STUDY ON BROILER PERFORMANCE BY SUPPLEMENTING WHOLE WHEAT IN BROILER RATION

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SHER-E-BANGLA AGRICULTURAL UNIVERSITY

DHAKA-1207

December 2019

STUDY ON BROILER PERFORMANCE BY SUPPLEMENTING WHOLE WHEAT IN BROILER RATION

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A Thesis
Submitted to the Department of Poultry Science
Sher-e-Bangla Agricultural University, Dhaka

In Partial Fulfillment of the Requirements for the degree of

MASTER OF SCIENCE (MS) IN POULTRY SCIENCE

SEMESTER: July-Dec/2019

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Certificate

This is to certify that the thesis entitled "STUDY ON BROILER PERFORMANCE BY SUPPLEMENTING WHOLE WHEAT IN BROILER RATION" submitted to the Faculty of Animal Science & Veterinary Medicine, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of Master of Science in Poultry Science, embodies the result of a piece of bona fide research work carried out by Md. Shaddam Patwary, Registration No. 12-04973 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that any help or source of information, received during the course of this investigation has been duly acknowledged.

Dated: December, 2019
Place: Dhaka, Bangladesh

Prof. Dr. Md. Anwarul Haque Beg
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Dedicated To
My Beloved
Parents, Teachers
and Friends

ACKNOWLEDGEMENT

*All praises are due to Almighty Allah, the Great, Gracious and Merciful, Whose blessings enabled the author to complete this research work successfully. The author like to express his deepest sense of gratitude sincere appreciation to his respected supervisor **Prof. Dr. Md. Anwarul Haque Beg**, Chairman, Department of Poultry Science & Treasurer, Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh for his scholastic guidance, support, encouragement and invaluable suggestions and constructive criticism throughout the study period and gratuitous labor in conducting and successfully completing the research work and in the preparation of the manuscript writing.*

*The author also expresses his gratefulness and best regards to his respected Co-supervisor, **Dr. Hossan Md. Salim,** Co-Supervisor, National laboratory Consultant, Animal Feed Quality Control Section, EQCLIFP Project, Department of Livestock Services (DLS), Bangladesh, Dhaka for his inestimable help, valuable suggestions and constant inspiration throughout the research work and preparation of the thesis.*

*The author expresses his sincere respect to **Dr. Maksuda Begum**, Assistant Professor, **DR. Md. Zahir Uddin Rubel**, Lecturer, Department of Poultry Science, Sher-e-Bangla Agricultural University, Dhaka and **Mst. Mayeeda Parvin,** MS Fellow for valuable suggestions and cooperation during the study period.*

The author also expresses heartfelt thanks to all the staffs of the Department of Poultry Science, SAU, Dhaka for their co-operation during the period of the study. The author expresses his sincere appreciation to his brothers, sister, relatives, well wishers and friends for their inspiration, help and encouragement throughout the study period.

The Author

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ACRONYMS AND ABBREVIATIONS

Abbreviation		Full meaning
A.M	=	Ante meridian
ANOVA	=	Analysis of Variance
BANSDOC	=	Bangladesh National Scientific And Technical Documentation Centre
BARC	=	Bangladesh Agricultural Research Council
BLRI	=	Bangladesh Livestock Research Institute
Ca	=	Calcium
CF	=	Crude Fibre
Cm	=	Centimeter
cm^2	=	Squre Centimeter
CONTD.	=	Continued
CP	=	Crude Protein
CRD	=	Complete Randomized Design
Dr.	=	Doctor
e.g.	=	For Example
EDTA	=	Ethylene Diethyle Tetraacitic Acid
et al.	=	Associates
FC	=	Feed Consumption
FCR	=	Feed Conversion Ratio
g	=	Gram
i.e.	=	That is
IBV	=	Infectious Bronchitis Vaccines
kcal	=	Kilo-calorie
Kg	=	Kilogram
LSD	=	Least Significant Difference
Ltd.	=	Limited
M.S.	=	Master of Science
ME	=	Metabolizable Energy

ACRONYMS AND ABBREVIATIONS (CONT'D)

Abbreviation		Full meaning
ml	=	Mililitre
mm	=	Milimeter
mmol	=	Milimol
MT	=	Metric ton
N	=	Nitrogen
NDV	=	Newcastle Disease Vaccine
No.	=	Number
NS	=	Non-significant
P	=	Phosphorus
Pp	=	Page to page
ppm	=	Parts per Million
AME	=	Apparent metabolisable energy
SAU	=	Sher-e-Bangla Agricultural University
SED	=	Standard Error Difference
SPSS	=	Statistical Package for Social Sciences
viz.	=	Such as
Vs	=	Versus
WW	=	Whole Wheat
WPSA	=	World's Poultry Science Association

LIST OF SYMBOLS

Symbols		Full meaning
:	=	Ratio
@	=	At the rate of
+	=	Plus
$<$	=	Less than
$>$	=	Greater than
°C	=	Degree Celcius
°F	=	Degree Fahrenheit
%	=	Percentage
&	=	And
*	=	5% level of significance
**	=	1% level of significance
/	=	Per

STUDY ON BROILER PERFORMANCE BY SUPPLEMENTING WHOLE WHEAT IN BROILER RATION

BY

MD. SHADDAM PATWARY

ABSTRACT

Whole grain feeding has recently received renewed interest in the commercial poultry industry as a mean of lowering feed manufacturing cost. Wheat is the cereal grain of choice for whole grain feeding. The aim of the present study was to determine the influence of whole wheat on production performances, internal and immune organs and hematological parameters. The experiment was conducted at Sher-e-Bangla Agricultural University poultry farm, to evaluate the productive performance of commercial broiler chicks fed whole wheat (WW) with basal diet. A total of 300 day old Cobb-500 broiler chicks were divided randomly into 5(five) experimental groups Control (T_0), T_1 (4% WW), T_2 (8%WW) T_3 (12%WW) and T_4 (16%WW) of 5 replicates each with 12 chicks per replications. Here result showed that significantly ($P<0.05$) higher weekly body weight gain found in 4% WW treated groupT_1 (624.20 ± 6.29) and 8% WW treated group T_2 (627.40 ± 5.29) group compared to control group T_0 (574.40 ± 13.81). In case of final live weight of broiler significantly ($P<0.05$) higher body weight found in all treated groups T_1 (4%), T_2 (8%) T_3 (12%) and T_4 (16%) compared to control ($T_{0)}$ group. The highest ($P<0.05$) body weight was found in 8% whole wheat Supplemented group T_2 (2258.40 ± 21.47) group whereas lowest in T_0 (2125.40 ± 15.34) group of broiler. In case of total feed intake significantly ($P<0.05$) 16% whole wheat supplied group T_4 (3268.90 ± 47.59) consumed higher amount of feed and 8% whole wheat treated group T_2 (3036.10 ± 22.24) consumed lower amount of feed. Lowest weekly feed intake ($P<0.05$) found in **8**% whole wheat Supplemented group T_2 (982.80±23.98) and highest in T_0 (1099.20±11.17) groups. Significantly ($P < 0.05$) better FCR found in 8% whole wheat Supplemented group T_2 (1.34 ± 0.01) than T_0 (1.52 ± 0.01) groups. In case of weekly FCR at end of 5th week Significantly better FCR was found in **8**% whole wheat Supplemented group T_2 (1.57±0.05) compared to T_0, T3, T4 groups. Dressing percentage and livability was insignificant ($P>0.05$) in different dietary groups mean value 67.28 ± 0.29, 96.67 ± 0.83 respectively. Gizzard and intestine weight was insignificant ($P>0.05$) in different dietary groups mean value 41.26 ± 0.75 and 107.26 ± 2.56 respectively. Insignificant ($P>0.05$) spleen weight found in different dietary groups but numerically higher weight found in 8% whole wheat Supplemented group T_2 (2.23±1.10). Different dietary group showed Insignificant ($P>0.05$) effect on glucose (mg/dl), cholesterol (mg/dl) and hemoglobin (g/dl) value. The mean average value was 278.20±2.61, 194.56±2.36 and 9.28 ± 0.27 respectively. From the above result it can be concluded that final live weight, total feed consumption and FCR was significantly ($P<0.05$) superior in 8 % WW treated groups. Therefore, suggested 8% WW to be used on broiler chicken ration for higher performance.

