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Digestibility of feeds in broiler chicken (G*alus galus* linnaeus, 1758) in Africa: a review

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ABSTRACT

Feed digestibility indicates how much the body uses feed and its nutrients. This study aimed at making a literature review on the digestibility of balanced feed given to broiler chicken in Africa. Data used for this literature review were collected through many scientific papers published from 2008 to 2018 and uploaded to Google Scholar, Pubmed, Agora search engines and in national university libraries. Numerous scientific studies in this field indicate that more than forty feedstuffs are commonly used to formulate balanced feed delivered to broiler chicken in modern system in Africa. Feed digestibility is generally assessed *in vivo* by the direct method in broiler chicken. The data compiled shows that feed digestibility of broiler chicken varies enormously depending on the feedstuffs in balanced feed and also on their incorporation rate. This literature review reveals that balanced feeds used to feed broiler has Apparent Digestibility more than 50%.

Keywords: Balanced feed, *In vivo* digestibility, Broiler chicken, Africa.

INTRODUCTION

In modern poultry production, breeders produce themselves or purchase feeds made by products and byproducts, minerals and vitamins (Traore and Bebay, 2006). Thus, balanced feed offered to broiler may vary depending on the available feedstuffs. However, this balanced feed can be digested differently by broiler chicken. It must undergo a series of physical and chemical actions prior to obtaining simple, absorbable constituents called nutrients (Sauvant, 2004). In broiler, the transit of food for their digestion is relatively fast and lasts an average of twenty-four (24) hours (Deiltel et al., 2012).

Ingested feed are not absorbed in total by body: part of the ingestas is not used and passes through the digestive tract and is found excreted in faeces (Deiltel et al., 2012). "Feed digestibility" indicates how much the body uses feeds or nutrients (Deiltel et al., 2012). Nutrient digestibility refers to the notion of bioavailability. It depends on the animal (species, strain, age), the composition of feedstuff, and eventual technological treatments (thermal and / or mechanical).

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A digestible fraction of food is the part of the "ingesta" that is not found in the faeces. Digestibility is the main factor of variation in the energy value of feed. Digestibility is therefore an index of the disappearance of food in the intestine, but not of the efficiency of use of food by animal metabolism. A food can be very digestible without providing enough nutrients to make up needs of animal.

FEED DIGESTIBILITY IN BROILER AND BALANCED EXPERIMENT

Feed digestibility in broiler chicken

The feed ingested by chicken is not entirely used by his body; part of "ingestats" passes through the digestive tract and is found in the faeces. In poultry, the determination of digestibility is complex and very delicate, because the faeces and urine are evacuated together by the same orifice which is the cloaca (Dimi, 1990). Urine compounds are mostly nitrogenous. The separation is then based on the fact that most of the urinary nitrogen is in the form of uric acid and that almost all of the fecal nitrogen is of a protein nature (Mahoungou-Mouéllé, 1996). Consequently the requirement and feed composition are expressed in metabolizable energy.

In vivo digestibility study makes it possible to better understand the percentage of nutrient utilization (organic matter, amino acids, fat and metabolizable energy) absorbed in digestive tract and which constitutes the fraction that can be used for metabolism (INRA, 1989). It is a quantitative concept that results in digestibility coefficient (INRA, 1989, Adoum, 2007). There are two types of digestibility coefficients: Apparent Digestibility Coefficient and the Real Digestibility Coefficient.

Most studies on broiler chicken in Africa focus on feed apparent digestibility, limiting themselves to the balance between the nutrients of ingestats and excretas.

Determination of Apparent Digestibility in broiler chicken

According to Rivière (1991), food digestibility can be determined from three (03) groups of methods: (i) *In vivo* methods; (ii) in vitro methods (laboratory method); iii) Mathematical or prediction methods.

