Potential of mango (*Mangifera indica* L.) seed kernel as a feed ingredient for poultry: a review

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Mango (*Mangifera indica*) is an important fruit crop grown in the tropics mostly for its pulp. Mango seed, which represents between 20-60% of the fruit, has limited food or industrial use in most producing countries and is therefore wasted. The kernel contained in the seed (mango seed kernel: MSK) is a good source of carbohydrates (58-80%), contains moderate quantities of proteins (6-13%) and fat (6-16%). The protein of MSK has a good essential amino acid profile and its oil is a good source of stearic and linoleic acids. However, despite these attributes MSK contains a number of anti-nutritional factors (*e.g.* tannins, phytate, cyanide, antitrypsin, oxalate and saponins) which limit its utilisation in poultry diets. Amongst these factors, tannins are largely responsible for the poor nutritional value of MSK. Several processing methods have been used to reduce the concentration of anti-nutritional factors in MSK and improve its utilisation by poultry. The following paper reviews the composition (nutrients and anti-nutrients) of MSK, recommendations for its use in poultry diets and processing methods to enhance its utilisation by poultry.

Keywords: mango seed kernel; nutritive value; anti-nutritional factors; processing; poultry feeding

Introduction

Starch from materials such as maize is an important source of energy in poultry diets and has several industrial uses. The production of maize may no longer be able to keep pace with the demands from agriculture, and will result in increased demand for other cereals for food, further worsening the food-feed competition in the near future. This situation has increased research interest in alternative energy sources for poultry feeding.

The mango (*Mangifera indica* L.) tree, which originated from South-East Asia, is now widespread in tropical and sub-tropical areas of the world (Sukonthasing *et al.*, 1991; Orwa *et al.*, 2009). Mango is ranked as the third most important tropical fruit crop after

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bananas and plantains (FAO, 2011) with its production estimated at 39 million tonnes in 2010 (Jedele *et al.*, 2003; FAO, 2011). Taking mango seed as 20 to 60% of the whole fruit, and the kernel as 45 to 75% of the seed (Maisuthisakul and Gordon, 2009), this represents between 4 and 18 million tonnes of mango kernel available per year. Due to its abundance and its limited use as a by-product in most parts of the world, there is economic advantage in investigating the use of mango kernel meal in poultry feeding.

Mango seed kernel (MSK) is reported to be a good source of carbohydrates (NFE) (El Saadany *et al.*, 1980; Jansman *et al.*, 1995; Teguia, 1995; Anand and Maini, 1997; Diarra and Usman, 2008; Diarra *et al.*, 2010; 2011), and contains high quantities of proteins and fats (Anand and Maini, 1997). The major problem affecting the nutritional value of MSK is that it contains various antinutritional factors. Although there are reports of the consumption of MSK as porridge in India (El Saadany *et al.*, 1980; Opeke, 1982), this by-product has limited food, feed or industrial uses in most mango producing countries thus making it readily available. MSK meal has received much research attention in recent years as an alternate energy source for poultry. This paper reviews the composition of MSK, its recommendations in poultry diets and the effects of processing on its nutritional quality.

Nutritive composition of mango seed kernel (MSK)

Mango seeds consist of about 68% kernel, 29% shell and 3% testa (Odunsi, 2005). There is a vast body of information on the nutritional composition of MSK, however it is difficult to give representative values for the constituents as they vary widely (*Table 1*).

Table 1 Proximate composition of dry mango seed kernel (MSK), maize, and sorghum grains (g/100 g DM).