Keywords: Broiler; growth performance; whole wheat; hematological parameter.

CHAPTER 1

INTRODUCTION

Poultry farming has emerged as one of the fastest growing agribusiness industries in the world, even in Bangladesh. Research on meat production globally indicates poultry as the fastest growing livestock sector especially in developing countries. It has triggered the discovery and widespread use of a number of ‘feed additives’. The term feed additive is applied in a broad sense, to all products other than those commonly called feedstuffs, which could be added to the ration with the purpose of obtaining some special effects. The main objective of adding feed additives is to boost animal performance by increasing their growth rate, better-feed conversion efficiency, greater livability and lowered mortality in poultry birds.

Feed cost has been a great deal of expenses (70% of all expenses) in poultry production. Many studies have been conducted to minimize the expenses. Whole grain feeding, through the reduction of energy consumption for grinding, could significantly lower the feed cost. Furthermore, this mode of feeding has not only shown positive effects on the performance of broilers, gut development and utilization of feed nutrients but also meets consumer demands for a ‘natural’ feeding system and improved bird welfare (Gabriel *et al*., 2008). Today, commercial feed has been used in poultry production including feed formulation cost. Nowadays, conventional poultry production has reached a level that the domestication of chicken without the sense of animal welfare, their metabolic and physiologic comfort. Moreover, the food would be formulated by animals more accurately than by man if diet selection principles are carefully considered (Forbes, 1995). This gives poultry nutritionist some advantages in practice including less consumption of commercial food, the evaluation of surplus of crop production, minimizing the sudden chances in feeds and less manure production (Forbes, 1995). The present literature concerning choice feeding with whole grain under practical conditions shows insufficient information, although there has been an increase demand to assess choice feeding with regard to performance, carcass characteristics besides feeding cost under practical (commercial) conditions. Following experiments were, therefore, designed to asses whether use of whole wheat in choice feeding system in semi-commercial conditions was applicable or not with respect to growth, food efficiency and carcass parameters in broiler chickens so that this kind of studies can give the opportunity to minimize feed cost by shortening the chain between the harvest of raw materials and animal feeding procedure.

The price of whole wheat makes it attractive ingredients for broiler feeds but, because of its low protein content and imbalanced amino acid composition, it must be offered in different way such as choice feeding or sequential feeding or dilution of commercial feeds (Forbes and Covasa, 1995). According to Forbes and Covasa (1995), feeding whole wheat to poultry is not new and it was a standard practice 50-60 years ago (Ewing, 1951, cited from their article). Despite this research into choice feeding, using whole wheat is needed be studied for further progress.

Sequential feeding of wheat and commercial food in broiler chickens was investigated by Covasa and Forbes (1994). Female broiler chickens were offered either ground or whole wheat for 6 h period each day followed by a conventional food. Although body weight was reduced in the first 3-weeks, chickens compensated for their loss and attained a similar body weight at 7 weeks of age to those fed conventionally. When birds fed whole wheat consumed ate less amount of protein. Also they fed female broiler chickens a mash food in which ground or whole wheat was gradually incorporated and found that the birds reached final body weights that have similar to those birds fed with conventional food. Recently, conducted an experiment to compare whole grain feeding methods for broilers and to determine whether whole grain feeding would affect performance, carcass parameters and feeding cost of broiler chicks. They found that inclusion of whole wheat to the diet or offering whole wheat as a choice or feeding whole wheat for 8-h a day can provide considerable reduction in feed cost for body gain, while increasing fat deposition due to excess energy intake.

Dry feeding in mash or pellet form is the widest and most accepted feeding practice around the world. However, wet feeding more readily accepted by broiler than dry. It has been reported that wet feeding will stimulate dry matter intake, growth rate and feed conversion efficiency. Also, it has been reported that wet fed broilers in hot tropic can reduces heat stress and improve feed intake. Also, there are some barriers to the commercial utilization of wet feeding, for instance lack of information as to whether newly hatched chicken fed with wet feed (Forbes et al, 2005). However, in some literature reported that wet feeding had no effect on carcass weight and dry matter digestibility in broiler chicken and effect of wet feeding on some characteristics of broilers such as gut morphology or immune responses is rare in literatures. Thus, the present experiment was performed to evaluate the effect of whole wheat, wet feeding and their interaction on growth performance and immunity of broiler chicks. With this background, the work was planned to explore the possibilities of whole wheat in broiler chicken feeds, with the following specific objectives:

1. To evaluate the growth performance, visceral & immune organs characteristics of broiler chicken fed whole wheat supplemented diet.

2. To find out the effect of whole wheat on hematological properties of broiler chickens.

CHAPTER 2

REVIEW OF LITERATURE

Sources of literature

(i) Book and journal in different libraries as mentioned below

a. Sher-e-Bangla Agricultural University (SAU) Library, Dhaka.
b. Bangladesh Agricultural Research Council (BARC) Library, Farmgate, Dhaka.
c. Bangladesh National Scientific And Technical Documentation centre (BANSDOC) Library, Agargaon, Dhaka

(i) Bangladesh Livestock Research Institute (BLRI) library, Savar, Dhaka.

(ii) Abstract searching at BARC, Farmgate, Dhaka and BANSDOC, Dhaka.

(iii) Internet Browsing

A total about 100 literature were reviewed to identify the background, drawbacks and prospects of research, understand previous findings and to answer the research status. Among them 22 were full article and 60 abstracts, 18 were only titles and some were miscellaneous.

