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RESEARCH ARTICLE

Nutrient Digestibility Values and Apparent Metabolizable Energy of Corn, Wheat and Sorghum by Pheasants (*Phasianus colchicus*)

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ABSTRACT

Apparent nutrient digestibility and metabolizable energy of selected grains by different types of pheasants was assessed. Wheat, sorghum and maize were fed in mash to four different types (n=72) adult male pheasants e.g., Cheer, Silver, Ring necked and Golden for eight days. Birds from each type (n=18) were replicated (n=9) with 2 birds per replicate in metabolic cages (n=36) for feces collection. Different nutrients and gross energy in grains and feces were measured and digestibility coefficients and apparent metabolizable energy were determined. Dry matter digestibility was maximum for maize (0.801) followed by wheat and sorghum, respectively. Organic matter was significantly more digestible in maize fed cheer pheasants (0.833) to wheat (0.802) and sorghum (0.786). Nitrogen retained in maize fed birds was higher 12.24 and 23.32% to wheat and sorghum, respectively. Fat from wheat was less digestible ranged from 0.668 to 0.687 in different type of pheasants. Digestibility of fibre was higher in Cheer type (0.627) and lower in Ring Necked pheasants (0.60). Higher calcium digestibility (0.528) was noted in maize fed Golden pheasants and lowest for sorghum (0.477) fed Ring Necked pheasants. Digestibility coefficient of phosphorus in maize (0.531) and wheat (0.515) was higher fed to Cheer pheasants. Apparent metabolizable energy of maize was significantly greater (13.4 MJ/kg) compared to wheat and sorghum. It can be deduced that both cereal and pheasant type influence nutrient digestibility and metabolizable energy differently. More accuracy is needed in digestibility values in formulating ration for pheasants from different sources.

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INTRODUCTION

Pheasant (*Phasianus colchicus*) is a common game bird found everywhere. Presently 52 different types have been identified globally (Riley and Schulz, 2001; Gonzalez-Redondo and Garcia-Dominguez, 2012). Of these only 6 are indigenous to Pakistan. Population of the pheasants is declining due to various ecological factors including lack of balanced feed sources in the form of wild seeds and insects. In Khyber Pakhtunkhwa captive breeding program in *Dhodial*, district Mansehra was initiated in early 1980's to maintain pheasant's population. There has been a great amount of work done on the natural population, distribution and other ecological needs of pheasants including seasonal behavior and reproduction. However, no or less work has been done on the nutrient requirements and ration of pheasants. Nutrients requirements of chicken have been regularly examined by different research groups, e.g. National Agriculture Research Council, Degussa, Rhône-Poulenc at different parts of the world and ages of birds. There is however dearth of information on the nutrient requirements of pheasants in captivity. Pheasants mostly relay on seeds and insects in wild of their own choice to fulfill their nutrient requirements (Doxon, 2005). These birds when raised in captivity are fed commercial poultry rations. The provision of commercial poultry feed to pheasants can either led to under or over nourishment resulting poor performance and wastage of nutrients. Nutrient requirements of the different poultry species are different due to differences in the efficiency of nutrient utilization, digestive enzymes production, body size and homeostatic mechanism. Moreover, the digestibility of nutrients in different cereals are different mainly due to differences in physical structure, distribution of starch and protein granules and the presence of various anti-nutritional factors (Leeson and summers, 2005). Assessment of the nutrient digestibility of individual cereal grain is of great importance to formulate a balanced diet to fulfill the nutrient requirements of poultry and other game birds. To avoid the confounding factors of the nutrients from other ingredients in complete diet individual cereal grain are either tube fed or fed for classical total collection to determine nutrient digestibility. Digestibility of the nutrients of wheat, maize and sorghum has been studied for both meat and egg type birds (NRC, 1994) but lesser or no such research work has been done in pheasants particularly for pheasants reared in the pheasantry of Mansehra, Khyber Pakhtunkhwa. These grains are commonly used in ration formulation of other types of poultry birds. There is great variation in the nutrient content and digestibility of different feed ingredients and its precise and accurate data is needed for balanced ration formulation to maximize production performance of pheasants. The aim of this study is to generate some data on nutrient digestibility and metabolizeable energy that would be of great help to formulate a balanced ration to fulfill the nutrient requirements of pheasants in captivity.