Constituents	MSK	Maize grain	Sorghum grain
Dry matter	89 -91.5	86	89
Crude protein	6 - 10	8 - 9	9.8 - 10
Crude fibre	1.11 - 2.9	2.0 - 2.2	2.0 - 3.5
Ether extract	7.87- 14.80	3.5 - 3.8	4.4
Nitrogen-free extract	67 - 82	-	-
Metabolisable energy (Kcal/kg)	3,275 - 3,454*	3,330 - 3,514	2,650 - 3,464
References	1, 2, 3, 4, 5, 6	3, 7, 8	7, 8

*Value for boiled mango kernel
1: Sandhu and Lim, 2007; 2: Fowomola, 2010; 3: Diarra *et al.*, 2011; 4: Odunsi, 2005; 5: Dakare *et al.*, 2012; 6: Kittiphoom, 2012; 7: Jadhav and Siddiqui, 2010; 8: Damron, 2009

Among the factors responsible for differences in composition, variety receives the most attention, as, according to Kansci *et al.* (2008), there are about 1,000 varieties of mango world-wide. Varietal differences in the composition of MSK are well documented (Lakshminarayana *et al.*, 1983; Percival *et al.*, 2006; Rodriguez *et al.*, 2006; Rocha Ribeiro *et al.*, 2007; Mirghani *et al.*, 2009). Lakshminarayana *et al.* (1983) analysed the kernel from 43 varieties of mango in India and reported wide differences in protein (4.0-8.1%), fat (3.7-12.6%) and ash (1.0-3.7%) on a dry matter basis. Similarly, Sandhu and Lim (2007) reported the starch content of two cultivars of mango (Chausa and Kuppi) in South Korea to be 75.6 and 80.0% respectively.

Mango seed kernel (MSK) is a good source of starch (58-80%) (El Saadany, 1980;

Garg and Tandon, 1997; Sandhu and Lim, 2007) and is high in fats (Diarra *et al.,* 2011) which combine to give a metabolisable energy (ME) value comparable to that of maize (Diarra *et al.,* 2011). However, the carbohydrates contained in MSK are reported to be poorly digested by poultry. Ravindran and Rajaguru (1985) reported that only 52.5% of MSK carbohydrates were metabolised by poultry. The protein content of dried MSK (6-13%) (Kiflewahid *et al.*, 1982; Dhingra and Kapoor, 1985; Ravindran and Rajaguru, 1985; Arogba, 1999; Odunsi, 2005; Ekpe *et al.*, 2007; Fowomola, 2010; Diarra *et al.*, 2011) is comparable to that of maize and has a good essential amino acid profile especially in terms of lysine and methionine (Fowomola, 2010; Jadhav and Siddiqui, 2010) (*Table 2*).

Table 2 Essential amino acid profile of mango seed kernel (MSK) (g/100g protein), maize, sorghum and soyabean meal proteins (g/100 g DM).

Essential amino acids	Ingredients			
	MSK	Maize	Sorghum	Soyabean meal
Lysine	3.13 - 5.0	0.26	0.22	2.22
Methionine	1.04 - 2.2	0.17	0.17	0.53
Threonine	2.04 - 4	0.29	0.31	1.41
Arginine	5.17 - 9.0	0.37	0.38	2.60
Valine	3.80 - 5.2	0.39	0.46	1.68
Histidine	2.31 - 2.7	0.23	0.23	0.96
Phenylalanine	4.46 - 4.60	0.39	0.49	1.83
Isoleucine	3.23 - 4.60	0.28	0.37	1.61
References	1, 2, 3, 4, 5	6	6	6

1: Fowomola, 2010; 2: Jadhav and Siddiqui, 2010; 3: Ashoush and Gadallah, 2011; 4: Kittiphoom, 2012; 5: WHO, 1985; 6: NRC (1998)

MSK meal is moderately rich in oil (6-16%) (Schieber *et al.*, 2001; Gunstone, 2006; Jadhav and Siddiqui, 2010; Medina *et al.*, 2010; Diarra *et al.*, 2011), which is a good source of stearic (24-57%) and oleic (34-56%) acids which can be fractionated to yield olein and stearin (Gunstone, 2006).

Anti-nutritional factors in MSK

Despite its high content of nutrients, the use of MSK in poultry feeding is limited by the presence of several anti-nutritional factors (ANFs). The major ANFs identified in MSK include tannins and cyanogenic glucosides (Teguia, 1995; Ravindran and Sivakanesan, 1996; El Boushy and Van Der Poel., 2000; Farag, 2001; Sanon and Kanwe, 2010; Ashoush and Gadallah, 2011; Dakare *et al.*, 2012). Oxalates (Ravindran and Sivakanesan, 1996; Dakare *et al.*, 2012) and phytates, saponins, alkaloids and flavonoids (Dakare *et al.*, 2012) have been reported in trace quantities, but these may not constitute major constraints to the feeding of MSK to poultry. *Table 3* summarises the ANFs content of MSK.

