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Original Article

Inclusion of Stored Wheat in the Feed of Broilers Influences Intake, Growth Performance, Nutrient Digestibility, and Digesta Viscosity from 1-21 Days of Age

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ABSTRACT

The objective of the current study was to examine the effect of replacing maize with new or stored wheat on the nutrient intake, digestibility, digesta viscosity, and growth performance of growing broilers from 1-21 days of age. For this purpose, 560 one-day-old male broiler chicks were randomly divided into seven experimental treatments, each with 8 replicates of 10 birds. The control diet was a corn soybean-based diet, while six other experimental treatments replaced the corn of the control diet with either 50% or 100% of new, 1.5 year, and 2.5-year-old wheat. The results showed that the replacement of corn with new wheat at 50% and 100% in the diet of broilers significantly reduced feed intake and body weight gain, and increased FCR ($p<0.05$) at week 3. Similarly, in the overall period of the starter phase (1-21 days), replacement of corn with new wheat at 50% and 100% in the diet of broilers significantly reduced feed intake, nutrient digestibility, and body weight gain, and increased digesta viscosity and FCR ($p<0.05$). Based on the findings of the current study, it is concluded that stored wheat successfully replaces corn and new wheat in the diet of broilers. Furthermore, stored wheat has a positive impact on feed intake, performance parameter, digesta viscosity, and nutrient digestibility as compared to new wheat.

INTRODUCTION

The poultry industry is currently growing very fast, but facing the challenges of a lot of infectious diseases and nutritional disorders (Ali *et al.*, 2021; Ganapathy *et al.*, 2021; Khan *et al.*, 2021; Mahmood *et al.*, 2022; Saeed, 2022). These infectious diseases and nutritional disorders lead to economics losses to farmers (Mohsin *et al.*, 2021; Tahir *et al.*, 2021; Abdulrahman *et al.*, 2022). One of the best strategies to cope with economic losses due to infectious diseases and nutritional disorders is to rear birds on a diet with good nutritional profile using healthy ingredients (Saleem *et al.*, 2022; Sagor *et al.*, 2022; Zaheer *et al.*, 2022).

In commercial broiler production nowadays, nutrient dense rations are prepared to meet the nutrient requirement of birds and keep them healthy to fight against infectious diseases and nutritional disorders (Mahmood *et al.*, 2022; Onunkwo *et al.*, 2022). However, the prices of nutrient dense rations are too high, and commercial feed producers always try to reduce the prices of rations by different means. One of the ways to reduce prices is storing feed ingredients when they are abundantly available at a lower price. It has been reported that storage conditions and duration influence the nutritional profile of feed ingredients (Kim *et al.*, 2003; Mahmood *et al.*, 2020) and poultry performance.

Both corn and wheat are used as key ingredients in poultry rations. When these ingredients are abundant and cheaper, they are stored (Amerah, 2015; Kaul *et al.,* 2019), which makes an evaluation of the impact that storing these ingredients has on poultry performance of great interest for researchers (Fuente *et al.*, 1998; Pirgozliev *et al.*, 2006; Liu *et al.*, 2020; Tang *et al.*, 2021). Previous studies have reported that storing wheat for more than 3 months increases the performance of poultry birds by lowering contents of non-starch polysaccharides (Scott & Pierce, 2001; Yin *et al.*, 2017; Tammam *et al.*, 2020). Similarly, the studies of Kim *et al.* (2003) and Alshamiri *et al.* (2021) also reported that the storage of wheat results in a decrease in starch, soluble nonstructural polysaccharides (NSPs), acid detergent fibers, and lignin by the activation of endogenous in-seed phytase and xylanase enzymes (Ismael *et al.*, 2022). Therefore, inclusion of stored wheat may influence the performance of poultry positively by lowering the content of NSPs and phytate.