Direct method *in vivo* is used in the scientific papers used for this literature review. It is based on faecal digestibility measurements, the method of which was standardized in 1995 by the EGRAN group (Guermah, 2012). Representative sampling is used because slight differences in digestive function in broiler of the same breed, age and sex. Repetitions allow the detection of errors (Rivière, 1991). Feed samples as well as faeces samples are dried and used in the laboratory to determine their chemical composition according to the methods recommended by AOAC (1991); AOAC (2000). This chemical composition includes nutrients such as Dry Matter (DM), Crude Protein (CP), Fatty Matter (EE), and Crude Fiber (CF).

A typical digestibility experiment is conducted over a period of five (05) to ten (10) days by feeding daily experimental chicken. Before starting digestibility test, a period of acclimatization and food transition of 3 to 4 days is observed. To the experimental period are added stages of droppings drying, grinding and analysis (Bourdillon et al., 1990). Experiment on the assessment of feed digestibility in broiler chicken is carried out in digestibility cages equipped with a faeces collection device, on chickens that age and sex are known. Broilers are individually arranged per digestibility cage and data is collected daily by chicken. Thus, the quantities of feed delivered and refused as well as those of faeces are weighed and recorded daily.

After evaluation of the chemical composition of samples of feed served, refused and faeces, Apparent Digestibility of the experimental diet in its nutrients is calculated by its following formula:

Apparent digestibility = [(%Nutrients in feed X FI) – (%Nutrients in faeces X FO)]/ %Nutrients in feed X FI x100;

Where FI= feed intake and FO= faecal output Apparent digestibility determination in broiler chicken.

CONCENTRATED FEEDSTUFFS IN BROILER CHICKEN BALANCED FEED IN AFRICA

The rich tropical biodiversity, the great diversity of agricultural production systems in African countries in general and the presence of small agro-processing units contribute to a wide range of feedstuffs that can be used to feed animals (Archimède et al., 2011). The diet of chicken and rabbit generally involves two main types of concentrated feedstuffs (CFS): cereals and by-products.

These CFS include crop products; agro-industrial food and animal products and by-products. Their use depends mainly on the availability in the region, the season, the price and their ability to be kept for a long time (Toléba et al., 2007). Forty-four (44) different CFS used in the feeding of chicken in Africa and listed in this literature review are: Baobab leaf meal, Blood meal, Brewer Dried grains, Cassava flour, Cassava peel meal, Cottonseed cake, *Dacryodes edulis* Seed Meal, Degraded brewer dried grains, Ethanol-treated castor oil seed meal, Fermented *Parkia biglobosa* seed meal, Fermented *Terminalia catappa* whole fruit meal, Fish meal, Fresh bovine rumen epithelia tissues scrapings, Full fat soybean meal, Groundnut meal, Lime juice, Local processed groundnut cake meal, Maize (Yellow), Maize bran, Maize offal, Maize, Moringa leaf meal, Oil-sunflower, Okara, Palm kermel cake, Palm kernel meal, Palm oil, Palm oil sludge, Rye, *Senna obtusifolia* seed meal (raw, boiled, soaked, fermented), Sorghum varieties, Soy oil, Soya bean meal, Soya beans, Sunflower meal, Sweet orange peel meal, Treated Banana Peel Meal, Undecorticated Sunflower Seed Meal, Undegraded brewer dried grains, Urea fermented brewer's dried grains, Vegetable oil blend, Wheal Offal, Wheat bran, Whole soyabean.

Moreover, in the modern system, the diet of the broiler chicken is also based on the use of some vitamins, minerals amino acids and pigments (N'gom, 2004; Guindjoumbi, 2007; Kpodékon et al., 2009). In this category, twenty-two (22) feedstuffs in this category are commonly used in Africa. These feedstuffs are: Bone meal, Celite, Choline chloride, Chromic oxide premix, DCP, Dextrose, Dicalcium Phosphate, DL Methionine, Lime stone, L-Lysine, L-Lysine-HCl, Methionine, Mineral premix, Monocalcium phosphate, Oyster shell, Premix, Salt, Sodium bicarbonate, Sodium Chloride, Vitamin, Vitamin/mineral premix, Washed building sand.

