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Alternative cereal grains and cereal by-products as sources of energy in poultry diets- A review

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Abstract

The increase in the world population, high cost of conventional animal feed ingredients and low protein intake in most developing countries has necessitated animal scientists to search for alternative sources of feed ingredients. This can enhance the production of animals with short generation intervals such as poultry to overcome the protein deficiency. This paper reviews cereal grains and cereal by-products as alternative feed ingredients for formulating poultry diets. Results obtained from various sources indicate that diets formulated with alternative cereal grains and cereal by-products had no adverse effects on body weight gain, feed intake, feed conversion ratio and carcass quality of broiler chickens, cockerels and egg quality of laying hens. Inclusion of different levels of brewers' dried grain, maize offal, rice bran and broken rice are quite acceptable in poultry diets. Therefore, sorghum, millet, maize offal, rice bran and wheat offal, millet bran, spent sorghum grain and broken rice could be recommended as alternative sources of feed ingredients in poultry diets.

Keywords: Poultry, Alternative Cereal Grains, Cereal By-Products, Energy Sources

Introduction

The increase in the world population has led to the need to intensify livestock production, but this is constrained by high cost of production especially in Nigeria. Nigeria, a country with a population of about 140,903,542 people (NPC, 2006), is one of the countries in the world with the highest rate of population growth. Due to economic situation of the nation, protein intake of most Nigerians is inadequate and often lacks protein of high biological value derived from animal products. Recently, there is a tremendous decrease in poultry production as a result of high cost of protein and energy feedstuffs. Cereal grains especially maize which forms the bulk of energy in poultry feeds are in short supply as a result of industrial and human needs. This has resulted in competition between human and animal for available feed resources, and hence high cost of animal production. Rising cost of poultry feeds have continued to be a major problem in developing countries as feed cost is about 65 to 70% (Nworgu et al., 1999) and 70 to 75% (Opara, 1999) of the total cost of production compared to about 50 to 60% in developed countries (Tackie and Flenscher, 1995). Similarly, there has been a steady increase in the cost of conventional feed ingredients such as maize, groundnut cake, soybean meal and fish meal in the past years and this has led to increase in the prices of animal protein sources (Adejinmi et al., 2007).

Several workers have emphasized the need for utilizing alternative feed ingredients removed from human and industrial uses (Durunna et al., 1999; Fanimo et al., 2007; Nsa et al., 2007).There is, therefore, a dire need for the animal nutritionists to seek for alternatives to the inadequate and expensive conventional feedstuffs to forestall an impending serious food crisis. Some workers (Kwari et al., 2004; Okah, 2004) have stressed the need for utilization of alternative feed ingredients.

To avert the problem of low animal protein deficiency, the production of animals with short generation interval such as poultry is needed. Among the different kinds of livestock that are produced in Nigeria, animal scientists generally agreed that developing the poultry industry is one of the fastest ways of bridging the protein deficiency (Akinwumi and Adegeje, 1979). According to Ogundipe and Sanni (2002) and FAO (2006) reports poultry is considered to be a mean of livelihood and a way of achieving a certain level of economic independence of Nigeria.

Oluyemi (1985) stated that an average Nigerian consumes only about 8.6g of animal protein per day as against 53.3g by the inhabitants of developed countries. The situation may be worse now in view of the prevailing economic situation.

The poultry industry occupies a major position in the livestock sector of agricultural production because birds reproduce much quicker to produce meat and eggs and returns high profits on investment. Broiler chickens grow rapidly and are good feed converters (Obioha, 1992). The best logical solution to Nigeria's meat scarcity is to increase broiler chicken production (Babatunde, 1980). Therefore, any efforts to substitute maize in poultry feeds will significantly reduce the cost of poultry production (Bamgbose et al., 2004).

In view of these constraints, sources of feed ingredients in poultry diets should be searched for. Viable alternatives are sorghum, millet and cereal by-products such as maize offal, broken rice, wheat bran, rice offal and brewers' dried grain (BDG). This paper therefore, reviews the performance and productivity of chickens fed cereal grains and cereal by-products-based diets as alternative source of feed ingredients in poultry diets.