MATERIALS AND METHODS

All procedures involving live birds handling and lab protocols were pre-approved by the departmental board of studies meeting and ethical committee.

Pheasant husbandry and experimental procedure: Seventy two male adult pheasants of four different varieties, Silver (n=18), Golden (n=18), Ring-necked (n=18) and Cheer (n=18) pheasants birds were obtained from the Pheasantry in Mansehra. Each variety of pheasant had 9 replicates and each replicate contained 2 birds. These birds were shifted to 36 metabolic type cages (200cm x 85cm x 70cm) (2birds/cage). Optimum environmental conditions and strict hygienic measures were adopted in all cages during experimental period (October, 2013). Wheat (Siren 2010), maize (Kisan) and sorghum (NARC 96) were procured by the Agriculture Research Institute, Tarnab Peshawar. These grains were ground to mash form and were offered to birds in completely randomized fashion in a (4 x 3 x 3) factorial arrangement.

The digestibility assay was lasted for 8 days including 4 days of adaptation. During the last four days grains offered and refused were recorded to measure feed intake. Fresh feces were collected daily morning 8:00 am, weighed and stored in labeled plastic bags in freezer (-20^{o}C). The gross energy (GE) of the diets and excreta were determined using an adiabatic bomb calorimeter (at Animal Nutrition Section of Veterinary Research Institute, Peshawar) standardized with benzoic acid. One gram sample was weighed and pressed to a tablet with the help of Pellet Press (Parr Instrument Co, USA). Tablet weight was recorded and transferred to VM crucible and for combustion in the adiabatic bomb calorimeter. Gross energy for the samples was recorded. Dry matter, organic matter, ash, crude fiber, ether extract and total nitrogen content of the grains and fecal samples were determined using standard procedures (AOAC, 2000). Nitrogen was multiplied with 6.25 to get crude protein contents. Ca and P content of grains and feces samples were measured using acid digestion method and were detected using atomic absorption and spectrophotometer.

Calculations: Nutrient digestibility coefficients were calculated by the difference between the nutrients consumed and voided by the pheasants in feces using the following equation.

$$\text{Digestibility coefficients} = \frac{A-B}{A}$$

A = Quantity of nutrients consumed by the bird
B = Quantity of nutrients voided in feces

Apparent Metabolizable Energy: The AME (MJ/kg DM) values of the cereals were calculated using the following formula.

$$\text{AME grain} = \frac{\text{Energy intake - Energy lost}}{\text{Total grain intake}}$$

Statistical analyses: Data generated was statistically analyzed using completely randomized design in a factorial arrangement of (4 x 3 x 3). Means were separated based on LSD test and interaction of two factors was determined for digestibility parameters/coefficients. Statistical program SAS (2000) was used for this purpose.

RESULTS

Nutrient profile of different cereals used in the present experiment is given in Table 1. It can be seen that corn had highest fat (4%) and gross energy (17.44 MJ/kg) compared to wheat and sorghum. Gross energy of corn was higher by 3.75 and 4.62% from wheat and sorghum, respectively. It was observed that wheat had higher protein content (12.52%) followed by corn (10.19%) and sorghum (11.41%), respectively. The nutritive values of these cereals fall within the range of NRC, 1994.

Digestibility coefficient values of dry matter, organic matter, protein and crude fat of different cereal grains by different types of pheasants are shown in Table 2. Among cereal grains DM digestibility was maximum ($P<0.01$) for maize followed by wheat and sorghum, respectively. Dry matter digestibility of maize ranged from 0.791 to 0.801, wheat 0.772 to 0.783 and sorghum 0.726 to 0.742 across different pheasant types. The impact of pheasant type on the dry matter digestibility was insignificant for different cereals. However, a trend toward significance ($P<0.07$) can be observed in the values. It was noticed that digestibility coefficient of nutrients was numerically higher for Cheer pheasants compared to other pheasant types. A trend toward significance ($P<0.07$) was also observed in the interaction of pheasant type and cereals. This reflected that cereals grain’s dry matter is digested differently by different types of pheasants and *vice versa*.