APPARENT DIGESTIBILITY OF BALANCED FEED IN BROILER CHICKEN

Several authors in Africa studied feed digestibility in improved chicken fed with balanced diets based on various conventional and unconventional concentrated feedstuffs. Table 1 presents the digestibility of balanced feeds in broiler chicken in Africa. The apparent digestibility varied according rate of the feedstuff tested in study. Indeed, most of these digestibilities have been evaluated following the use of a feedstuff at different levels of incorporation into a basic diet formula. Majority of nutrients in balanced feeds delivered to broiler chicken in Africa are well digested. Digestibility Coefficient of the dry matter in balanced feed varied greatly from a study to another: they are greater than 55% and range from 56 to 97%. The lowest Digestibility Coefficient of dry matter is 56%. The digestibility of crude protein varies from 52 to 92%. However, a very low crude protein digestibility ranging from 13 to 47% were recorded in studies. The lowest fat digestibility recorded was 6% when most of fat digestibility varies from 46 to 93%. Crude fiber whose high content in balanced feed hampers the proper functioning of the digestive system are digested at a rate ranging from 50 to 76%. However, some low digestibilities of crude fiber ranging from 6 to 46% are recorded.

Tableau 1: Apparent digestibility of some balanced feeds in broiler in Africa.

Experimental Feedstuffs (Rate in the feed)	Feed composition	DDM (%)	DCP (%)	DEE (%)	DCF (%)	Authors (Country)
Ethanol-treated castor oil seed meal (10; 15; 20 kg/100 kg)	Ethanol-treated castor oil seed meal, Maize, Soya bean meal, Fish meal, Wheat offal, Bone meal, Oyster shell, Lysine, Methionine, Vit.Min premix, Salt	84.49-84.91	67.59-73.99	74.53-76.98	60.02-63.65	Sobayo et al., 2012 (Nigeria)
Acid organic (0.25 kg/100 kg)	Acid organic, Maize, Soybean meal, Fish meal, Palm kermel cake; Bone meal, Salt, Lysine, Methionine, Premix	66.44	62.87	60.76	31.82	Ndelekwete et al., 2016 (Nigeria)
Fermented *Parkia biglobosa* seed meal (0; 5.75; 11.50; 17.25; 23 kg/100 kg)	Fermented *Parkia biglobosa* seed meal, Maize, Wheat offal, Groundnut cake, Palm kernel cake, Fish meal, Blood meal, Bone meal, Lysine, Methionine, Vit/premix, Salt	ND	72.34-89.15	81.71-92	51.74-68.37	Obun, 2008 (Nigeria)
Moringa leaf meal, Baobab leaf meal (0; 0.15 kg/100 kg)	Moringa leaf meal, Baobab leaf meal, Maize, Soyabean, Wheat offal, Fish meal, Bone meal, Premix, Methionine, Lysine, Salt	66.26-79.66	81.71-88.27	66.46-83.24	ND	Igwebuike et al., 2017 (Nigéria)
Avizyme 1505, Phyzyme xp (0; 0.07; 0.2 g/1000 g)	Avizyme 1505, Phyzyme xp, Maize, Soybean meal, Full fat soybean meal, Rye, Vegetable oil blend, Dicalcium Phosphate, Limestone, Nacl, Vit+Premix, DL-Methionine, L-Lysine Washed builiding sand	74.3-75.7	65.9-71.4	77.9-84.1	13.4-16.3	Youssef et al., 2014 (Egypt)
African yam bean cake (0; 3.86; 7.72; 11.65; 15.50	African yam bean cake, Maize, Soybean,	96.45-96.97	38.86-40.42	52.02-52.97	63.72-65.11	Raji et al., 2015 (Nigéria)