2.1. Whole wheat feeding: Methodology and implication on the performance of poultry

In recent years, whole grain feeding has received renewed attention in the scientific community and commercial poultry industry, and is being increasingly used in many parts of world, especially Europe, Australasia and Canada. The primary aim is to reduce feed costs by eliminating the grinding step. Furthermore, this also meets consumer demands for a natural feeding system and improved animal welfare (Gabriel *et al.*, 2008). These beneficial effects have been attributed to the influence of whole grain feeding on the development and functionality of the gizzard. Published data on the effects of whole grain feeding on performance of broilers, however, have been contradictory, with some reports showing beneficial effects, while others failing to show any advantages. The discrepancy among published reports is due to a number of confounding factors, including differences in experimental methodology, inclusion level of whole grain, type and quality of grain, age of birds, and feeding regime. Moreover, most published data are based on whole wheat and data on other grains are scarce. Despite maize being the most commonly used cereal grain in poultry diets worldwide, little attempt has been made to use whole maize in poultry diets. The aim of this chapter is to review the available data on the influence of whole wheat feeding on various aspects of production performance and to highlight alternate feeding strategies for the utilization of whole maize in poultry diets. Factors responsible for variable responses with whole grain feeding and the potential of this strategy as a substitute for growth promoters and coccidiostats are also discussed.

2.2 Methods of whole grain feeding

The three methods generally employed for feeding of whole grains (Rose *et al*., 2007) are free choice feeding (FCF; *ad libitum* choice of the whole grain with another feed in separate feeders), mixed feeding (MF; whole grain mixed with another, often pelleted or compound feed) and sequential feeding (SF; whole grain and another feed in the same feeder, but at different times).

In these feeding regimes, whole grain can be given along with another feed, either in mash or pellet form, in one of three options: (a) protein concentrate (part of a complete diet provided as a concentrate to balance nutrients provided by the whole grain); (b) balancer diet (part of a complete diet other than whole grain, rich in all nutrients except carbohydrate); or (c) complete diet. Provision of whole grain in pellet form in MF can be further sub-divided into two categories, namely pre-pelleting (PRP; whole grain is first mixed with other feed components and then pelleted) and post-pelleting (PP; first other components of feed are mixed and pelleted, and whole grain is then mixed with pelleted feed). Except for PRP, all these feeding systems allow partial control of proportions of whole grain and protein concentrate actually ingested by birds. Figure1 depicts the different methods of adding the whole grain in poultry diets.

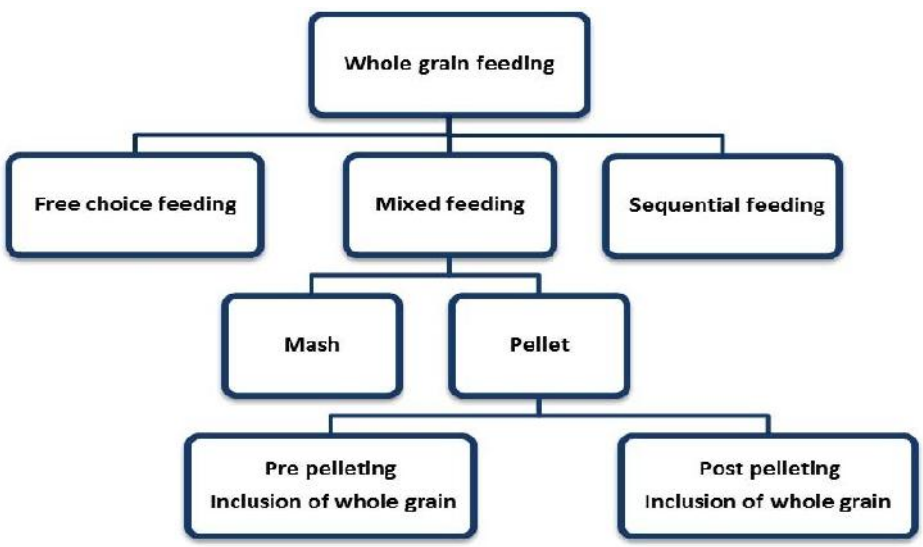

Figure 1. Diagrammatic representation of different methods employed for feeding of whole grain in poultry

2.2.1 Free choice feeding

In FCF, birds are usually offered a choice among three types of feedstuffs: an energy source, i.e., cereal grains; a protein source, e.g., soybean meal, fish meal, meat meal, etc., plus supplemental vitamins and minerals; and for laying hens, a calcium source, e.g., shell grit. The basic principle behind FCF is that individual birds are capable of consuming the required nutrients from various feed ingredients to compose their own diets according to their actual needs and production capacity. Interest in FCF may increase in the future as a result of current concerns over welfare of caged birds and the consequent move towards use of barn and free range production systems. Birds in these latter systems are likely to have a greater range of requirements which will depend on the amount of exercise they take (Henuk and Dingle, 2002). FCF is also likely to provide an effective means whereby home-grown whole grains can be used, thus lowering transport costs in addition to lowering cost of grinding and mixing.

The theory is that birds given a choice are able to formulate a balanced ration on their own using ‘nutritional wisdom’, but this is not always the case. A practical limitation of FCF in large poultry units is that it requires extra equipment because whole wheat and a balancer or complete diet has to be provided *ad libitum* in separate feeders. Rose *et al*. (2007) pointed out that FCF birds usually select a diet that gives rapid growth, but occasionally they will eat too much balancer and not enough whole wheat, resulting in higher feed costs.

Forbes and Covasa (1995) speculated that while birds will self-select the grain and protein concentrate, some factors can interfere with these choices. Feed form and shape are important, with birds preferring to eat larger particles as they grow older. Broiler chickens fed a mixture of mash supplement and whole grain will tend to eat the whole grain first and leave behind the mash to be eaten later. The larger, easier to manipulate grain is preferred, especially in finisher diets. Feeder design, number of birds in a pen, learning time, previous experience, and nutritional contents of the protein concentrate or balancer diet are other factors affecting eating preferences (Rose *et al*., 2007; and Covasa, 1995).

Published data evaluating FCF are limited and contradictory (Table 1). Whole wheat given in FCF resulted in increased relative weight of the gizzard, irrespective of the form of other feed (pellet or mash). Gabriel *et al*. (2003a) found no effect of whole wheat on the performance of broilers when offered free choice plus a pelleted complimentary diet. Gabriel *et al*. (2008) reported significant improvements in body weight with no effect on feed intakes and feed efficiency when whole wheat was given in FCF, with a complimentary feed in mash form. In contrast, Amerah and Ravindran (2008) reported significantly decreased body weights and feed intake, but found no effect on feed efficiency. Similarly, decreased body weight was reported when whole wheat was offered with a balancer pellet (Rose *et al*., 1995).