Storage influences the nutritional profile of both wheat and maize. It has been well documented that the storage of maize grains impacts their nutritional profile (Chulze, 2010). It has also been reported that offering diets comprising stored maize negatively influences the digestibility of nutrients and the performance of growing animals (Rehman, 2006; Setiawan *et al.*, 2010; Yaghobfar & Kalantar, 2017; Yin *et al.*, 2017). Inclusion of stored maize in poultry diets not only influences growth performance, but also affects the product quality. A recent study of Mu *et al.* (2019) reported that inclusion of stored maize in the diet of layers not only decreased the feed intake, but also resulted in lower egg weight and a lighter yolk color. Similarly, Liu *et al.* (2020) demonstrated that the inclusion of four years old maize in the diet of broilers results in low feed intake and poor FCR, and had detrimental impacts on immunity, antioxidant function, and intestinal health.

In Pakistan, maize is considered a key energy source for poultry. However, surplus wheat stored for human consumption during periods of scarcity is also included in poultry diets. It is well known that most studies have explored the nutritional profile of wheat stored for one year. However, no studies have evaluated the chemical composition/feeding value of longer wheat storage. Therefore, it is important to study how long storage influences the intake, growth performance, and nutrient digestibility of broilers. The current experiment was planned to evaluate the effect of replacing maize with stored wheat on the performance of growing broilers during the starter phase. Young birds have an underdeveloped digestive system that is not fully functional in the starter phase, mainly in the initial 10 days of the life (Barekatain & Swick, 2016). Therefore, the choice of the starter phase of broilers in the current study was due to the digestion of nutrients not being at the optimal level.

MATERIALS AND METHODS

This study was carried out at the "Poultry Research Center, University of Agriculture, Faisalabad". The synopsis committee, UAF, Pakistan, approved all procedures followed in the conduction of this experiment (protocol number: 939#12-10-2021).

Experimental Bird's Housing and Management

A total of 560 one-day-old male broiler chicks were procured from Arslan Chicks Pvt. Ltd and divided into seven treatments, with each experimental treatment having eight replicates, with 10 birds per replicate. In the current study, each replicate was housed in a pen with dimensions of 4.00′ × 3.00′ × 2.5′ feet. A three-inch litter was spread in each pen before the start of the experiment. Shed temperature was maintained with 35ºC before the arrival of chicks, and this temperature was maintained through the first week of experiment to serve the purpose of brooding. After that, the temperature was reduced by 3°C every week, until it reached 22°C. During the experiment, chicks were reared for 21 days maintaining the same environmental conditions for all treatments.

Experimental Diets

A total of seven dietary treatments were carried out in this experiment. Experimental diets were formulated as follows: control diet=corn-soybean based diet, no wheat; 50%-NW=50% replacement of control diet corn with new wheat; 100%-NW=100% replacement of control diet corn with new wheat; 50%-1.5YOW= 50% replacement of control diet corn with 1.5 year old wheat; 100%-1.5YOW= 100% replacement of control diet corn with 1.5 year old wheat; 50%-2.5YOW = 50% replacement of control diet corn with 2.5 year old wheat; and 100%-2.5YOW = 100% replacement of control diet corn with 2.5 year old wheat.

Data Collection

Growth Performance

Bird body weight was measured on day one and then every week for the calculation of body weight gain. The estimation of total or weekly feed intake was done by subtracting the total amount of feed refused from the total amount of feed offered during the starter phase. Feed intake and weight gain were used to calculate FCR, as described in the study of (Chiang *et al.*, 2005).

Digestibility Assay

A digestibility assay was carried out on day 21. Experimental birds were fed diets mixed with AIA (Celite®) on days 17-21 of the experiment. Diets were analyzed for DM, CP, EE, CF, and ash (AOAC, 2005). Fecal digesta samples were taken for a digestibility assay at day 21, for which the litter of each replicate (pen) was covered with plastic sheets to prevent contamination from bedding material. The excreta from each pen were completely cleaned of feathers and other extraneous objects. Each pen's excreta were weighed, homogenized, dried in the oven, and ground for further chemical analysis.