Experimental Feedstuffs (Rate in the feed)	Feed composition	DDM (%)	DCP (%)	DEE (%)	DCF (%)	Authors (Country)
kg/100 kg)	DCP, Lime stone, Salt, Lysine, Methionine, Premix					
Okara (0; 2.375; 4.75; 7.125; 9.50; 9.50 kg/100 kg) Cassava peel meal (0; 0.375; 0.750;1.125;1.50; 1.50 kg/100 kg)	Okara, Cassava peel meal, Maize, Soybean meal, GNC, Wheat offal, BDG, Palm oil, Fish meal, Bone meal, Oyster shell, DL Methionine, Lysine, Premix, Nacl	72.36-79.79	79.04-81.36	80.96-84.56	46.51-53.64	Silas et al., 2014 (Nigéria)
Palm kernel meal (0; 10; 20; 30; 40 kg/100 kg) supplemented enzyme Hemicell (0; 0.05 kg/100 kg), RoxazymeG (0; 0.02 kg/100 kg)	Palm kernel meal, Hemicell, RoxazymeG, Maize, Soybean meal, Palm oil, Bone meal,Limestone, Salt, Premix, Methionine, Lysine, Fish meal	58.43-71.18	46.59-60.12	49.34-68.05	28.31-39.91	Aya et al., 2013 (Nigéria)
Senna obtusifolia seed meal (0; 20 kg/100 kg) Raw *Senna obtusifolia* seed meal (0; 20 kg/100 kg) Boiled *Senna obtusifolia* seed meal (0; 20 kg/100 kg) Soaked *Senna obtusifolia* seed meal (0; 20 kg/100 kg) Fermented *Senna obtusifolia* seed meal (0; 20 kg/100 kg/100 kg)	*Senna obtusifolia* seed meal (raw, boiled, soaked, fermented), Maize, Maize offal, Soya bean meal, Fishmeal, Groundnut cake, Salt, Bone meal, Methionine, Lysine, Premix	92.79-93.54	18.64-19.98	6.57-7.55	5.90-8.84	Augustine Clement et al., 2017 (Nigéria)
Moringa leaf meal (0; 5; 10; 15; 20 kg/100 kg)	Moringa leaf meal, Maize, Soybean meal, Groundnut cake, Fish meal, Wheat offal, Brewwer Dried grains, Palm oil, Bone meal, Oyster shell, Salt, Premix, Methionine, Lysine,	58.06-64.44	ND	61.48-68.71	22.15-23.59	Tijani et al., 2016 (Nigéria)
Maize (56 kg/100 kg)	Maize, Wheat bran, Whole soyabean, Fish meal, Bone meal, Premix, Methionine	89.56	92.77	87.83	67.46	Kwari et al., 2011 (Nigéria)

Experimental Feedstuffs (Rate in the feed)	Feed composition	DDM (%)	DCP (%)	DEE (%)	DCF (%)	Authors (Country)
Sorghum varieties (56 kg/100 kg)	Wheat bran, Whole soyabean, Fish meal, Bone meal, Premix, Methionine	87.34-88.89	87.06-95.87	83.65-92.95	65.62-68.70	Kwari et al., 2011 (Nigéria)
Maize bran (0; 10; 20; 30 kg/100 kg)	Maize bran, maize, Wheat bran, Cottonseed cake, Soybean meal, Palm oil, Lysine, Methionine , Oyster shell, DCP, Premix Salt	75.40-77.28	ND	ND	ND	Guédou et al., 2016 (Bénin)
Dacryodes edulis Seed Meal (0; 15; 30; 45; 60 kg/100 kg)	*Dacryodes edulis* Seed Meal, Maize, Full fat soybean meal, Blood meal, Wheat offal, Fish meal, Bone meal, Oyster shell, Salt, Vitamin, Mineral premix, Methionine	56.30-63	ND	ND	40.63-56.28	Bratte, 2010 (Nigéria)
Lime juice (1.00; 1.50; 2.00; 2.50 kg/100 kg)	Lime juice, Maize, Soybean meal, Fish meal, Palm kernel cake, Wheat offal, Bone meal, Salt, Lysine, Methionine, Premix	75.05-77.05	65.23-78.87	74.03-88.23	45.05-46.03	Ndelekwute and Enyenihi, 2017 (Nigéria)
Undecorticated Sunflower Seed Meal (0; 9 ; 17.8 ; 26.4 kg/100 kg)	Undecorticated Sunflower Seed Meal, Maize, Fish meal, Soybean meal, Sunflower meal, Groundnut cake, Wheat offal, Bone meal, Oyster shell, L-Lysine-HCl, DL-Methionine, Premix, Sodium Chloride	83.30-87.48	64.78-68.11	60.75-69.61	62.94-76.61	Faliolu et al., 2015 (Nigéria)
Local processed groundnut cake meal (0; 6.50; 13.0; 19.50; 26.0 kg/100 kg)	Local processed groundnut cake meal, Maize, Soya beans, Fish meal, Wheat offal, Oyster shell, Bone meal, Premix, Salt, Lysine,	88.40-91.60	76.77-91.67	85.87-94.60	57.83-83.80	Aguihe et al., 2013 (Nigéria)