Organic matter digestibility of maize among other cereal grains was maximum (0.833) followed by wheat (0.802) and sorghum (0.786) by cheer pheasants.

Table 1: Nutrient profile (% Dry matter basis) of corn, wheat and sorghum used in the experiment

Nutrient	Corn	Wheat	Sorghum
Dry Matter	88.56	88.06	89.05
Organic Matter	98.02	97.97	97.87
Protein	10.19	12.52	11.41
Fat	4.4	1.5	3.2
Crude Fiber	2.3	2.2	2.4
Total P	0.3	0.3	0.29
Ca	0.05	0.04	0.05
Crude ash	1.98	2.03	2.13
Gross energy (MJ/kg)	17.44	16.81	16.67

Table 2: Apparent total tract digestibility co-efficient of dry matter, organic matter, protein and fat of cereals by different types of pheasants

Pheasant type	Cereal	Digestibility coefficient			
		Dry matter	Organic matter	Protein	Fat
Cheer					
	Maize	0.801[a]	0.833[a]	0.587[a]	0.763[a]
	Wheat	0.783[b]	0.802[b]	0.523[b]	0.687[c]
	Sorghum	0.742[c]	0.786[c]	0.476[c]	0.721[b]
Golden					
	Maize	0.791[a]	0.823[a]	0.570[a]	0.757[a]
	Wheat	0.776[b]	0.792[b]	0.521[b]	0.672[c]
	Sorghum	0.726[c]	0.772[c]	0.466[c]	0.722[b]
Silver					
	Maize	0.798[a]	0.816[a]	0.572[a]	0.760[a]
	Wheat	0.779[b]	0.799[b]	0.512[b]	0.671[c]
	Sorghum	0.732[c]	0.762[c]	0.471[c]	0.717[b]
Ringed Neck					
	Maize	0.800[a]	0.810[ab]	0.579[a]	0.762[a]
	Wheat	0.772[b]	0.812[b]	0.531[b]	0.668[c]
	Sorghum	0.739[c]	0.779[c]	0.458[c]	0.711[b]
Pooled SEM		0.02	0.03	0.03	0.04
Probability of greater F-values in ANOVA					
Pheasant type	P-value	0.07	0.06	0.07	0.08
Cereal	P-value	0.01	0.01	0.01	0.01
Pheasant type * cereal	P-value	0.07	0.08	0.09	0.07

Mean in columns carrying different superscripts are significantly different

Digestibility coefficients of OM of different grains remained insignificant across different types of pheasants. Range of organic matter digestibility in maize was 0.810 to 0.833, wheat 0.792 to 0.812 and sorghum 0.762 to 0.786 across different pheasant types. No significant influence of pheasant type was seen on organic matter digestion. There was however a trend toward significance (P<0.06) in the values. Interestingly the digestibility coefficients values of OM were numerically higher in Cheer pheasants except for wheat that was higher in ringed neck birds. Lesser but a trend toward significance (P<0.08) was also observed in the interaction of pheasant type and cereals reflecting that organic matter from different cereals is digested differently by different types of pheasants and *vice versa*.

Nitrogen retention from maize was higher by 12.24 and 23.32% compared to wheat and sorghum in Cheer pheasants. Lowest nitrogen retention (0.458) was observed for sorghum in Ring Neck pheasants. There was a numerical variation, statistically indifferent in the nitrogen retention of same type grain across different pheasant types. The difference in nitrogen retention of different cereal grain was significant. This study revealed that the pheasant type had no influence (P>0.05) to differently digest nitrogen content of cereal grains. Interaction between pheasant type and cereal grain was insignificant however a trend toward significance was observed (P=0.09).

It is apparent from the values that the digestibility coefficient of crude fat of wheat was poor among other cereals grains. Difference in the digestibility coefficient values for different cereals was significantly different across all pheasant types. It was observed that fat from wheat was less digestible ranged from 0.668 to 0.687. It was higher for maize (0.763) followed by sorghum (0.721) in cheer pheasants. Pheasant type did not alter (P=0.08) fat digestibility and its interaction with different cereal grains was insignificant (P=0.07).