Table 1: Influence of whole wheat feeding given in free choice feeding on performance and gizzard weight of broilers

Reference	Form of other feed	Inclusion rate (g/kg)	Age (days)	% Improvement[1] Weight gain	Feed intake	Feed per gain	% Increase in gizzard weight
Rose *et al*. (1995)	Balancer pellet	*Ad libitum*	24-45	-5.62*	-13.14*	-7.69	Not reported
Erener *et al.* (2003)	Standard compound feed	*Ad libitum*	7 -42	+3.61	+7.71*	+3.87	+26.0*
Gabriel *et al.*(2003a)	Pellet	400g	7-29	-7.62	0	0	+101.2**
Gabriel *et al.* (2008)	Mash	200g (1-14d) 300g (15-21d) 400g (22-44d)	8-44	+4.25 *	-0.91	-4.92	+25.8***
Amerah and Ravindran (2008)	Pellet	600-690g	7-35	-15.13*	-13.83*	+1.20	Unspecified increase

***P<0.05; **P<0.01; **P<0.001. 1 Improvement over ground grain = ((Whole grain - Control)/Control) x 100.**

2.2.2 Mixed feeding

In MF, whole grain is either substituted for a part of the ground grain in a complete diet or added to a complete diet in the same feeder at the same time in pellet or mash form. With the former method, the only change is in the form of grain (ground or whole) and nutrient density of finished feed is unaltered. The latter method of adding whole grain to a complete diet results in a dilution of nutrients in feed, but published data on this feeding method are scant. Whole grain inclusion in MF controls the proportion of whole grain and protein concentrate actually ingested by birds by allowing limited partial selection of feed ingredients differing in form, but such selection can be eliminated by pelleting the diet after whole grain and complete diet are mixed (i.e. pre-pelleting).

Feed given in pelleted form as compared to mash is known to improve weight gain, feed intake, and feed efficiency in broilers regardless grain source (Douglas *et al*., 1990; Nir *et al*., 1995; Jensen, 2000; Nir and Pitchi, 2001). These improvements have been attributed *inter alia* to elevated nutrient density, increased nutrient intake, reduced feed wastage, and decreased energy spent eating (Calet, 1995; Jensen, 2000). Because pelleting requires a large input of electrical energy, it adds approximately 10% to the total feed cost (Cheeke, 1999). Another advantage of MF is that it allows for simple management without investment on additional feeders and manpower. Even with whole grain inclusion, an almost homogenous feed similar to that of a conventional, finely ground diet is assured. However, literature on the effects of MF on the performance of poultry is limited and the results show considerable inconsistency (Table 2 to 3).

2.3. Pre-pelleting inclusion of whole grain

Results of studies examining the effects of pre-pelleting inclusion of whole wheat have produced equivocal results (Table 2). Wu *et al*. (2004) found that pre-pelleting inclusion of 200 g/kg whole wheat improved feed per gain, but had no effect on gizzard weight. On the other hand, Jones and Taylor (2001) and Taylor and Jones (2004a), using the same level of whole wheat inclusion, found no effect on broiler performance, but relative gizzard weights were increased by 11 and 8%, respectively. Similarly Svihus *et al*. (2004a), with inclusion of 500 g/kg whole wheat pre-pelleting, found that relative gizzard weight increased by 26% without any effect on the performance parameters of broilers. In contrast to wheat, Jones and Taylor (2001) reported that inclusion of 200 g/kg whole triticale improved feed efficiency with significant increases in gizzard weight. These reports indicated that inclusion level and type of whole cereal may be responsible, in part, for the inconsistent results. Further studies are required to understand the factors responsible for the variable effects of pre-pelleting inclusion of whole wheat on performance and gizzard development of broilers.

Table : 2. Influence of pre-pelleting inclusion of whole grains in mixed feeding systems on performance and gizzard weight of broilers

Reference	Inclusion rate (g/kg)	Age (days)	% improvement[1] Weight gain	Feed intake	Feed per Gain	% Increase in gizzard Weight
Jones and Taylor (2001)	200g (triticale)	5-42	-0.14	NR[2]	-2.29 *	+11.0*
	200g (wheat)	5-42	+0.40	NR	+1.75	+10.7*
Taylor and Jones(2004a)	200g	5-42	-1.56	NR	0	+7.79**
Wu *et al*. (2004)	200g	0 -21	+ 0.12	- 0.16	- 4.09*	0
Svihus *et al*. (2004a)	500g	11-25	+1.46	-0.16	+1.43	+26.6***

***P<0.05; **P<0.01; ***P<0.001. [1] Improvement over ground grain = ((Whole grain - Control)/Control) x 100. [2] Notreported.**

2.4. Post-pelleting inclusion of whole grain

Most studies involving MF have evaluated post-pelleting inclusion of whole wheat and all report increased gizzard weight with no adverse effects on weight gain of broilers (Table 3). The only exception was that of Ravindran *et al.* (2006) who reported significantly lower weight gain in broilers. In general, this method of whole wheat inclusion either had no effect or decreased feed intake, but the response on feed efficiency was variable between studies. It is interesting to note that post-pelleting inclusion of whole wheat when substituted for a part of the ground wheat in complete diets showed either no effect (Hetland *et al.*, 2002, 2003; Svihus *et al.*, 2004a) or beneficial effects on feed per gain in broilers (Wu *et al.*, 2004; Wu and Ravindran, 2004; Ravindran *et al*., 2006; Amerah and Ravindran, 2008). These findings indicate that addition or substitution of whole grain to a complete diet leads to dilution of nutrients, adversely affecting the performance of broilers. Rose *et al.* (2007) suggested that if high proportions of whole wheat are given then the nutrient composition of the pelleted diet needs to be rich in all nutrients except carbohydrates. This is often termed as a 'balancer' diet. In the study of Rose *et al.* (2007) where whole wheat was substituted for part of a balancer pelleted diet that contained twice the concentration of minerals and vitamins than the control diet, there were no adverse effects on any of the performance parameters of broilers.

2.5. Mixed feeding of whole grain in mash feeds

Mixed feeding studies where whole wheat was included in mash feed have resulted in significant increases in body weight gain in broilers with no effect on feed intake, but responses in feed per gain and gizzard weight were variable (Table 4). Low level inclusion of whole wheat (100 g/kg) resulted in similar performance responses, but failed to show any effect on gizzard weight. Similarly, Nahas and Lefrancois (2001) reported improved weight gain with inclusion of 100-350 g/kg whole wheat, but found no effect on gizzard weight of broilers.