Experimental Feedstuffs (Rate in the feed)	Feed composition	DDM (%)	DCP (%)	DEE (%)	DCF (%)	Authors (Country)
	Methionine					
Treated Banana Peel Meal (0 ; 5.64 ; 11.28 ; 16.92 kg/100 kg)	Treated Banana Peel Meal, Maize, Soybean Meal, Groundnut cake, Brewers Dry Grain, Wheal Offal, Palm oil, Fish Meal, Bone Meal, Oyster Shell, Lysine, Methionine, Premix, Salt	81.63-87.21	79.38-87.52	90.78-93.39	71.09-76.36	Fas et al., 2015 (Nigéria)
Fresh bovine rumen epithelia tissues scrapings (0; 1.25; 2.5 kg/100 kg)	Fresh bovine rumen epithelia tissues scrapings, Maize, groundnut Cake Soybean meal, Palm kernel Cake, Fish meal, Wheat offal, Oyster shell, Bone meal, Salt, Methionine, Lysine, Vit./Mineral Premix	68.82-69.87	71.81-81.77	67.78-69.43	51.43-66.44	Salami et al., 2013 (Nigéria)
Low energy and high crude protein, high energy and low crude protein, normal energy and normal crude protein, Low energy and low crude protein	Maize, Maize offal, Soybean meal, Groundnut meal, Fish meal, Bone meal, Oyster shell, NaCl, Vitamins and minerals premix, Lysine, Methionine, Palm oil sludge	60.3-69.3	52.0-62.0	60.7-69.1	68.5-70.3	Dairo et al., 2010 (Nigéria)
Fermented *Terminalia catappa* whole fruit meal (0; 9; 18; 27; 36 kg/100 kg)	Fermented *Terminalia catappa* whole fruit meal, Maize, Soybean meal, Wheat offal, Cassava flour, Fish meal, Blood meal, Bone meal, Oyster shell, DL-Methionine, Lysine, Vit/min premix, Salt	ND	62.80-72.10	58.60-75.40	25.70-42.30	Apata, 2010 (Nigéria)
Degraded brewer dried grains (0; 3; 5; 7 kg/100 kg)	Degraded brewer dried grains, Maize, Wheat offal, Groundnut cake,	75.05-80.04	73.93-79.73	53.82-62.54	50.54-57.32	Lawal et al., 2016 (Nigéria)