Alternative energy sources in poultry diets

1. Sorghum grain

Sorghum (*Sorghum bicolor*) is a crop which can be successfully cultivated in the semi-arid regions of Asia and Africa and it is cheaper and more readily available than maize (Ravindran and Blair, 1991; Douglas et al., 1993). Sorghum has been used in poultry feeds to a limited extent, but there are apprehensions regarding the use of sorghum in formulating poultry feeds. Farmers have the notion that sorghum has tannin and has lower energy (2650 kcal/kg) compared to maize (3300kcal/kg) (Seshaiah, 2000). Maize has remained the major energy source in poultry diets especially in Nigeria and it is expensive due to competition between brewing industries, man and livestock. Drought has also affected the production of maize in the semi- arid areas of Nigeria. This has led to the search for alternative cereal grains and sorghum as a viable alternative.

Sorghum as an energy source in poultry diet

These grains are often used interchangeably in poultry diets. Sorghum is similar in composition to maize but contain anti-nutritive factors, the tannin, while the tannins give sorghum several agronomic advantages (bird resistance, reduced pre-harvest seed germination and molding), they lower the nutritive values of the grain for non-ruminants (Jacob et al., 1996). Other characteristics of tannins as anti-nutritive factors for non-ruminant animals are reduction of dry matter and protein digestibility (Nelson et al., 1975; Gualittieri and Rapaccini, 1990). Inhibition of the digestive enzymes had also been reported *in vitro* (Griffiths, 1981) and *in vivo* (Longstaff and Mcnab, 1991). Sorghum was reported to contain 0.2 to 2.0% tannin and when used as replacement for maize adversely affect growth and feed efficiency in broilers (Knox et al., 1975; Elkin et al., 1990; Douglas et al., 1993). Conversely, low tannin sorghum is similar to maize in nutritional value and responds equivalent to that observed in maize-based diets (Gualitteiri and Rapaccini, 1990; Jacob et al., 1996). Fuller et al. (1996) reported .variation in tannins from 0.2 to 2.0% and ME from 2617 to 3516kca1/kg for sorghum. Gowda et al. (1984) reported 0.55% tannins in sorghum, while Sharma et al. (1979) observed no tannin in sorghum.

Lucberd and Castain (1986) stated that the nutritional value of sorghum with a tannin content of lower than l0g/kg was similar to that of maize. These findings were confirmed by Pour-Reza and Edriss (1997) who showed that all the dietary maize could be replaced by low-tannin sorghum. Similar experiment was conducted by Medugu et al. (2010) who fed high- and low tannin sorghum varieties fed to broiler chickens. Medugu et al. (2010) reported that the final body weight, average daily weight and feed conversion ratio (FCR) were similar when maize, millet, low–and high tannin sorghum were used as energy sources in broiler chickens. Similarly, Similar results were reported by Adamu et al. (2001) when millet, maize and sorghum were fed to broiler chickens. They concluded that high-and-low tannin sorghum can be incorporated into broiler chicken diets without adverse effects on the performance viz: final body weight, daily feed intake, daily weight gain and feed conversion ratio. Tables 1, 2 and 3 summarize variations in chemical composition of sorghum, the chemical composition of sorghum and maize, and the performance of broilers fed maize, millet and sorghum based diets respectively.

2. Pearl millet (*Pennisetum glaucum*)

Millet referred to as 'Gero' or 'Maiwa' or 'Dauro' is a staple food crop in arid and semi-arid zones especially, Nigeria. Millet is the name used for a number of different cereals belonging to various genera which originated in Asia and Africa and are widely known in these continents (Gill et al., 1980; Kent, 1983). Pearl millet has the potentials of an alternative source of energy in poultry rations. Millet grows under hot climatic conditions unsuitable for maize production. Millet utilizes soil moisture better than maize in drier areas of Africa and Asia. This grain (millet) has not been fully exploited because it is susceptible to rust. Thus, rust resistant cultivars have now been developed and have superior amino acids balance.