Table 3 :. Influence of post-pelleting inclusion of whole grains in mixed feeding systems on performance and gizzard weight of broilers

			% Improvement			
Reference	+ standard commercial diet (g/kg)	Age (days)	Weight gain	Feed intake	Feed per gain	in gizzard weight
Rose *et al*. (1995)[b]	400g (24-30d), 500g (31-37d) and 600g (38-45d) + balancer diet	24-45	0.00	-0.32	-0.51	NR
Uddin *et al*. (1996)[a]	150g (24-33d) and 300g (33-44d) + Standard commercial diet (Riband variety)	24-42	-1.73	+1.28	+3.27	NR
	150g (24-33d) and 300g (33-44d) + Standard commercial diet (Haven variety)	24-42	-2.55	+1.14	+3.90	NR
Preston *et al*. (2000)	333g	14-42	-4.64	-8.15 DM intake	+3.33	+47.0***
Hetland *et al*. (2002)	300g (10-29d) and 440g (29-38d)	10-38	-5.21	-10.02	+7.14	+85.7***
	125g (10-29) and 300g (29-38d)	10-38	-5.64	-8.99	+5.36	+100.0***
Hetland *et al*. (2003)	385g	11-33	+5.13	+3.05	-1.56	+35.4*
Svihus *et al*. (2004a)	375g	11-20	-2.14	-1.34	-1.45	NR

Table. Continued

Reference	commercial diet (g/kg)	Age(day)	Weight gain	Feed intake	Feed per gain	in gizzard weight
Wu *et al*. (2004)	200g	0-21	+2.12	- 3.95*	-5.85*	+73.2*
Wu and Ravindran (2004)	100g (1-21d) and 200g (22-35d)	1-35	-2.63	-6.33***	-3.33**	+43.0***
Ravindran *et al*.(2006)	100g (1-21d) and 200g (22-35d)	1-35	-6.78*	-10.56*	-4.27*	+50.0*
Amerah and Ravindran (2008)	100g (1-21d) and 200g (22-35d)	1-35	-2.21	-3.02	-1.80	Unspecified increase

***P<0.05; **P<0.01; ***P<0.001. [1]Improvement over ground grain = ((Whole grain - Control)/Control) x 100. [2]Not reported.**

[a] Whole grain added to the complete diet.

[b] Whole grain added to balancer diet

Table 4: Influence of whole grain inclusion in mash mixed feeding systems on performance and gizzard weight of broilers

			% Improvement[1]			
Reference	Inclusion rate (g/kg of feed)	Age (days)	Weight gain	Feed intake	Feed per gain	% Increase in gizzard weight
Nahas and Lefrancois (2001)[a]	100g (7-21d) and 200g (22-38d)	7-38	+4.20**	+6.09	-2.00	+4.72
	100g (7-21d) and 350g (22-38d)	7-38	+5.15**	+2.24	+2.00	+0.79
	200g (7-38d)	7-38	+1.28**	+0.63	+0.17	+1.57
	200g (7-21d) and 350g (22-38d)	7-38	+2.01**	+0.58	+0.67	-0.79
Erener *et al*. (2003)[a]	Standard compound feed + 5,10, 20, 30 and 40g /kg in weeks 2-6	7-42	-8.14*	+5.60	+14.36*	+26.0*

***P<0.05;** ****P<0.01; ***P<0.001.**

[1] Improvement over ground grain = ((Whole grain - Control)/Control) x 100.

[a] Whole grain added to the complete diet.

2.6. Sequential feeding

In this feeding technique, birds are given time-limited *ad libitum* access to the whole grain followed by time-limited *ad libitum* access to a complete or balancer diet (Rose *et al*., 1995). Whole grain is offered to birds with a complete or balancer feed in the same feeder, but at different times. This feeding regime is based on the principle of choice feeding and allows birds to exercise their freedom of choice between whole grains and complete or balancer feed with restriction of time. Compared to FCF, this method is economical and efficient as it does not require offering food in two separate feeders. In addition, SF offers more control on amount of whole grain to be ingested by birds due to time restriction. However, SF remains to be validated in practice. Only two published reports are available on use of SF in poultry feeding (Table 4).

Rose *et al*. (1995) compared four different durations of access (4, 8, 12 and 24 h) to WW and balanced diet. The balancer diet contained twice the concentration of the vitamin and mineral mixture than the complete diet as 500 g of ground wheat removed from 1 kg of complete diet and concentration of component in the remaining 500 g of mix were used to formulate the balancer diet. It was assumed that a bird that selected equal proportions of balancer and whole wheat will choose a diet with the same nutrient concentration as the complete diet. Whole wheat accounted for over 40% of the total food intake of broilers when sequential times of 8 h or more were used and 20% in the 4 h SF. Weight gain of broilers given SF was lowest in the 4 h feeding period and highest in the 8 h period. However, weight gain decreased linearly as SF period increased above 8 h. In a subsequent trial, these researchers compared 8 h SF of whole wheat and balancer diet with a complete single diet. It was found that weight gain and feed intake decreased in birds fed 8 h SF in comparison to those fed a complete single diet, but there was no effect on feed efficiency. In contrast, when Erener *et al*. (2003) offered the birds 18 h access to standard compound feed followed by 6 h access to whole wheat, there were no adverse effects on any performance parameters but an increase in gizzard weight was observed. These contradictory results may be, attributed to the amount of whole wheat ingested and, thus, the total nutrient intake.

2.7. Effect of whole wheat feeding on digestive tract characteristics

A rapid and conspicuous enlargement of the gizzard is observed when whole wheat is included in the diet, indicating that whole grain feeding influences development and, possibly, morphology and physiology of the gastrointestinal tract. The predominant hypothesis is that beneficial effects observed with whole wheat inclusion is mechanistically linked to gastrointestinal development, particularly gizzard development (Svihus *et al*., 2002; Gabriel *et al*., 2003a; Svihus, 2010a; Svihus, 2011). However, effects of whole wheat feeding on development of segments of the gastrointestinal tract other than the gizzard are inconsistent (Forbes and Covasa, 1995; Jones and Taylor, 2001; Banfield *et al*., 2002; Gabriel *et al*., 2003a; Taylor and Jones, 2004a; Engberg *et al*., 2004; Wu and Ravindran, 2004; Ravindran *et al*., 2006; Amerah and Ravindran, 2008; Gabriel *et al*., 2008).

2.7.1 Gizzard

The gizzard is a muscular, grinding organ made up of two muscles that reduce particle size of ingested foods and mixes them with digestive enzymes (Duke, 1986). Mechanical pressure applied in grinding by the gizzard may exceed 585 kg /cm^2 (Cabrera, 1994). However, in conventional feeding regimes where whole grain is ground before incorporation into feed, such grinding action is carried out by the feed mills. As a result, in contrast to birds fed diets containing whole wheat, ground-wheat-fed birds show dilation of the proventriculus and a relatively underdeveloped gizzard (Forbes and Covasa, 1995; Jones and Taylor, 2001; Gabriel *et al*., 2003a; Gabriel *et al.*, 2008). Thus, under conventional feeding regimes, the gizzard becomes a transit rather than a grinding organ (Cumming, 1994). However, the amount of whole grain in the diet required to stimulate gizzard development is not known. In his latest review, Svihus, (2011) recommended that at least 200 g/kg cereal particles larger than 1.5 – 2.0 mm in size or at least 300 g/kg particles larger than 1 mm in size in diet are needed to stimulate gizzard development.