Excreta samples were subsequently oven dried in a hot air oven at 105 °C for 2 hours for DM determination (Arshad *et al.*, 2020; Rehman *et al.*, 2019). Ash content was estimated by burning the sample in a muffle furnace at 650 °C for 2 hours (Bajwa *et al.*, 2020; Shahid *et al.*, 2020). Crude protein content was calculated by multiplying nitrogen (through Kjeldahl method) by 6.25 (AOAC, 2000). Nutrient digestibility was determined by the marker method using the following formula:

$$\text{Digestibility (\%)} = 100 - (100 \times \frac{\text{\% marker in feed}}{\text{\% marker in feces}} \times \frac{\text{\% nutrient in feces}}{\text{\% nutrient in feed}}$$

Chemical Analysis

Triplicate samples of all feeds including new, 1.5-year, and 2.5-year-old wheat were collected and oven dried by a hot air oven at 65 °C. Dried samples were then ground and passed through a 0.5 mm sieve. Ground samples were further analyzed for proximate composition (AOAC, 2005).

Determination of Viscosity

Two broilers were slaughtered to collect digesta for determining sample viscosity. Digesta contents of the gastrointestinal tract of slaughtered birds were gently collected by finger, by denudation of each gastrointestinal tract segment. Collected digesta were subsequently frozen at −20 °C for future analysis. Digesta samples were pooled in a falcon tube for each replicate. The viscosity of digesta samples was determined by using a Brookfield DV-E viscometer (Brookfield Engg., Middleboro, Mass., USA). The tubes were centrifuged for 5 min at 3000 rpm, and the supernatant was then centrifuged for 5 min at 12,500 rpm. The viscometer was preheated at 25 °C and then the digesta supernatant was introduced in it. The average shear rate used for measuring viscosity ranged between 45.0 s^{-1} and 22.5 s^{-1} (Galmarini *et al.*, 2011).

Statistical Analysis

Collected data of all parameters were analyzed by using the GLM function of the Minitab Statistical software 17 (Minitab Inc. 2010) under CRD. Significant means were compared using Tukey's test.

RESULTS

Growth Performance

Feed intake results of replacing corn with fresh and stored wheat in broiler diets are presented in Table 1. Weekly feed intake data showed that the inclusion of fresh or stored wheat in the diet of broilers did not influence feed intake in the 1st and 2nd weeks ($p>0.05$). However, in the 3rd week, replacement of corn with fresh wheat at 50% and 100% in broiler diets significantly reduced feed intake ($p<0.05$), and the lowest feed intake was seen in the 100% fresh wheat diet ($p<0.05$). Similarly, in the overall starter phase (1-21 days), replacement of corn with fresh wheat at 50% and 100% in broiler diets significantly reduced

Table 1 – Effect of stored wheat supplementation on the feed intake (g) of broiler chickens during starter phase.

Feed intake (g) (Weeks)	Control	Dietary Treatments						SEM	*p*-Values
		50%-NW	100%-NW	50%-1.5YOW	100%-1.5YOW	50%-2.5YOW	100%-2.5YOW		
Week 1	187.25	180.75	179.50	183.75	182.13	186.50	182.01	3.02	0.053
Week 2	382.50	371.01	364.75	380.88	374.02	379.25	377.75	1.36	0.156
Week 3	636.13[a]	622.25[b]	615.38[c]	633.38[a]	631.25[a]	635.63[a]	634.00[a]	1.01	0.018
Week 1-3	1205.9[a]	1174.01[b]	1159.6[b]	1198.05[a]	1187.4[a]	1201.41[a]	1193.81[a]	7.02	0.000

Control diet=no wheat, 50%-NW=Replacement of corn with new wheat (50%), 100%-NW=Replacement of corn with new wheat (100%), 50%-1.5YOW=Replacement of corn with 1.5-year-old wheat (50%), 100%-1.5YOW=Replacement of corn with 1.5-year-old wheat (100%), 50%-2.5YOW =Replacement of corn with 2.5-year-old wheat (50%), 100%-2.5YOW =Replacement of corn with 2.5-year-old wheat (100%).

feed intake ($p<0.05$). Table 2 shows the data on body weight gain for broilers fed experimental diets. Weekly body weight gain data showed that the inclusion of fresh or stored wheat in broiler diets does not influence body weight gain in the 1st and 2nd weeks ($p>0.05$). However, in week 3 and for the overall starter phase (0-21 days), replacement of corn with fresh wheat at 50% and 100% in broiler diets significantly reduced body weight gain ($p<0.05$). FCR results during the starter phase are presented in Table 3. First, 2nd and 3rd week FCR data showed that no significant difference was observed in FCR for birds fed the different dietary treatments. In the overall starter phase, replacement of corn with fresh wheat at 50% and 100% in broiler diets had a significant effect on FCR ($p<0.05$), with a poor FCR being observed in these treatments.