Table 1: Chemical composition as reported by some researchers

	Sources	Protein (%)	Ether extract (%)	Crude fibre(%)	Ash (%)	ME kcal/kg
1	Sharma et al. (1979)	10.0 – 14.1	-	-	-	2510
2	Eshwaraiah et al. (1990)	10.0 – 14.1	-	-	-	-
3	Reddy et al.(1976)	-	1.8 – 5.7	1.5 – 5.9	-	-
4	Sinha et al. (1980)	-	1.85 – 5.75	-	-	-
5	Thakur et al. (1984)	-	-	1.5 – 5.9	-	-
6	Reddy and Reddy (1970)	-	-	-	1.77 – 3.6	-
7	Gowda et al. (1984)	-	-	-	-	3257

ME = Metabolizable Energy

Table 2: Chemical composition of sorghum and maize

Composition	Sorghum	Maize
Energy (kcal/kg)	2650.0	3300
Proteins (%)	10.0	9.0
Fat (%)	3.0	3.9
Moisture (%)	9.0	10.0
Fibre (%)	4.0	3.0
Calcium (%)	0.2	0.2
Phosphorus (%)	0.3	0.4
Lysine (%)	0.3	0.2
Methionine (%)	0.3	0.2

Source: Seshaiah (2000); similar metabolizable energy (AME) (Davis et al., 2003).

Millet as a source of energy in Poultry diets

Literature on the use of millet as energy source for poultry appears to be very limited in semi-arid zones. However, some researchers (Cromwell and Coffey, 1993) exonerated millet from the anti-nutritional properties (phytate and tannin) associated with wheat and sorghum. NRC (1996) reported that millet has no tannin. Millet has high nutritional value, with no tannin and higher protein and mineral contents than maize and sorghum (Appa-Rao et al., 1989; NRC, 1996). Studies conducted by some researchers (Singh and Barsoul, 1976; Sharma et al., 1979; Medugu et al., 2010) have shown that millet could be compared with maize in poultry diets. The report of Flurharty and Loerch (1996) showed that high energy finisher diets results in high performance with no detrimental effect on poultry in the tropics when millet is used in poultry diets. Table 3 shows the productive performance of broiler chickens fed maize, millet, high-and- low tannin sorghum-based diets. Davis et al. (2003) demonstrated that inclusion of 500g/kg of millet cultivars resulted in no loss of performance of broiler chickens. Similarly, Singh et al. (2000) showed that inclusion of millet up to 600g/kg gave excellent egg production and better FCR.

Café et al. (1999) assessed performance and egg quality of commercial laying hens fed diets with increasing substitution levels of metabolizable energy of pearl millet for maize and there was no statistical differences in egg production, feed intake, feed conversion, mean egg weight and percentage of shell, yolk and albumin. On the other hand, yolk pigmentation evaluated using a 'Roche colour fan' was poorer in egg from hens fed pearl millet-based diets. Some workers (Ojewola and Oyim, 2006) reported that millet had higher crude protein (11.90%), crude fibre (7.92%) and ash (3.83%) than maize and sorghum. Table 4 shows the performance of laying hens fed diets formulated with increasing levels of pearl millet and Table 5 shows the performance of cockerels fed millet-based diet compared with maize and sorghum-based diets.

In earlier studies, Artkinson et al. (1975) reported that little or no differences were observed in body weight, feed efficiency or percent mortality when either maize or millet was fed to birds. Similarly, the reports of Andrew and Kumar (1992) and report of NRC (1996) concluded millet neither reduces feed efficiency nor rate of gain and can fully replace maize in chickens' ration with no adverse effects on performance.

3. Wheat grain

Wheat grain is another important cereal grain used in formulating poultry diet as energy source. The energy content ranges between 323 to 343 kcal/kg and protein content vary between 10 and 20% with average of 13% (Olomu, 1995). The tryptophan in wheat is higher than that of maize and lysine is the most limiting amino acid of wheat (Olomu, 1995). Wheat has higher nutrient value compared to Barley (Jadhav and Siddiqui, 2010). It is more palatable and contains good amount of β-complex vitamins. Damaged wheat and broken–wheat, a by–product of flour mill are commonly used for preparing poultry feed (Jadhav and Siddiqui, 2010).