2.7.2 Proventriculus

Compared to whole wheat-fed birds, ground-wheat-fed birds showed a dilation of the proventriculus (Forbes and Covasa, 1995; Jones and Taylor, 2001; Gabriel *et al*., 2003a; Gabriel *et al*., 2008). This dilation, however, did not necessarily result in any change in relative weight of this organ (Gabriel *et al*., 2003a; Gabriel *et al*., 2008). Taylor and Jones (2004a) reported reduced proventriculus proportional mass of 22 and 16%, respectively, in broilers fed diets containing either whole wheat or whole barley compared to those based on ground grains. Similarly, Jones and Taylor (2001) found a 14% reduction in relative proventriculus weight with inclusion of whole triticale in broiler diets. In contrast, some authors have failed to observe any change in relative weight of this organ with inclusion of whole wheat, (Banfield *et al*., 2002; Gabriel *et al*., 2003a; Wu and Ravindran 2004; Ravindran *et al*., 2006; Amerah and Ravindran, 2008). Taylor and Jones (2004b) speculated that the absence of proventriculus dilation with whole wheat feeding may have positive effects on bird health by decreasing mortality due to ascites.

2.7.3. Pancreas

Inclusion of 100-200 g/kg whole wheat post-pelleting was reported to have no effect on relative weight of the pancreas (Ravindran *et al*., 2006; Amerah and Ravindran, 2008). In contrast, Wu *et al*. (2004) reported that pre-pelleting inclusion of whole wheat at the same level increased the relative weight of pancreas by 20%. Similarly, inclusion of 200-400 g/kg whole wheat was shown to increase relative pancreatic weight by Banfield *et al*. (2002), Engberg *et al*. (2004) and Gabriel *et al*. (2008). Reasons for these variable effects of whole grain feeding on pancreatic weight are unclear.

2.7.4 Small intestine

Most studies have shown no changes in the relative weight and length of intestinal segments with substitution of ground wheat for whole wheat (Preston *et al*., 2000; Jones and Taylor, 2001; Banfield *et al*., 2002; Engberg *et al*., 2004; Wu *et al*., 2004; Ravindran *et al*., 2006). However, changes in relative size of intestinal segments in response to whole wheat feeding have been observed in some studies. Gabriel *et al.* (2003a) reported 16% lower duodenal weight in birds fed whole wheat compared to those fed the ground wheat diet. Taylor and Jones (2004a) found increased duodenal length, but no differences in weight with 200 g/kg whole wheat inclusion in pelleted diets. Gabriel *et al*. (2008) found a 16% decrease in relative length of jejunum in broilers fed whole grains. Interestingly, Amerah and Ravindran (2008) reported whole wheat inclusion in MF had no effects on the relative weight and length of intestinal segments of broilers. In contrast, whole wheat in FCF resulted in increased weights.

2.8 Morphology and enzymatic activity of gastrointestinal tract

Wu *et al*. (2004) studied the effect of including 200 g/kg whole wheat on the morphology of gizzard and small intestine. No significant effects were observed on the thickness of the *tunica muscularis* layer of the gizzard or villus height, crypt depth, goblet cell number and epithelial thickness in the ileum. In addition, Gabriel *et al*. (2003a) reported that inclusion of whole wheat resulted in no changes at the cellular level; there were no differences in cell size, tissue activity, ribosomal capacity and rate of mitosis. Alkaline phosphatase activity expressed per unit of tissue weight was also not affected. In contrast, Gabriel *et al*. (2008) observed that whole wheat feeding from 8 to 44 days post-hatch resulted in increased duodenal villus to crypt length and surface ratios, due to lower crypt depth and numerically smaller crypt area. Alkaline phosphatase activity was higher in the duodenum and jejunum of whole wheat-fed birds. However, activities of leucine aminopeptidase and maltase were similar between whole and ground wheat based diets. It was speculated that with whole wheat, morphology of the upper part of the intestine improves and may contribute to better absorption of nutrients and their utilization.

2.9 P^H of the digesta

When birds were fed with coarse structured feed in comparison to finely ground feed, lower pH was recorded in the gizzard (Nir *et al*., 1994a) and proventriculus (Nir *et al*., 1995). Similarly, a significant reduction in the pH of gizzard contents of birds fed diets containing 200 g/kg whole wheat was reported by Gabriel *et al*. (2003a). However, Hetland *et al*. (2002) conducted an experiment with very high (500 g during 10-24 days and 600 g during 24-38 days), high (300 g during 10-24 days and 400 g during 24-38 days) and moderate (125 g during 10-24 days and 300 g during 24-38 days) replacement of ground wheat per kg of diet with whole wheat, barley and oats, and found that pH of gizzard contents was not conclusively affected by cereal type or form of the cereal. The effect of whole wheat feeding on pH of intestinal contents is also contradictory. Engberg *et al*. (2004) observed lower pH in duodenum and jejunum with whole wheat, whereas higher pH was reported in the duodenum with whole wheat by Gabriel *et al*. (2003a), but no effect on pH of jejunal or ileal digesta. Taylor and Jones (2004a) reported no effect of whole wheat on the pH of contents from any intestinal segment.

2.10 Effect of whole grain feeding on feed passage rate

Passage rate is the time between when feed is ingested by the bird to when it is expelled as faeces. Passage rate of digesta is usually measured using an insoluble (solid phase) marker such as chromic oxide. In broiler chickens, solid phase markers appear in excreta 1.6 to 2.6 h after ingestion, but results may be confounded by preferential retention of particles of particular size in particular segments of the gut, by adherence to other particles, or by dissolution (Amerah *et al*., 2007). Passage rate of a non-structural marker is not dependent on diet structure (Svihus *et al*., 2002). Several other factors such as particle size and viscosity of digesta are known to affect the passage rate of solid phase markers. Svihus *et al*. (2002) hypothesised that rapid passage rate reduces time available for digestion and absorption, whilst slower passage rate limits feed intake. However, in general, larger particles are retained longer than finer particles in the gizzard (Nir *et al*., 1995), prolonging the mean residence time. The proportion of coarse fibre in gizzard contents is double that present in feed, reflecting selective retention of coarse particles (Hetland *et al*., 2004; 2005) and slower digesta flow out of the gizzard. Amerah and Ravindran (2008) reported a three-fold (9.5 vs. 3.0 g/kg body weight) increase in gizzard contents of birds offered whole wheat as compared to those offered ground wheat.

Moreover, coarse particles need to be ground to a certain critical size before they can leave the gizzard (Clemens *et al*., 1975; Moore, 1999). Such an effect would be expected to lengthen transit time for digesta when whole wheat is fed. Surprisingly, however, overall retention time does not increase when birds are fed whole grains (Svihus *et al*., 2002; Wu *et al*., 2004 Amerah *et al*., 2007; Amerah and Ravindran 2008). Rapid dissolution of starch granules and protein from whole grain in the low pH environment of the gizzard causes a rapid reduction of particle size and may be responsible for the lack of effect on passage rate, as speculated by Hetland *et al*. (2005). Xylanase supplementation with whole wheat is reported to reduce digesta viscosity (Yasar, 2003) and may influence feed passage rate**.** Wu *et al*. (2004), however, found no effect of xylanase supplementation on feed passage rate of birds fed diets containing whole wheat, but noted increased passage rate of those fed diets containing ground wheat.