Table 2 – Effect of stored wheat supplementation on the weight gain (g) of broiler chickens at day 21.

Weight gain (g) (Weeks)	Control	Dietary Treatments						SEM	*p*-Values
		50%-NW	100%-NW	50%-1.5YOW	100%-1.5YOW	50%-2.5YOW	100%-2.5YOW		
Week 1	160.09	150.16	143.98	155.23	158.22	157.75	155.40	4.82	0.068
Week 2	298.81	288.55	283.52	297.24	294.03	296.13	297.31	3.84	0.617
Week 3	458.84^{a}	440.26^{ab}	427.85^{b}	455.82^{a}	456.78^{a}	453.63^{a}	456.81^{a}	5.88	0.031
Week 1-3	917.74^{a}	878.97^{bc}	855.35^{c}	908.30^{ab}	909.03^{ab}	907.51^{ab}	909.52^{a}	6.94	0.003

Control diet=no wheat, 50%-NW=Replacement of corn with new wheat (50%), 100%-NW=Replacement of corn with new wheat (100%), 50%-1.5YOW=Replacement of corn with 1.5-year-old wheat (50%), 100%-1.5YOW=Replacement of corn with 1.5-year-old wheat (100%), 50%-2.5YOW =Replacement of corn with 2.5-year-old wheat (50%), 100%-2.5YOW =Replacement of corn with 2.5-year-old wheat (100%).

Table 3 – Effect of stored wheat supplementation on the feed conversion ratio of broiler chickens at day 21.

FCR (Weeks)	Control	Dietary Treatments						SEM	*p*-Values
		50%-NW	100%-NW	50%-1.5YOW	100%-1.5YOW	50%-2.5YOW	100%-2.5YOW		
Week 1	1.18	1.21	1.31	1.19	1.15	1.18	1.17	0.04	0.527
Week 2	1.28	1.29	1.29	1.28	1.27	1.28	1.27	0.02	0.025
Week 3	1.38	1.42	1.44	1.39	1.38	1.41	1.39	0.02	0.1534
Week 1-3	1.32	1.34	1.36	1.32	1.31	1.32	1.31	0.01	0.0027

Control diet=no wheat, 50%-NW=Replacement of corn with new wheat (50%), 100%-NW=Replacement of corn with new wheat (100%), 50%-1.5YOW=Replacement of corn with 1.5-year-old wheat (50%), 100%-1.5YOW=Replacement of corn with 1.5-year-old wheat (100%), 50%-2.5YOW =Replacement of corn with 2.5-year-old wheat (50%), 100%-2.5YOW =Replacement of corn with 2.5-year-old wheat (100%).

Digesta Viscosity

The data on digesta viscosity of the current experiment is presented in Table 4. Results showed that replacement of corn with fresh wheat at 50% and 100% in broiler diets significantly enhances digesta viscosity ($p<0.05$), while replacement of corn at 100% and 50% with 1.5 YOW and 2.5 YOW had no effect on digesta viscosity as compared to control ($p>0.05$).

Table 4 – Effect of stored wheat supplementation on the gut viscosity of broiler chickens at day 21.

Viscosity (cps)	Control	Dietary Treatments						SEM	*p*-Values
		50%-NW	100%-NW	50%-1.5YOW	100%-1.5YOW	50%-2.5YOW	100%-2.5YOW		
	5.53^{d}	11.16^{b}	13.75^{a}	7.70^{c}	7.32^{c}	7.65^{c}	6.82^{cd}	0.34	0.002

Control diet=no wheat, 50%-NW=Replacement of corn with new wheat (50%), 100%-NW=Replacement of corn with new wheat (100%), 50%-1.5YOW=Replacement of corn with 1.5-year-old wheat (50%), 100%-1.5YOW=Replacement of corn with 1.5-year-old wheat (100%), 50%-2.5YOW =Replacement of corn with 2.5-year-old wheat (50%), 100%-2.5YOW =Replacement of corn with 2.5-year-old wheat (100%).