Experimental Feedstuffs (Rate in the feed)	Feed composition	DDM (%)	DCP (%)	DEE (%)	DCF (%)	Authors (Country)
	Soya bean meal, Fish meal, Bone meal, Oyster shell, Premix, Salt, Lysine, Methionine					
Undegraded brewer dried grains (0; 7 kg/100 kg)	Undegraded brewer dried grains, Maize, Wheat offal, Groundnut cake, Soya bean meal, Fish meal, Bone meal, Oyster shell, Premix, Salt, Lysine, Methionine	70.90-71.37	68.88-69.70	46.24-49.30	34.53-35.46	Lawal et al., 2016 (Nigéria)
Urea fermented brewer's dried grains (0; 8.32 16.70; 25.00; 33.5 kg/100 kg)	Urea fermented brewer's dried grains, Maize (Yellow), Groundnut cake, Fish meal, Blood meal, Oyster shell, Bone meal, Palm oil, Premix, Methionine, Salt	60.19-81.73	13.27-20.05	ND	ND	Isikwenu, 2008 (Nigéria)
Sweet orange peel meal (0; 4.90; 9.80; 14.70; 19.60; 24.50 kg/100 kg)	Sweet orange peel meal, Maize, Soybean meal, Brewers dried grain, Blood meal, Bone meal, Common salt, Methionine, Lysine, Vitamin/mineral premix	ND	60.23-64.48	62.69-66.88	57.49-62.83	Oluremi et al. 2017 (Nigéria)
Sorghum varieties (45 kg/100 kg) supplemented with 500 FTU microbial phytase and 1600 BXU xylanase	Sorghum varieties, Soyabean, L-lysine, DL-Methionine, Vitamin-mineral premix, Limestone, Salt, Monocalcium phosphate, Sodium bicarbonate, Oil-sunflower, Celite	ND	61.0-66.0	66.0-77.0	ND	Mabelebele et al., 2017 (South Africa)
Corn (91.1 kg/100 kg)	Soy oil, Salt, Limestone, Monocalcium phosphate, Chromic oxide premix, Choline	ND	63.3	ND	ND	Iyayi and Adeola, 2014 (Nigéria)

Experimental Feedstuffs (Rate in the feed)	Feed composition	DDM (%)	DCP (%)	DEE (%)	DCF (%)	Authors (Country)
	chloride, Vit-min premix					
Sorghum (85.0 kg/100 kg)	Soy oil, Salt, Limestone, Dextrose, Monocalcium phosphate, Chromic oxide premix, Choline chloride, Vit-min premix	ND	66.9	ND	ND	Iyayi and Adeola, 2014 (Nigéria)
Full fat soybean (55.6 kg/100 kg)	Soy oil, Salt, Limestone, Dextrose, Monocalcium phosphate, Chromic oxide premix, Choline chloride, Vit-min premix	ND	78.8	ND	ND	Iyayi and Adeola, 2014 (Nigéria)
Fish meal (32.6 kg/100 kg)	Soy oil, Salt, Limestone, Dextrose, Monocalcium phosphate, Chromic oxide premix, Choline chloride, Vit-min premix	ND	82.1	ND	ND	Iyayi and Adeola, 2014 (Nigéria)
Peanut flour (31.1 kg/100 kg)	Soy oil, Salt, Limestone, Dextrose, Monocalcium phosphate, Chromic oxide premix, Choline chloride, Vit-min premix	ND	81.7	ND	ND	Iyayi and Adeola, 2014 (Nigéria)
Wheat bran (48.1 kg/100 kg)	Soy oil, Salt, Limestone, Dextrose, Monocalcium phosphate, Chromic oxide premix, Choline chloride, Vit-min premix	ND	38.1	ND	ND	Iyayi and Adeola, 2014 (Nigéria)

DDM= Dry Matter Digestibility; DCP= Digestibility Crude Protein; DEE= Ether Extract Digestibility; DCF= Crude Fiber Digestibility; ND= Not Determined

Conclusion

A total of twenty-five (25) scientific articles were used to provide information on balanced feed digestibility in broiler chicken, in Africa. The data demonstrate that the compound feeds delivered to chicken are often digestible. This inventory will be useful to assess the digestibility of each of concentrated feedstuffs in broiler chicken to develop a table of their nutritional composition in Benin.

COMPETING INTERESTS

The authors declare that they have no competing interests.

AUTHORS' CONTRIBUTIONS

GSTA collected scientific papers on feed digestibility in broiler chicken published from 2008 to 2018 in Africa. After compiling and analyzing informations collected, she wrote the paper draft. Après avoir compilé et analysé les informations collectées, elle a rédigé le projet d'article. FMH, CAAMC and GAM read and corrected the paper draft before submission.

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