2.11. Effect of whole grain feeding on digesta particle size

Hetland *et al*. (2004) stated that poultry can consume whole grains as the gizzard has a remarkable ability to grind seeds to a consistently fine size regardless of the original particle size. Hetland *et al*. (2003) reported that whole wheat inclusion had no effect on digesta particle size distribution in the duodenum. Similarly Svihus *et al*. (1997) did not find any differences in digesta particle size in the duodenum of birds fed either whole or ground barley. These studies supported the hypothesis that particles need to be ground to a certain critical size before they can leave the gizzard (Clemens *et al*., 1975; Moore, 1999). Digesta passing through the gizzard had a consistent particle size distribution, with the majority of particles being smaller than 40 μm regardless of the original feed structure (Hetland *et al*., 2002).

2.12. Effect of whole grain feeding on carcass characteristics

Whole wheat inclusion (50, 200 and 350-650 g/kg whole wheat during 0-6, 6-13, and 27-48 days, respectively) in wheat-barley-based diets had no effect on carcass yield and abdominal fat pad weight of broilers. Similar results were reported by Wu and Ravindran (2004). Increases in abdominal fat of 5.3, 19, and 12% with whole grain inclusion have also been reported by Preston *et al*. (2000), Nahas and Lefrancois (2001) and Jones and Taylor (2001), respectively. In contrast, Amerah and Ravindran (2008) found that PP inclusion of whole wheat (100 and 200 g/kg whole wheat replacing ground wheat during 7-21 and 21-35 days, respectively) in wheat-soy diets significantly reduced carcass recovery by 4% and relative weight of abdominal fat by 16%, but there was no effect on breast meat yield. These conflicting results regarding the effects of whole wheat feeding may be attributed, in part, to an incorrect protein: energy ratio in the basal diet (Erener *et al*., 2003; Wu and Ravindran, 2004).

2.13. Effect of whole grain feeding on digesta viscosity

Studies investigating this aspect are limited. Feeding wheat based diets with a fine particle size was found to increase digesta viscosity compared to birds fed whole wheat diet (Yasar, 2003). In contrast, whole wheat feeding increased digesta viscosity and improved feed per gain (Engberg *et al*., 2004). Degree of digesta viscosity is dependent upon the amount of non- starch polysaccharide (NSP), which varies amongst cereals grains (Amerah *et al*., 2007). Digesta viscosity higher than 10 mPa·s limits bird performance by reducing passage rate and mixing of digestive enzymes with substrate nutrients (Bedford and Schulze, 1998). Negative effects of digesta viscosity can be largely overcome by the addition of exogenous glycanase enzymes (Bedford and Schulze, 1998). Wu *et al*. (2004) compared pre- and post-pelleting methods of inclusion of whole wheat and found increased viscosity of digesta in the duodenum and jejunum of birds fed with diets containing 200 g/kg whole wheat, irrespective of method of whole wheat inclusion, compared to those fed diets containing ground wheat. However, xylanase supplementation caused a significant reduction in digesta viscosity in all intestinal segments.

Similar results were reported by Taylor and Jones (2004a) with pre- pelleting inclusion of 200 g /kg whole wheat supplemented with enzyme. However, neither pre-pelleting inclusion of 200 g/kg whole barley in their study nor enzyme supplementation altered viscosity of digesta beyond the duodenum. It was speculated that the presence and activity of endogenous enzymes may have contributed to this observation with whole barley. Petersen *et al.* (1999) stated that NSP associated with viscosity are not degraded by digestive enzymes and that endogenous grain enzymes may exert some effect. The additive effect of whole grain with exogenous enzyme could be attained due to greater grinding activity of a larger and more developed gizzard in birds fed whole grain leading to enhanced mixing of substrate with enzymes. Effect of whole grain feeding on nutrient utilization. As discussed above, whole wheat feeding is generally associated with an increase in gizzard size and it has been hypothesised that the resultant increase in grinding activity will favourably influence the bird's ability to better utilise nutrients (Svihus and Hetland, 2001). In addition to the grinding effect, an active gizzard also serves as a mixing compartment for digestive juices and substrates. Furthermore, large fibre particles seem to enhance digesta motility and backflow within the gastrointestinal tract (Williams *et al.*, 1997). These effects are consistent with results of several studies showing improvement in apparent metabolisable energy (AME) and starch digestibility with the inclusion of whole grain in broiler diets (Svihus *et al*., 2004a; Wu *et al*., 2004).

2.14. Apparent metabolisable energy

McIntosh *et al.* (1962) reported that unground wheat yielded 5 to 10% more metabolisable energy than ground wheat. Wu *et al.* (2004) compared pre and post- pelleting inclusion of 200 g/kg whole wheat in broiler diets and reported improvements in AME irrespective of method of whole wheat inclusion. Post–pelleting inclusion, however, resulted in 6% greater improvement in AME than pre-pelleting inclusion. Similarly, Svihus *et al.* (2004a) reported that AME was increased at both day 14, and 20 when 375 g/kg whole wheat instead of ground wheat was included pre-pelleting. However, in a subsequent experiment with pre-pelleting inclusion of 500 g/kg whole wheat, no effect on the AME was observed. Preston *et al*. (2000) also reported an increase in AME when ground wheat was replaced by whole wheat, whereas Uddin *et al*. (1996) found no differences when two wheat cultivars were fed ground or whole at different levels (100- 400 g/kg) to broiler chickens from 19 to 27 days.

2.15. Starch digestibility

Some studies have shown that inclusion of whole wheat resulted in improved starch digestibility (Svihus and Hetland, 2001; Hetland *et al*., 2003; Svihus *et al*., 2004a). Svihus *et al*. (2004a) reported that post-pelleting inclusion of 375 g/kg whole wheat increased the digestibility of starch at both the ileal and excreta levels. However, a subsequent experiment using pre-pelleting replacement of ground wheat with 500 g/kg whole wheat failed to show any improvement in starch digestibility. Svihus (2006) hypothesised that modern broiler strains are selected to over consume feed and, when pellet diets containing high levels of wheat are fed, this can lead to intestinal starch overload and reduced starch digestibility. Increases in gizzard size with whole wheat indicates that this organ may be the site for prevention of starch overload in the intestinal tract by reducing feed intake in WW fed birds which may be a result of satiety due to increased grinding activity (Svihus and Hetland, 2001). Moreover, the gizzard, apart from functioning as regulator of feed intake

(Svihus, 2006), improves gut motility (Ferket, 2000) by increasing levels of cholecystokinin release (Svihus *et al*., 2004a) which in turn may stimulate secretion of pancreatic enzymes and gastro-duodenal reflux (Duke, 1992; Li and Owyang, 1993). Hetland *et al*. (2003) reported that total amount of bile acids in the gizzard increased in laying hens with access to wood shavings, indicating increased gastro-duodenal reflux.

