. (2017). Physicochemical characteristics and cytotoxic effect of the methanolic extract of Croton heliotropiifolius Kunth (Euphorbiaceae). *African Journal of Pharmacy and Pharmacology*, *11*(28): 321–326. http://doi.org/10.5897/AJPP2017.4798

Stirpe, F., Pession-Brizzi, A., Lorenzoni, E., Strocchi, P., Montanaro, L., & Sperti, S. (1976). Studies on the Proteins from the Seeds of Croton tiglium and of Jatropha curcas. *Biochemistry Journal*, *156*(May): 1–6. http://doi.org/10.1042/bj1560001

Tenaw, G., Mitiku, A., & Tamene, M. (2017). Geospatial based biofuels suitability assessment in Ethiopia. *Journal of Geography and Regional Planning*, *10*(6): 148–162. http://doi.org/10.5897/JGRP2016.0605

Thijssen, R. (1998). Domestication and commercialization of non-timber forest products in agroforestry systems - Croton megalocarpus, the poultry-feed tree how local knowledge could help to feed the world. In *Domestication and commercialization of non-timber forest products in agroforestry systems*. Nairobi, Kenya: FAO.

Torres, M. C. M., Assunção, J. C., Santiago, G. M. P., Andrade-Neto, M., Silveira, E. R., Costa-Lotufo, L. V., … Pessoa, O. D. L. (2008). Larvicidal and nematicidal activities of the leaf essential oil of Croton regelianus. *Chemistry and Biodiversity*, *5*(12): 2724–2728. http://doi.org/10.1002/cbdv.200890227

Van Ee, B., & Berry, P. E. (2010). Typification notes for Croton (Euphorbiaceae). *Harvard Papers in Botany*, *15*(1): 73–84. http://doi.org/10.3100/025.015.0122

Vasconcelos, I. M., & Oliveira, J. T. A. (2004). Antinutritional properties of plant lectins. *Toxicon*, *44*(4): 385–403. http://doi.org/10.1016/j.toxicon.2004.05.005

Waiganjo, N., Ochanda, H., & Yole, D. (2013). Phytochemical analysis of the selected five plant extracts. *Chemistry and Materials Research*, *3*(9): 2225–956.

Wu, D., Roskilly, A. P., & Yu, H. (2013). Croton megalocarpus oil-fired micro- trigeneration prototype for remote and self-contained applications : experimental assessment of its performance and gaseous and particulate emissions. *Interface Focus*, *3*(20120041): 1–11. http://doi.org/10.1098/rsfs.2012.0041

Xiao, J., Zhang, H., Niu, L., Wang, X., & Lu, X. (2011). Evaluation of detoxification methods on toxic and antinutritional composition and nutritional quality of proteins in jatropha curcas meal. *Journal of Agricultural and Food Chemistry*, *59*(8): 4040–4044. http://doi.org/10.1021/jf200104b

Yumnamcha, T., Nongthomba, U., & Damayanti, D. M. (2014). Phytochemical screening and evaluation of genotoxicity and acute toxicity of aqueous extract of Croton tiglium L. *International Journal of Scientific and Research Publications*, *4*(1): 2250–3153. Retrieved from www.ijsrp.org