Investigations carried out by Salahuddin et al. (1996) to compare the energy availability for chickens of ground and whole grain samples of two wheat varieties, and found that there were no differences between the two wheat varieties or the diet on growth rate or FCR. They reported that the growth rate of the broiler chickens given a conventional starter and finisher dietary regimen tended to be slightly greater than the broiler chickens given wheat–diluted diets. They concluded that there were no differences in broiler chicken performance when the whole wheat was ground and the optimum economic rate of inclusion of

Table 3: Productive performance of broiler chickens fed maize, millet, low-and-high tannin sorghum-based diets

Parameters	Diets/treatments			
	Maize	Millet	Low-tannin sorghum (“chakalere”)	High-tannin sorghum (“Jigari”)
Initial body weight (g)	353.30	350.33	343.33	353.33
Final body weight (g)	2142.00	2218.67	2112.00	1931.33
Daily weight gain (g)	41.39	43.17	39.66	34.44
Daily feed intake (g)	97.41	94.03	98.79	100.71
Feed conversion ratio	2.45	2.24	2.88	2.94

Source: Medugu et al. (2010)

Table 4: Performance of laying hens fed diets formulated on a total or digestible amino acid basis with increasing levels of pearl millet (25-45 weeks)

Pearl millet substitution for maize	Feed intake (g/day)	Egg-production (%)	Feed conversion ration	Egg weight (g)
0%	94.86	87.56	1.82	59.65
25%	92.25	84.34	1.86	59.10
50%	87.74	81.61	1.88	57.72
75%	86.69	82.42	1.85	57.12
100%	86.61	79.72	1.90	57.37

Source: Rostango et al. (2000)

Table 5: Performance response of cockerels fed varying dietary energy sources

Parameters	Maize	Sorghum	Millet
Mean initial body weights (g)	430.00	415.00	390.00
Mean final body weight (g)	1675.00	1675.00	1575.00
Mean total weight gain (g)	1270.00	1270.00	1206.00
Mean daily weight gain	22.68	22.68	21.52
Total feed intake (g)	4740.00	5050.00	3589.00
Fed conversion ratio	3.73	3.98	2.98

Source: Ojewola and Oyim (2006)

whole wheat grain will depend on factors such as the concentration of the limiting nutrients in the feed, growth performance of the broiler chickens as well as the economic value of broiler chicken meat.

Mammo and Sultan (2010) reported that there were significant differences in average feed intake and body weight gain when using selected energy sources on the performance and carcass characteristics of broiler chickens and no significant difference in FCR of all the treatment groups. Average live weight, the thigh and breast weight were significantly higher for treatment groups that containing wheat grains (Mammo and Sultan, 2010). However, they stated that the eviscerated weights and percent of the carcass were significantly lower for treatment group that contain maize grain. Despite the fact that eviscerated carcass weights and eviscerated carcass percentage of birds were heavier for birds fed on diets containing maize grains than other treatment groups, the major muscle parts of the carcass such as thigh and breast weight were heavier for birds on diet containing wheat grains than the other treatment group.

4. Barley grain

The use of barley in poultry diet has been limited because of its inconsistent nutritional value, contribution to wet and sticky faeces and depressed animal performance (Gohl et al., 1978; Hesselman et al., 1982; Rotter et al., 1989). The ability of soluble fibre to retard postprandial release of nutrients from the gut almost certainly arises from increased viscosity and a reduced rate of mixing and diffusion (Morris, 1990). The addition of non–starch polysaccharides (NSP) splinting enzymes to barley diets ameliorates the negative effects of soluble fibre on nutrient utilization and broiler chicken performance (Campbell and Bedford, 1992). Barley is low in energy, high in fibre and less palatable compared to maize, sorghum and wheat (Jadhav and Siddiqui, 2010).