Table 3 represents AME and digestibility coefficient ash, crude fiber, calcium and phosphorus of different cereal grains by different types of pheasants. Ash digestibility among cereal grains was maximum (P<0.01) for maize (0.627) followed by wheat (0.563) and sorghum (0.567), respectively in Cheer and Golden pheasants. Ash digestibility of maize ranged from 0.593 to 0.620, wheat 0.542 to 0.563 and sorghum 0.551 to 0.567 across different pheasant types. The impact of pheasant type on the ash digestibility was insignificant, however, a trend toward significance (P<0.07) was observed in the values of ash digestibility. It is depicted from data that numerically the digestibility coefficients of different cereals were higher for Cheer and Golden pheasants among other types of pheasants. Poor (P<0.09) interaction was observed in pheasant type and cereal grains. Changes observed in the digestibility values of ash were insignificantly affected by pheasant type.

Crude fiber from maize was maximum among other cereal grains. Its digestibility coefficient was higher in cheer type (0.627) and lower in ring neck (0.60) that was statistically indifferent among different pheasant types. There was no significant difference in the digestibility coefficients of fiber of wheat and sorghum in Cheer, Silver and Golden pheasants, however the difference was significant in Ring Neck type of pheasants. Interestingly sorghum had higher CF digestibility in the first two pheasant types and lower in the last two types. Significant influence of pheasant type was seen on fiber digestion with a trend toward significance (P<0.06) in the interaction of pheasant type and cereal grain.

Total tract digestibility of calcium and phosphorus of different cereal grains by different types of pheasants is given in Table 3. There was a significant difference (P=0.01) among different cereal grains in the digestibility coefficient of calcium across different pheasant types. Higher calcium digestibility (0.528) was recorded for maize fed to golden pheasants. Lowest was noted for sorghum (0.477) in ring neck pheasants. There was a numerical variation in the digestibility of calcium from same cereal type across different pheasant birds. This is however insignificant. Difference in the higher (0.528) and lower (0.519) level of digestibility of calcium in maize was 1.73% in different pheasant types. This difference for wheat and sorghum was 1.43 and 2.10%, respectively. It is reflected from the data that change in the digestibility of calcium was insignificant but with a tendency to significance (P=0.06). No significant interaction was seen in pheasant type and cereal grain (P=0.09).

This data revealed that there is significant difference in the digestibility coefficient of phosphorus of different cereal grains across various pheasant types except in

Table 3: Apparent metabolizable energy (AME) and digestibility co-efficient of ash, crude fiber, calcium and phosphorus of cereals by different types of pheasants

Pheasant type	*Cereal*	Apparent metabolizable energy and digestibility coefficient				
		AME	Ash	Crude fiber	Calcium	Phosphorus
Cheer						
	Maize	13.4[a]	0.607[a]	0.627[a]	0.522[a]	0.531[a]
	Wheat	12.8[b]	0.563[b]	0.583[b]	0.512[b]	0.515[b]
	Sorghum	12.7[b]	0.557[b]	0.597[b]	0.486[c]	0.486[c]
Golden						
	Maize	13.2[a]	0.620[a]	0.619[a]	0.528[a]	0.529[a]
	Wheat	12.6[b]	0.559[b]	0.580[b]	0.510[b]	0.510[b]
	Sorghum	12.5[b]	0.567[b]	0.590[ab]	0.487[c]	0.486[c]
Silver						
	Maize	13.1[a]	0.593[a]	0.623[a]	0.524[a]	0.525[a]
	Wheat	12.5[b]	0.542[b]	0.595[b]	0.505[b]	0.506[b]
	Sorghum	12.4[b]	0.551[b]	0.586[b]	0.486[c]	0.496[b]
Ringed Neck						
	Maize	13.3[a]	0.599[a]	0.600[a]	0.519[a]	0.519[a]
	Wheat	12.6[b]	0.551[b]	0.583[b]	0.509[b]	0.506[b]
	Sorghum	12.1[b]	0.557[b]	0.577[c]	0.477[c]	0.479[c]
Pooled SEM		0.02	0.02	0.03	0.02	0.01
Probability of greater F-values in ANOVA						
Pheasant type	P-value	0.08	0.09	0.04	0.06	0.05
Cereal	P-value	0.02	0.01	0.01	0.01	0.01
Pheasant type * cereal	P-value	0.09	0.10	0.06	0.09	0.06

Mean in columns carrying different superscripts are significantly different

silver pheasant where the difference between wheat and sorghum phosphorus digestibility was insignificant.