Nutrient Digestibility

Data on the impacts of including stored and fresh wheat in broiler diets on nutrient digestibility are presented in Table 5. Results showed that inclusion of fresh or stored wheat in the diet of broilers influences nutrient digestibility ($p>0.05$). Replacing corn with fresh wheat at 50% and 100% in broiler diets significantly reduced DM, CP, CF, EE, and Ash digestibility in broilers ($p<0.05$), while replacing corn with 2.5 YOW and 1.5 YOW had no effect on DM digestibility as compared to control.

DISCUSSION

Grains are a major energy source for commercial poultry production. Poultry feed mills sometimes procure grains from farmers and use them fresh, but grains are most commonly stored to provide feed ingredient reserves during scarcity periods. It has been reported that new season grains are problematic for broiler production due to the high contents of soluble NSPs, which are responsible for increasing digesta viscosity (Pirgozliev *et al.*, 2006). Storing grains for

Table 5 – Effect of stored wheat supplementation on the nutrient digestibility of broiler chickens at day 21.

Parameters	Control	Dietary Treatments						SEM	*p*-Values
		50%-NW	100%-NW	50%-1.5YOW	100%-1.5YOW	50%-2.5YOW	100%-2.5YOW		
DM digestibility	79.22[a]	62.08[b]	57.25[b]	72.51[a]	77.25[a]	73.54[a]	77.71[a]	1.31	0.009
CP digestibility	60.99[a]	50.62[b]	47.39[b]	58.71[a]	57.72[a]	58.98[a]	60.76[a]	0.84	0.008
CF digestibility	71.33[a]	55.82[b]	56.27[b]	68.62[a]	69.73[a]	69.27[a]	71.28[a]	1.73	0.009
EE digestibility	74.84[a]	65.24[bc]	64.84[c]	72.30[ab]	73.84[a]	72.95[a]	74.74[a]	1.30	0.002
Ash digestibility	49.83[a]	40.49[bc]	39.21[c]	44.14[abc]	47.30[ab]	44.38[abc]	45.34[abc]	1.29	0.007

DM=Dry matter; CP=Crude protein; CF=Crude fiber; EE=Ether extract.

Control diet=no wheat, 50%-NW=Replacement of corn with new wheat (50%), 100%-NW=Replacement of corn with new wheat (100%), 50%-1.5YOW=Replacement of corn with 1.5-year-old wheat (50%), 100%-1.5YOW=Replacement of corn with 1.5-year-old wheat (100%), 50%-2.5YOW=Replacement of corn with 2.5-year-old wheat (50%), 100%-2.5YOW=Replacement of corn with 2.5-year-old wheat (100%).

three to four months also improves nutritive values and has a positive impact on broiler chicken production (Choct, 1997; Ravindran, 2001).

In the present study, the inclusion of 1.5-year-old wheat and 2.5-year-old wheat in broiler diets had a positive impact on broiler performance in the starter phase. At day 21, poor feed intake and weight gain were observed in birds fed 100% new wheat diet, as compared to the corn-based diet and the 1.5 YOW and 2.5 YOW diets. Feed intake and weight gain findings for the wheat-based diet are consistent with the findings of a previous study by Scott and Pierce (2001). Scott & Pierce (2001) reported that 6-month storage of wheat improved voluntary feed intake and body weight gain of broiler chicks by 16.1 and 22.7%, respectively. Similarly, Yaghobfar & Kalantar (2017) also reported that voluntary bird feed intake and average daily gain decreased for birds fed new wheat. Scott & Pierce (2001) reported that inclusion of stored wheat in broiler diets has a positive impact on voluntary feed intake. Another factor that could influence broiler feed intake is digesta viscosity, which decreased with the stored wheat diet in the current study. It has been reported that higher digesta viscosity reduces feed passage rate (Scott & Pierce, 2001; Isaac, 2021), which would be the reason for less feed intake with the new wheat diet in the current study.