In an experiment, Vukic and Wenk (1995) evaluated the influence of extruded versus untreated barley in the feed, with and without dietary enzyme supplement on broiler performance. They reported that extrusion increased viscosity and water binding capacity of the barley, and chickens fed extruded barley in the diet increased water consumption. There was significant depression in feed efficiency, feed apparent metabolizable energy (AME), fat and protein utilization of broiler chicken performance when extruded barley was included in the diet. In general, enzyme supplemen tation had more impact on chick growth performance than extruded barley. Weight gain, feed intake and feed efficiency were increased by the addition of enzyme to barley (Vukic and Wenk, 1995). Similar, experiment conducted by Ankrah et al. (1999) on hydrothermal and β-glucanase effects on the nutritional and physical properties of starch in normal and waxyhull-less barley on broiler chickens, showed that, there were no differences in body weight gain, feed intake, FCR or intestinal starch digestibility due to starch type. Feeding waxy starch barely resulted in higher digesta viscosity than normal starch barley, which was attributed to its β-glucan content (Ankrah, et al., 1999). Pelleting did not affect body weight gain, feed intake and FCR, but reduced digesta viscosity and increased starch digestibility in non-enzyme supplemented diets. β-glucanase addition improved body weight gain, feed intake, FCR and starch digestibility than normal starch hull-less barley diets (Ankrah et al., 1999).

Cereal by-products in poultry diets

Other important energy sources that be incorporated in poultry diets are the cereal by-products or agro-industrial by-products. By-products of cereal milling processes are appealing because they often have considerable amounts of protein, starch and fat. Various cereal by-products have been investigated to be useful for livestock feeding. Brewers dried grain (BDG), wheat offal, maize offal, rice bran, broken rice have been widely tested and incorporated into livestock diets (Farinu, 2004; Ajayi et al., 2005; Aderemi et al., 2006; Afolabi et al., 2006). They reported that these ingredients can be incorporated into the diet of monogastrics without any detrimental effects on the performance and health of the animals. By-products of malted cereals are preferred because they often have sufficient amount of protein as well as energy (Annison et al., 1994). They however, contain high concentrations of non-starch polysaccharides (NSP) and some tannins which have been shown to interfere with nutrient digestibility of chicks (Lacassagne et al., 1988; Longstaff and MacNab, 1991). The NSP cause a general inhibition of absorption of the macronutrients (Annison, 1993) and probably the micronutrients (Vanderliss, 1993).

Use of cereal by-products in poultry diets as energy sources

1. Rice bran

The two main by-products obtained from rice milling are the hulls and rice meal. Bran is the coarse outer covering of grains separated during processing. They are obtained from the milling of wheat, maize and rice. Bran normally contains 9 to 18% crude protein and 10 to 14% crude fibre (Atteh, 2002). They have laxative action in the gut and because of their high fibre content; they can be used as nutrient diluents for monogastric animals (Atteh, 2002). Large quantities of rice bran are produced annually in Nigeria and the composition and nutritive quality of this potential feedstuff for poultry has been determined by Warren and Farrel (1990a). Levels of 10%, 20% and 25% rice bran can be used in broiler starter, finisher and layer diets respectively with no significant decline in production (Farrel, 1994). In related experiments Warren and Farrel (1990b) reported that the apparent metabolizable energy (AME) of rice bran was estimated to be 9.6 to 10.9 mg/kg DM in broiler chickens. Oyeyiola (1991) recommended 40% inclusion rate for pullets and 20% for layers. Dafwang and Shwarmen (1996) also reported that broiler chicks could tolerate 10% rice bran in their diets, while Salami et al. (2009) recommended a safe inclusion level of 20% rice offal/bran at the expense of dietary maize for broiler starters if their diets are supplemented with exogenous enzyme (Roxazyme-G). Salami et al.(2009) concluded that the feeding value of rice bran despite its high crude fibre content and low energy contents was improved when it was included to partially replace dietary maize proportion with enzyme added. They further stated that the maximum safe inclusion level was 60% of the dietary maize proportion of the broiler finisher diet which is capable of reducing feed cost and over dependence on the expensive maize.