Table 3 Anti-nutritional factors in mango seed kernel (MSK) meal.

Anti-nutritional factors	Concentration	References
Condensed tannins (g/kg DM)	1.2 - 4.0	(1, 2, 3, 5)
Tannic acid (g/kg DM)	56.5 - 75	(1, 2, 3, 4, 6)
Hydrocyanic acid (g/kg DM)	64 - 71	(4, 6)
Oxalates (mg/kg DM)	11.92 - 42	(5, 6)
Trypsin inhibitor activity (TIU/g)	20 - 30	(4, 5, 6, 7)
Phytates (mg/100g)	1.44 - 487.3	(5, 7)
Alkaloids (mg/100g)	1 - 6.3	(5, 7)
Saponin (mg/100g)	4 - 10.5	(5, 7)

1: Ashoushand Gadallah (2011); 2: Teguia (1995); 3: Sanon and Kanwe (2010); 4: Farag (2001); 5: Dakare *et al.* (2012); 6: Ravindran and Sivakanesan (1996); 7: Fowomola (2010)

A dietary tannin concentration of 0.5% has been reported to reduce feed intake in chickens (Vohra *et al.*, 1966), decrease nitrogen retention and cause 5% mortality in rats (Glick and Joslyn, 1970). Jansman *et al.* (1989) reported that the tolerated level of dietary tannic acid by chicks was 0.3%. Diarra *et al.* (2011) observed that adult birds tolerate more tannin than young chicks. Concentrations of hydrocyanic acid (HCN) as low as 25 mg/kg diet affect the performance of laying hens while broiler performance was reported to be affected only when the concentration reached 100 mg/kg (Panigrahi, 1996). Additionally, dietary trypsin inhibitor activity as low as 2.8 mg/kg has been associated with poor growth performance in broilers (Perilla *et al.*, 1997).

Effects of processing on the ANF content of MSK

The effects of different processing methods on the reduction of ANFs in MSK have been investigated. Soaking and boiling were reported to significantly lower the ANF contents of MSK (Teguia, 1995; Ravindran and Sivakanesan, 1996; Diarra *et al.*, 2011). An additional advantage of soaking or boiling was seen as an increase in the ME content of the kernel (Ravindran and Sivakanesan, 1996; Diarra *et al.*, 2011). Ravindran and Sivakanesan (1996) observed an increase in the ME from 7.9 MJ/kg DM in the dried raw kernel to 10.3 MJ/kg DM in the boiled and soaked kernels. The increased nitrogen-free extract (soluble carbohydrates) observed in the processed kernels compared to the raw kernels (Ravindran and Sivakanesan, 1996; Diarra *et al.*, 2011; Dakare *et al.*, 2012) was probably due to the breakdown of complex carbohydrate fractions. Recently, Amao and Siyanbola (2013) reported an increase in the ME content of dry heat treated MSK compared to the raw MSK. Soaking, boiling, autoclaving, acid or alkali treatment have been reported to remove tannins and trypsin inhibitors (El Boushy and Van Der Poel., 2000; Farag, 2001; Dakare *et al.*, 2012) and the HCN (El Boushy and Van Der Poel, 2000; Dakare *et al.*, 2012) in MSK.

El Boushy and Van Der Poel (2000) observed that soaking was more efficient in removing tannins and HCN from MSK than boiling, acid or alkali treatment. In another report, Ravindran and Sivakanesan (1996) found boiling to be more efficient in removing tannins and HCN compared to soaking. Treating with acid followed by alkali treatment removed all of the tannins and much of the cyanogenic glucosides of MSK (Patil *et al.*, 1982). Dakare *et al.* (2012) reported significant reduction of tannin, HCN, trypsin inhibitor activity and oxalate in boiled compared to soaked MSK, while boiling in alkali was most efficient in reducing phytic acid content. The authors observed that boiling following soaking further reduced the concentration of these factors in mango kernel. Abdullahi (2012) investigated the effect of processing on the reduction of anti-nutritional factors in MSK and found that boiling in water was more efficient in reducing phytate and oxalate while soaking efficiently reduced HCN. Maximum tannin reduction and enhancement of MSK proteins were obtained by the combined action of soaking and autoclaving (Messay and Shimelis, 2012).