In the current study, a better feed conversion ratio was observed in the birds fed the control diet with no wheat and birds fed the diet with stored wheat; while a poor feed conversion ratio was observed in birds fed diets with 50%-NW and 100%-NW. New season wheat as an ingredient in broiler diets has a negative effect on feed efficiency, which could be attributed to the high NSPs content in wheat, which enhances digesta viscosity (Pirgozliev *et al.*, 2006). Higher digesta viscosity is responsible for a lower broiler feed intake, nutrient digestibility, and growth performance. Similar results for the feed conversion ratio have been reported by (Yaghobfar & Kalantar, 2017; Shawky *et al.*, 2020). In the current study, better DM, CP, and CF digestibility were observed in birds fed diets based on corn and stored wheat. Previous studies showed that grain storage not only improves grain quality, but also results in the breakdown of soluble NSPs by the activation of endogenous enzymes, such as glycanases (Conchie *et al.*, 1968; Lee & Ronalds, 1972; Farooq & Kashif, 2021). Higher crude fiber digestibility in the current study could also be due to the partial cleavage of the polymers, which eliminates their anti-nutritive action and causes bird's endogenous enzymes to be more capable of cleaving the NSPs present in the diet. Similar results have been reported by (Svihus *et al.*, 1995; Svihus & Gullord, 2002; Yosi *et al.*, 2022). Higher crude fiber and DM digestibility in broiler chickens fed barley, oats, and wheat have also been reported elsewhere (Svihus *et al.*, 1995; Svihus & Gullord, 2002).

In the current study, crude fiber digestibility results indicated that carbohydrate digestion was high in the corn-based diet and the stored-wheat-based diet, which may release the available protein matrix for the digestion of broiler's endogenous proteolytic enzymes, resulting in higher protein digestibility. Previous studies have reported that protein digestibility varies depending on the ingredients used is bird feeds (Yu *et al.*, 2002), and that the improved nutritive value (especially proteins and carbohydrates) of stored wheat may be caused by the enhanced CP digestibility, alongside the efficient work of gastric and pancreatic juices in the gastrointestinal tract of broilers. In the current experiment, CP digestibility was better in broiler birds fed the corn-based and stored-wheat-based diets, while poor CP digestibility was seen in broilers fed the new-wheat-based diet. It has been reported that starch granules are embedded in the protein matrix, and it is well established that starch is rapidly digested as compared to protein (Waldron *et al.*, 1995; Wiseman, 2000). Nutrient digestibility is influenced by the inclusion of the stored grains in the diet of broilers (Thomke, 1972).

Ash mainly represents the mineral contents of the diet. Higher digestibility was observed for the corn-based and stored-wheat-based diets, which could be due to the improvement of nutritional value during storage through the breakdown of complex structures in grains, which make minerals more available for digestion and absorption (Svihus *et al.*, 1995).

The reduced digesta viscosity found in this study for the 1.5-year, and 2.5-year-wheat-based diets, especially at the 100 percent inclusion level, is similar to the findings of Thomke (1972), who reported an improvement in the nutritive value of barley during grain maturation due to a decrease in its viscosity. Scott & Pierce (2001) reported that beta-glucan levels of stored grain decreased, resulting in lower digesta in broilers fed diets containing stored grains. Similarly, Fuente *et al.* (1998) reported decreased digesta viscosity using barley as storage time increased. It is well established that the activation of endogenous-NSP-degrading enzymes are mainly responsible for the low digesta viscosity of stored wheat (Kim *et al.*, 2003).

CONCLUSION

Based on the findings of the current study, it is concluded that stored wheat successfully replaces corn and new wheat in broiler diets. Furthermore, stored wheat has a positive impact on feed intake, performance parameters, viscosity, and nutrient digestibility as compared to new wheat. Therefore, it is recommended that wheat is stored before inclusion in broiler diets.

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