2. Broken rice

Broken rice is not preferred for human consumption and is disposed off for animal feeding purposes because of its lower cost (Akinusi, 1999). Rice is potential energy source (Bolton and Blair, 1977; Tyagi et al., 1994a) and feeding trials using broken rice in poultry diets have yielded good results (Phalaraksh et al., 1978; Tyagi et al., l994b). Rice milling waste (RMW) is the by–product obtained from small scale rice mills that process parboiled rice through a mechanism which combines husk removal and polishing into one operation to produce the clean grains and rice offals which contain husk, bran, polishing and small quantities of broken grains (Dafwang and Shwarmen, 1996; Akinusi, 1999). Utilization of dietary fibre like rice milling waste has been reported to reduce fat deposition in the body and increase carcass yield of the birds (Iheukwumere et al., 2001). Rice milling waste is readily available, cheap and usually discarded as waste product by burning to reduce pollution (Akinusi, 1999). In an experiment conducted by Iheukwumere et al. (2001) to evaluate the effect of treated RMW on nutrient metabolizability, carcass yield and intestinal organ weights of finisher broiler chickens, they reported that birds fed rice milling waste treated with urea had a superior final body weight, daily weight gain, dressed weight and best feed conversion ratio compared to the other treatment groups. They concluded that, this could be attributed to the effect of the urea treatment. Their report is in line with the reports of Abu et al. (1999) who showed that urea improved the nitrogen content of the treated material which invariably lead to improved performance. Similarly, Nwoche et al. (2009) reported that there was variations in mean live weight, dressed weight and percent dressed weight when local turkeys were fed with rice milling waste as substitute for dietary maize. They reported that the enhanced weight and mean dressed weight produced by turkey fed 50% RMW could be attributed to better fibre utilization by the birds. However, there are reports that the inclusion of broken rice in laying hen diets at 20% to 26% decreased egg production (Chawla et al., 1980; Tyagi et al., 1994b).

3. Maize offal

One of the envisaged alternative feedstuff is maize offal. In the manufacture of starch and glucose from maize, number of by-products are obtained, which are suitable for farm animals. The de-germ grain is finely ground and separated by wet screening (McDonald et al., 1995). This process gives rise to three by-products, the germ, bran and gluten which are collectively referred to as maize offal (McDonald et al., 1995). The offal has low energy and high fibre contents. Nsa et al. (2009) replaced 50% of maize with maize offal in broiler finisher diet should be encouraged. They further stated that maize offal is relatively cheaper than maize and should be allowed to contribute to poultry production in Nigeria. Since 50% dietary maize offal meal did not depress feed intake, weight gain and feed conversion ratio, 50% maize offal meal is recommended to conveniently replace maize in broiler finisher diets. The diets used in the study and the performance of the broilers in the reported work (Nsa et al., 2009) are presented in Tables 6 and 7 respectively.

4. Wheat bran

One of the most popular and important feed stuff is the wheat bran. It is highly palatable to stock and it has a mild laxative effect (Morrison, 1975). Wheat bran has 16.4% crude protein and 4.5% fat and usually does not contain more than 10% fibre (Morrison, 1975). Wheat bran has about 66.9% total digestible nutrients (TDN), the protein is of better quality than that of maize but it is not as good as the protein in feeds such as soybean meal (SBM), milk, meat by-products and fish by-products, (Morrison, 1975). Wheat bran is the richest source of phosphorus (1.29%) and 0.13% calcium (Morrison, 1975). With these nutrients in wheat bran, it is a good source of energy, protein and fibre in poultry ration formulation. Nuhu et al. (2008) reported that the FCR of birds fed on wheat offal diets were efficiently more utilized than those birds fed on maize offal–based diets. These workers concluded that 20% wheat offal inclusion in broiler diets is recommended to farmers.

5. Brewers' dried grain (BDG) and sorghum waste "Burkutu wastes"

The use of brewers' dried grains and sorghum wastes is gaining popularity especially now that the prices of cereal grains are increasing. Sorghum wastes are by-products obtained from the processing of sorghum to produce "Burkutu", a local beer. It is abundant all the year round in cities and villages where local beer is being made.