From the previous evidence, it is difficult to recommend a single processing method, but factors such as the variety of mango, the type of toxic factors present and the cost of processing should be considered when deciding the best method to implement. Where heat treatment is to be adopted, temperature and duration need to be defined to minimise losses of nutrients. Leaching of soluble nutrients in soaking water may also occur, thus the need for research into optimum soaking conditions is required. The effects of selected domestic processing methods on the ANFs contents of MSK are shown in *Table 4*.

Table 4 Effect of selected processing methods on the antinutritional factor reduction in mango seed kernel (MSK).

Reduction of toxic factors (%)	Soaking in water 24 hrs	72 hrs	Boiling in water (100C for 30min)	Soaking 24 hrs + boiling (30min)	References
Tannins	48.2	-	61.1	80.2	Dakare *et al.* (2012)
	-	42.86	47.43	-	Abdullahi (2012)
	-	-	65.51	-	Diarra *et al.* (2010)
	61.0		-	-	EL Boushy *et al.* (2000)
	-	-	84.0	-	Abdulrashid *et al.* (2007)
Cyanide	-	-	84.0	-	EL Boushy *et al.* (2000)
		77.78	77.78	-	Abdullahi (2012)
	19.1	-	37.6	57.1	Dakare *et al.* (2012)
Trypsin inhibitor activity	33.8	-	98.2	100	Dakare *et al.* (2012)
Phytate	-	82.22	84.44	-	Abdullahi (2012)
	23.8	-	42.8	52.4	Dakare *et al.* (2012)
Oxalate	-	20.0	24.0	-	Abdullahi (2012)
	22.6	-	81.1	89.7	Dakare *et al.* (2012)

Feeding trials

BROILERS

Feeding of MSK to broiler chickens is well documented. Patil *et al.* (1982) observed that replacing 14.1% dietary maize with raw MSK had no adverse effects on broiler chickens growth, but 28.2% replacement caused growth to be adversely affected. In corroboration, Teguia (1995) reported adverse effects on weight gain and feed consumption of broiler chickens fed 20% ground MSK as replacement of maize. Recently, Amao and Siyanbola (2013) observed significantly lower feed intake, higher body weight and better feed conversion in finishing broilers fed 30% dry heat treated MSK as a replacement for maize compared to the maize-fed control group.

There are reports to show that performance losses in birds fed raw MSK above 10% of the diet (as a replacement for maize) were lessened with processing (Joseph and Abolaji, 1997; Farag, 2001; Odunsi, 2005; Diarra and Usman, 2008; Diarra *et al.*, 2011). Odunsi (2005) observed significant growth depression in broilers fed more than 10% raw MSK as a replacement for maize, while 20% replacement with soaked MSK had no adverse effects on broiler growth. Similarly, Joseph and Abolaji (1997) observed no adverse effects of feeding 10% raw or 20% boiled mango kernel as a replacement for maize on broiler performance (feed intake, weight gain and feed efficiency).

The bitter taste of MSK has been attributed mainly to the presence of tannins (Ravindran and Sivakanesan, 1996; Arogba, 2000). Ravindran and Sivakanesan (1996) observed improvements in broiler performance with processed MSK in parallel with tannin reduction, indicating that tannins are largely responsible for the poor nutritive value of raw MSK.

The effect of age on the ability of birds to tolerate dietary MSK has been reported. Diarra and Usman (2008) observed that replacing 20% maize with raw MSK in broiler chickens diets significantly depressed performance during the starter phase which were compensated for during the finisher phase; suggesting that the ability of broiler chickens to utilise MSK increases with age. Similarly, Diarra *et al.* (2011) reported that the replacement of 50 and 70% of dietary maize with boiled MSK in broiler starter and finisher diets respectively significantly reduced feed cost without adverse effects on growth and feed utilisation.