Digestibility coefficient of phosphorus of maize (0.531) and wheat (0.515) was higher in Cheer pheasants and for sorghum (0.496) was greater in Silver pheasant. Lower phosphorus digestibility of maize, wheat and sorghum was noticed by Ring Neck pheasants. Digestibility of phosphorus varied significantly with types of pheasant. Interaction between pheasant type and cereal was not significant.

Apparent metabolizable energy values measured total classical collection method of different cereal grains by different types of pheasants is given in Table 3. It was noted that AME value of maize was significantly higher (13.4 MJ/kg) compared to wheat and sorghum in all different treatments of pheasants. It was observed that AME value of maize remained insignificant across different pheasant types. Maize AME value ranged from 13.1 to 13.4 MJ/kg, wheat, 12.5 to 12.8 MJ/kg and sorghum 12.1 to 12.7 MJ/kg. There was no significant difference between the AME values of wheat and sorghum across different pheasant types. The impact of pheasant type and its interaction with cereal grain was insignificant. Cheer pheasant were more efficient in utilizing energy from different cereal grains compared to other pheasants.

DISCUSSION

Nutrient composition of maize, wheat and sorghum fell within the range given in the NRC, 1994 and support present determined values. Previous reports have also shown that nutritive value of corn is superior to wheat and sorghum (Torres *et al.,* 2013). Differences in the nutrient composition with past studies could be attributed to the differences in the varieties used and lab protocols as well.

Digestibility of all nutrients of wheat and sorghum was poor as compared to corn by different types of pheasants. Wheat is one of the important feed ingredients in the consumption of human being and in poultry diets, but the nutritive value of wheat is highly variable (Black *et al.,* 2005; Mirzaie *et al.,* 2012). It mainly provides energy that depend on the extent of digestion and the amount eaten by birds (Black *et al.*, 2005). It has been reported that the average apparent metabolizable energy (AME) of wheat is 12.1 MJ/kg DM, but ranges from 8.8 to 14.9 MJ/kg (Choct *et al.,* 2006) and coincide with findings of present study. Wheat digestibility was higher to sorghum except for fat that was lower in wheat. It has been previously demonstrated by Nadeem *et al.* (2005) that corn digestibility was higher to wheat and sorghum and are in line to values of nutrient digestibility obtained in present study.

Better nutrient digestibility of corn can be attributed to its microscopic structure of caryopsis (Benedetti *et al.,* 2011) where protein bodies and starch granules are arranged in a much harmonized fashion that renders its nutrient to the host highly available. Corn possesses no or less antinutritional factors (Acamovic, 2001) and have higher nutrient digestibility (Yegani and Korver, 2013) and support present findings. Certain factors e.g. soluble non-starch polysaccharides (Caprita and Caprita, 2012) in wheat limit the availability of nutrients due to increased gut viscosity (Classen, 1996; Choct *et al*., 2006). Reduced nutrient digestibility and AME of wheat to corn could be supported by the findings of Choct *et al.* (2006) and Annison and Choct (9991). Similarly, Gheisari *et al*. (2003) reported that amount of ME of wheat is 3270 Kcal/kg, moisture level 7.8%, CP 12%, crude fat 2.2% and crude fiber 3.5% that is somewhat similar to our results. Nadeem *et al.* (2005) assessed the digestibility coefficients of different cereals and agreed to present study.