In poultry, Uchegbu and Udedibie (1998) found that up to 75% of maize in broiler finisher can be replaced with sorghum dried brewers' grains without reducing performance. They advocated for the use of the product as a way of reducing costs. Kwari et al. (1999) noticed that up to 40% of maize could be replaced by sorghum wastes in diets of laying chickens without deterioration in performance. Studies carried out by Igwebuike et al. (2001) to evaluate the replacement value of spent sorghum grains (SSG) for maize in broiler finisher diets, reported that the final body weight, daily weight gain were similar. Feed intake and FCR did not differ significantly in all the treatment groups. The FCR reported by Igwebuike et al. (2001) was superior to the values reported by Uchegbu and Udedibie (1998) but can be compared favourably with the values reported by Abu et al. (2000) who fed moderate fibre diets to broiler finisher chickens. Feed cost per kg was better with birds fed on SSG than maize as reported by Igwebuike et al. (2001). They concluded that the use of sorghum wastes reduced feed cost and resulted in higher profit margin. Table 8 shows the chemical composition of sorghum wastes "burkutu waste" as reported by various scientists.

6. Millet bran

The protein content of millet grain compares favourably with that of wheat, barley and maize, varying from 8.6 to 17.45%, with the largest proportion found in bran (Rooney and McDonough, 1981). The lipid content of millet bran ranges from 3.0 to 14.45% with free fatty acid level of about 2 to 12% (Rooney and McDonough, 1981). No condensed tannin has been reported in millet bran (Sullins and Rooney, 1977). In an experiment (Diarra et al., 2002) chickens fed millet bran in place of wheat bran consumed more feed, when millet bran was substituted for wheat bran in broiler chicken diet, although, weight was not affected. Furthermore, cost per kg gain was better in the groups receiving millet bran.

Table 6: Gross composition of the experimental diets

Ingredients (%)	T_0	T_1	T_2	T_3	T_4
Maize	60.00	45.00	30.00	15.00	0.00
Maize offal	0.00	15.00	30.00	45.00	60.00
Wheat offal	7.50	7.50	7.50	7.50	7.50
Palm kernel meal	4.00	4.00	4.00	4.00	4.00
Soyabeam meal	20.50	20.50	20.50	20.50	20.50
Fish meal	2.00	2.00	2.00	2.00	2.00
Palm oil	2.00	2.00	2.00	2.00	2.00
Bonemeal	2.00	2.00	2.00	2.00	2.00
Oyster shell	1.00	1.00	1.00	1.00	1.00
Lysine	0.25	0.25	0.25	0.25	0.25
Methionine	0.25	0.25	0.25	0.25	0.25
Premix	0.25	0.25	0.25	0.25	0.25
Salt	0.25	0.25	0.25	0.25	0.25
Total	100	100	100	100	100
Determined analysis					
Crude protein (%)	21.40	21.51	21.67	21.77	21.90
Crude fibre (%)	4.71	4.88	5.21	5.48	5.93
ME(kcal/kg)	2998	2914	2755	2549	2412

Source: Nsa et al. (2009)

Table 7: Performance of broiler chicken fed levels of maize offal as a replacement for maize

Parameter	T_0 (0%mo)	T_1 (15%mo)	T_2 (30%mo)	T_3 (45%mo)	T_4 (60%mo)
Initial live weight (g/bird)	420.30	421.10	422.05	417.80	422.00
Final body weight (kg/bird)	2.34	2.30	2.02	1.87	1.30
Average daily weight gain (g)	48.92	46.11	43.32	38.13	30.25
Total feed intake (g/bird)	4217.50	4274.20	4921.35	4974.90	4711.35
Average daily feed intake (g/bird)	120.50	122.12	140.61	142.14	134.61
Feed conversion ratio (FCR)	2.46	2.65	3.25	3.73	4.45
Abdominal fat (g)	1.31	1.34	1.51	1.72	1.87
Cost of 1kg feed (₦/kg)	68.25	56.41	45.34	40.72	35.19
Cost of feed consumed (₦/kg)	287.84	241.11	223.14	202.58	165.79
Cost of feed/kg live weight gain (₦/kg)	167.90	149.49	147.36	151.89	156.60

Source: Nsa et al. (2009); MO = Maize offal

Constraints

Although, the importance of cereal and cereal by-products as a source of feed ingredient in poultry production cannot be underestimated. They also have some negative effects on performance.