LAYERS

Unlike broilers, documented information on the feeding of MSK to laying hens is still limited. Odunsi (2005) observed depressed feed intake, rate of lay, egg mass, and feed efficiency in laying hens above 10% replacement of maize with raw MSK. However, shell quality was maintained with up to 15% replacement and internal egg qualities were not affected even at 25% replacement. These results suggest that raw MSK cannot readily replace maize in laying hens' diets. Like in broilers, processing might however, allow higher levels of inclusion but this does not seem to have been investigated at the moment.

ORGAN WEIGHTS, HAEMATOLOGY AND SERUM BIOCHEMISTRY

There are reports on the effects of feeding MSK on organ weights, haematology and serum bio-chemical constituents of broiler chickens. Odunsi (2005) observed increased weights of the liver and lungs in broiler chickens fed 20% raw MSK as a replacement for maize compared to the control, but the weights of heart, kidneys and spleen were not affected by the replacement. Up to 25% replacement of maize with cooked MSK had no deleterious effects on the weights of the liver, heart and lungs. As the liver is primarily concerned with detoxification by converting toxic materials into forms that can be readily excreted, the increased liver weight on the raw MSK diet might be a response to toxic substances which were overcome by processing. Abdullahi (2012) observed no adverse effects of replacing 100% of dietary maize with soaked MSK on the weights of the liver, kidney and spleen of broiler chickens, but the weights of lungs and heart increased with increasing level of MSK in the diet. Recently however, Amao and Siyanbola (2013) fed finishing broilers 30% dry heat treated MSK for maize and observed reduced weights of the liver, heart and pancreas compared to the control.

Haematology and blood chemistry of broilers were not affected when dietary maize was replaced with 60% boiled (Diarra *et al.*, 2010), 100% soaked (Abdullahi, 2012) and 30% dry heat processed (Amao and Siyanbola, 2013) MSK. These results suggest that several factors including the variety, age of birds, processing method and conditions need to be looked into when considering MSK as a feed ingredient for poultry.

FURTHER RESEARCH

Several chemical additives have been used to improve the utilisation of tannins by poultry. Supplementation of tannin rich diets with DL-methionine has been reported to overcome the adverse effects of tannins (Armstrong *et al.*, 1974; Elkin *et al.*, 1978) by hydrolysing them into gallic acid which is excreted via urine as 4-O- methyl gallic acid

(Potter and Fuller, 1968). Tannin binding agents such as polyethylene glycol (PEG), activated charcoal, gelatine and polyvinylpyrrolidone (PVP) have been shown to improve the nutritional value of tannin-rich feeds (Jones and Mangan, 1977; Hewitt and Ford, 1982; Salunkhe *et al.*, 1990; Maghsoud and Akbar, 2011). These substances contain large number of oxygen atoms which form strong bonds with the hydrogen in phenolic groups of tannins and precipitate them from solution (Jones, 1965). At the moment however, there is little or no documented information on the use of these additives in MSK-based diets. This could form an important area for further research with the view of maximising the inclusion of this valuable and readily available resource in poultry diets.

Conclusions

Mango seed kernel has potentially attractive nutritional attributes that are useful when considering its inclusion in poultry diets, but the presence of a number of anti-nutritional factors (tannins, cyanide, trypsin inhibitors etc.) and the poor digestibility of its carbohydrates seem to limit its utilisation by poultry. Raw MSK is not recommended at more than 10% replacement rates for maize in layer and broiler diets, but processed kernels can be included at the rates of 25 and 50% as replacements for maize in layers and broilers diets respectively. The use of additives (amino acids and tannin binding agents) as supplements to mango seed kernel-based diets for maximum utilisation by poultry may also be considered. The seasonality of the crop and problems of seed collection due to the lack of processing plants in most mango producing areas, as well as the cost of processing may, however, hinder the effective harnessing of mango seed kernel as poultry feed.

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