Sorghum has been used in poultry feed due to its nutritive value and low cost globally (Ali *et al.,* 2009). Sorghum contain a comparable level of lysine, methionine, crude ether extract, ash and phosphorus contents, when compared to maize (Gualtieri and Rapaccini, 1990; Emami *et al.,* 2012). Sorghum exhibits lower digestibility and ME to corn probably due higher tannin contents (Douglas et al., 1993) that has been observed in present study. Findings of this study could also be supported by (Elkin *et al*., 1990; Douglas *et al*., 1993; Knox and McNab, 1995; Selle *et al.,* 2010)) who reported that tannins, phytate and kaffirin sorghum reduced growth performance, feed efficiency and nutrients availability compared to other cereals. Similarly, Gualitieri and Rapaccini (1990) also reported that tannins lower dry matter and protein digestibility. Oria *et al*. (1995) reported that sorghum protein digestibility is lower due compared to other grains due to presence of kafirin. β- and kafirins contain cystein, forming disulfide bonds in mature grains which reduces the digestibility of sorghum proteins and other nutrients (Weaver *et al*., 1998) and support the findings of current study. Weurding *et al.* (2001) observed that protein bodies and starch granules arrangement in sorghum grain compromise digestibility sorghum. All these and other factors may accounts for lower digestibility in pheasants of sorghum grain.

Present finding can also be supported by the reports of Hicks *et al*. (2002) and Torres *et al.* (2013) who noticed sorghum poor feeding value in poultry compared to other cereals. In term of protein content present finding are in dis-agreement with Douglas *et al*. (1990) and Hulan and Proudfoot (1982) who reported higher protein levels for sorghum than maize. Ca and P retention is influenced by a number of dietary factors including diet or ingredient type source of minerals and levels. To our knowledge no previous study has compared the mineral retention for pheasants fed sorghum, wheat and maize. The retention coefficients of 0.45 for Ca and 0.50 for P were determined in poultry birds by Thomas and Ravindran (2010) is comparable with that of ours results. The major difference between digestibility and retention coefficients are the method and the site of determination.

Conclusion: It was concluded that digestibility coefficient values of nutrients in different cereal grains by pheasants were almost similar to or greater than poultry and can effectively utilize cereal grains. It is, however, needed to examine nutrient digestibility in pheasant at different stages of life.

REFERENCES

Ali MA, A Abbas, S Niaz, M Zulkiffal and S Ali, 2009. Morpho-physiological criteria for drought tolerance in sorghum (sorghum bicolor) at seedling and post-anthesis stages. Int J Agric Biol, 11: 674-680.

Acamovic T, 2001. Commercial application of enzyme technology for poultry production. Worlds Poult Sci J, 57: 225-242.

Annison G and M Choct, 1991. Antinutritive activities of cereal nonstarch polysaccharides in broiler diets and strategies minimizing their effects. World Poult Sci J, 47: 232-242.

AOAC Official Methods of Analysis, 2000. 17th Ed. Association of Official Analytical Chemists, Washington DC, USA, pp: 147-152.

Benedetti MP, JR Sartori, FB Carvalho, LA Pereira, VB Fascina, AC Stradiotti, AC Pezzato, C Costa and JG Ferreira, 2011. Corn Texture and Particle Size in Broiler Diets. Braz J Poult Sci, 13: 227-234.

Black JL, RJ Hughes, SG Nielsen, AM Tredrea, R MacAlpine and RJ van Barneveld, 2005. The energy value of cereal grains, particularly wheat and sorghum, for poultry. Aust Poult Sci Sym, 7: 21-29.

Căpriţă R and A Căpriţă, 2012. The variation of relative and reduced viscosity with concentration in wheat and barley aqueous extracts. Ani Sci Biotech, 45: 117-120.

Choct M, M Sinlae, RAM Al-Jassim and D Pettersson, 2006. Effects of xylanase supplementation on between-bird variation in energy metabolism and the number of Clostridium perfringens in broilers fed a wheat-based diet. Aust J Agric Res, 57: 1017-1021.

Classen HL, 1996. Successful application of enzymes relies on knowledge of the chemical reaction to be affected and conditions under which the reaction will occur. Feed Mix, 4: 22-28.

Douglas JH, TW Sullivan, NJ Gonzalez and MM Beck, 1993. Differential age response of Turkeys to protein and sorghum tannin levels. Poult Sci, 72: 1944-1951.

Douglas JH, TW Sullivan, PL Bond and FJ Struwe, 1990. Nutrient composition and metabolizable energy values of selected sorghum varieties and yellow corn. Poult Sci, 69: 1147-1155

Doxon ED, 2005. Feeding ecology of ring-necked pheasant (*Phasianus colchicus*) and northern bobwhite (*Colinus virginianus*) chicks in vegetation managed using conservation reserve program (crp) practices. Master thesis, University of Kansas, Lawrence, USA.