Sorghum contains the anti-nutritive factor, tannins, which lower the nutritive values of the grain for non-ruminants (Jacob et al., 1996). Another characteristics of tannins as anti-nutritive factors for non-ruminant animals are reduction of dry matter and protein digestibility (Gualittieri and Rapaccini, 1990). Inhibition of the digestive enzymes had also been reported *in vitro* (Griffiths, 1981) and *in vivo* (Longstaff and McNab, 1991).

Millet contains C-glycosyl flavones, carbon hydrate C-C linked to a flavonoid nucleus) which appeared to be resistant to hydrolysis (Reichert et al., 1980). Although NRC (1996) reported that millet has no tannins, recent findings are proving otherwise; millet has tannins which tend to bind both exogenous and endogenous proteins including enzymes of the digestive tract, thus affecting the utilization of proteins (Griffiths, 1985, Asquith and Butler, 1986). Medugu et al. (2010) reported that millet used in their study contained 2.32% tannin. Whether this is environmental or varietal specific is yet to be ascertained.

Some of the limiting factors associated with cereal by-products as animal feedstuffs include; cost of procurement, availability, poor intake, high fibre content, low digestibility of nutrient content and subsequently low animal performance (Adegbola and Oduozo, 1992). In a study conducted by Southgate and Damin (1970) and Nwokolo and Brady (1985), it was found that as intake of dietary fibre increases, the apparent digestibility of the diet decreases. The presence of fibre has also been shown to depress mineral availability in feedstuff (Hunger, 1981).

Solutions

There are some methods employed to remove or reduce anti-nutritional factors in feedstuff. These methods enhance the absorption and utilization of nutrients by the digestive tract and are summarized below:

1. Cooking was reported (Kaankuka et al., 1988) to lower phytic acid levels of feed.
2. Supplementation of high-tannin diets with orthophosphoric acid or dicalcium phosphate (Ibrahim et al., 1988) or sodium bicarbonate (Banda-Nyirenda and Vohra, 1990) had a positive effect in terms of detoxification of tannins. Addition of chemicals with high affinity for tannins such as polyethylene g1yco1 and gelatin (Salunkhe et al., 1990) has been shown to reduce the adverse effect of tannins. They explained that the chemicals would bind dietary tannin thereby preventing the tannins from binding to nutrients.
3. Thorough investigation of the chemical composition of the nutrients.
4. Amino acid, tannin and fibre levels should be checked, otherwise utilization will be affected; and
5. Availability and cost must be critically evaluated to justify the use of alternative feed ingredients in poultry diet.

Conclusions

The use of low-tannin sorghum in poultry diet is similar to maize in nutritional value and gives response equivalent to maize in terms of performance and reduced cost. Inclusion level of sorghum lower than 10g/kg was similar to that of maize; this implies that high-and-low tannin sorghum can be incorporated in poultry diets as a replacement to maize without adverse effect on performance. Inclusion level of 50% millet in pou1try diet resulted in better performance and carcass quality of broiler chickens. In cockerels, pearls millet diet had no effect on body weight gain, feed intake and feed conversion ratio. Inclusion level of up to 600g/kg millet gave excellent egg production, thus, diets formulated with millet have no negative effects on egg production and egg weight. The use of cereal by-products in poultry production led to reduction of feed cost. Hence, increase in poultry production, although inclusion levels vary due to their nutrient content, palatability and other anti-nutritive factors that limit their utilization. Inclusion levels of 75%, 50%, and 26% of brewer's dried grain (BDG), maize offal and rice offal respectively can be used as a replacement for maize in poultry diet. Therefore, the use of alternative grains and cereal by-products in poultry diets should be adopted as a means of reducing feed cost.

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