Emami F, N Maheri, A Ghorbani and T Vahdatpour, 2012. Effects of feeding untreated or reconstituted sorghum grain (*Sorghum bicolor* L.) on growth performance of Japanese quails (*Coturnix coturnix japonica*). Int J Biosci, 2: 31-37

Elkin RG, JC Rogler and TW Sullivan, 1990. Comparative effects of tannins in ducks, chicks and rats. Poult Sci, 69: 1685-1693.

Gheisari A, R Bahadoran, S Tdayonfar, 2003. Determination of chemical composition and suitable levels of wheat feed screening and macaroni wastes in broiler chick diets. J Sci Tech Agric Nat Resour, 72: 161-169.

Gonzalez-Redondo P and P Garcia-Dominguez, 2012. Typification and characterisation of the pheasant (*Phasianus colchicus*) game farms in Spain. Spanish J Agric Res, 10: 1005-1015.

Gualtieri M and S Rapaccini, 1990. Sorghum grain in poultry feeding. World Poult Sci J, 46: 246-254.

Hicks C, MR Tunistra, JF Pedersen, FE Dowell and KD Kofoid, 2002. Genetic analysis of feed quality and seed weight of sorghum inbred lines and hybrids using analytical methods in NIRS. Euphytica, 127: 31-40.

Hulan HW and FC Proudfoot, 1982. Nutritive value of sorghum grain for broiler chickens. Can J Anim Sci, 62: 869-875.

Knox AI and JM McNab, 1995. Selection between high and low-tannin diets by broiler chickens. Brit Poult Sci, 36: 849 - 851

Leeson S and JD Summers, 2005. Commercial poultry nutrition. University Books, Guelph, Ontario, Canada.

Mirzaie S, M Zaghari, S Aminzadeh, M Shivazad and GG Mateos, 2012. Effects of wheat inclusion and xylanase supplementation of the diet on productive performance, nutrient retention, and endogenous intestinal enzyme activity of laying hens. Poult Sci J, 91: 413-425.

Nadeem MA, AH Gilani, AG Khan and Mahr-un-Nisa, 2005. True metabolizable energy values of poultry feedstuffs in Pakistan. Int J Agric Biol, 7: 990-994

National Research Council, 1994. Nutrient Requirements of Poultry. 8th Rev. Ed. National Academy of Science Washington, DC.

Oria MP, BR Hamaker and JM Schull, 1995. In vitro protein digestibility of developing and mature sorghum grain in relation to α-β-γ-kafirin disulfide crosslinking. J Cereal Sci, 22: 85-93.

Riley TZ and JH Schulz, 2001. Predation and Ring-necked Pheasant population dynamics. Wildlife Society Bulletin, 29: 33-38.

Selle PH, DJ Cadoganb, X Li and WL Bryden, 2010. Implications of sorghum in broiler chicken nutrition. Anim Feed Sci Tech, 156: 57-74.

Thomas DV and V Ravindran, 2010. Mineral retention in young broiler chicks fed diets based on wheat, sorghum or maize. Asian-Aust J Anim Sci, 23: 68-73.

Torres KA, JM Pizauro, CP Soares, TG Silva, WC Nogueira, DM Campos, RL Furlan, M Macari, 2013. Effects of corn replacement by sorghum in broiler diets on performance and intestinal mucosa integrity. Poult Sci J, 92: 1564-1571.

Weaver CA, BR Hamaker and JD Axtell, 1998. Discovery of grain sorghum germ plasm with uncooked and cooked in vitro protein digestibility. Cereal Chem, 75: 665-670.

Weurding RE, A Veldman, WAG Veen, PJ Van der Aar and MWA Verstegen, 2001. Starch digestion rate in the small intestine of broiler chickens differs between feedstuffs. J Nutr, 131: 2329-2335.

Yegani M and DR Korver, 2013. Effects of corn source and exogenous enzymes on growth performance and nutrient digestibility in broiler chickens. Poult Sci, 92: 1208-1220.