2.16. Influence of whole wheat feeding on gut microflora

The ban on use of growth promoters (AGP) in poultry diets in the European Union has put tremendous pressure on the poultry industry to look for viable alternatives of AGP. It is unlikely that a single economically viable replacement for AGP will be possible (Dibner and Richards, 2005). It is evident that a multifactorial approach is needed and whole grain feeding may be a part of this strategy. Dietary inclusion of whole grains has been shown to influence microbial ecology of the intestinal tract of poultry. Santos *et al*. (2007) conducted an experiment with broilers raised either on litter floor or cages and fed either a finely ground or whole triticale based diet from 0-42 days. They reported that the intestinal tract of birds fed the finely ground treatment had lower microbial diversity and higher salmonella prevalence than those fed the whole triticale diet. It was suggested that the combination of high dietary fibre content and increased diet coarseness in the whole triticale diets was responsible for observed beneficial effects, possibly through a competitive exclusion type mechanism.

Similarly, dietary inclusion of whole wheat decreased intestinal salmonella colonisation (Bjerrum *et al.,* 2005; Santos *et al*, 2008) and *Clostridium perfringens* in broilers (Bjerrum *et al.,* 2005). Gabriel *et al.* (2003b) also reported that birds fed whole wheat had higher counts of beneficial microflora and lower counts of *Coliform* bacteria. Gabriel *et al*. (2006) showed that whole wheat given with pelleted protein concentrate led to a more beneficial microflora, higher count of *Lactobacilli* spp*.,* and lower count of *Coliform* bacteria in broilers at 22 days compared to those fed a complete ground and pelleted diet. Bjerrum *et al*. (2005) demonstrated that whole wheat feeding influenced the development of *Salmonella* spp. infection and speculated that the gizzard has an important barrier function that prevents pathogenic bacteria from entering the distal intestinal tract. These authors found greater number of *Salmonella* spp. in the gizzard of broilers fed pelleted feed than those consuming pelleted feed supplemented with whole wheat. Furthermore, physical characteristics of feed influence pH of digesta contents in broilers (Nir *et al*., 1994a; Svihus *et al*., 2004a). Engberg *et al*. (2004) reported that the addition of whole wheat resulted in increased gizzard weight, decreased pH of gizzard contents and lowered intestinal numbers of lactose-negative *Enterobacteria* spp. and *Clostridium perfringens.* They proposed that gastric function was being stimulated through increased hydrochloric acid (HCl) secretion from the proventriculus and thorough increased grinding in the gizzard. Overall, these data suggest that whole grains may encourage colonisation of commensal bacteria and discourage pathogenic and harmful bacteria in the intestinal tract through competitive exclusion, HCl secretion or grinding action of gizzard.

2.17. Whole grain feeding to layers

Studies evaluating whole grain feeding in layers are limited. Faruk *et al*. (2010) fed layers equal proportions of whole wheat and a protein-mineral concentrate (balancer diet) in sequential or MF systems. Control birds were fed a complete conventional layer diet. Decreased feed intake was reported with sequential feeding of whole wheat, but egg production, egg mass and egg weight were similar among treatments resulting in improvement in efficiency of feed utilisation by 10% and 5% compared to MF and control treatments, respectively.

Inclusion of 300 g/kg WW without any enzyme supplementation (Senkoylu *et al*., 2009), and 100 g/kg whole pearl millet (Garcia and Dale, 2006) in layer diets had no adverse effect on egg production. Feather pecking is a major welfare problem in layers (Blokhuis *et al*., 2007). Van Krimpen *et al*. (2009) supplemented layer diets with 150 g/kg oat hulls and reported that hens that were fed a standard diet had more feather damage compared with hens fed oat hull diets. In the second part of this study, improved feather condition at 49 wks of age was reported when a diluted rearing diet was fed to hens. It was suggested that with energy dilution of feed, pullets were increasingly 'imprinted' on feed as pecking substrate. This feeding strategy could be exploited with whole grain feeding for control of feather pecking. Therefore, inclusion of whole grains in layer diets has the potential not only to lower feed costs, but also of addressing welfare concerns.

2.18. Factors responsible for variable responses with WW feeding

2.18.1. Quality of wheat

Variation in physical and chemical characteristics and AME that exist between the wheat used in different studies may partly explain the equivocal results in studies with whole wheat feeding. However, in none of these studies, the quality of wheat has been characterised. Studies from several parts of the world have shown that, amongst cereal grains, wheat is known to be most variable in AME content for poultry (Wiseman, 1993; Choct *et al*., 1999; Hughes and Choct, 1999). The AME of wheat for broilers varies considerably and variations of up to 5.86 MJ/kg have been reported (Ravindran and Amerah, 2009). This variation is attributed largely to variations in the soluble NSP, which have a significant bearing on how effectively dietary components are utilised by poultry. It is well known that the quality of wheat in terms of composition and nutritive value of a given type and variety is influenced by year-to-year variation, location, agronomic conditions and climatic conditions. (McNab, 1992, 1996; Wiseman, 1993; Tester *et al*., 1995; Tester 1997). Amerah *et al*. (2009) reported physical characteristics such as endosperm hardness of wheat had a great impact on bird performance and suggested that endosperm hardness must be considered when choosing whole wheat for inclusion in broiler diets.

2.18.2 Time of introducing of WW

Difference in the age of birds at introduction of whole wheat in different studies may have contributed to the inconsistencies reported in responses with whole grain feeding. The size of whole grain and its hardness are physical limitations to feed whole grains to newly hatched chicks. They face difficulties in breaking or swallowing of whole grain, particularly during the first few days of life. To address this problem, most researchers have delayed introduction of whole wheat until chicks are at least 5 days old (Jones and Taylor, 2001; Nahas and Lefrancois, 2001; Erener *et al.*, 2003; Gabriel *et al*., 2003a; Taylor and Jones, 2004a;Amerah and Ravindran, 2008; Gabriel *et al*., 2008) to as long as 11 to 24 days old (Rose *et al.*, 1995; Uddin *et al*., 1996; Preston *et al.*, 2000;Hetland *et al*., 2002; Hetland *et al*., 2003; Svihus *et al.*, 2004a). However, some researchers (Wu and Ravindran, 2004; Wu *et al.*, 2004; Ravindran *et al*., 2006) have introduced the whole wheat from day 1. Ravindran *et al*. (2006) observed that chicks had difficulties in swallowing whole wheat during the first few days of life and, found significantly decreased feed intake and body weight of broilers. Similar reductions in feed intake have been reported in other studies where whole wheat was introduced from day 1, but no adverse effects on final body weight were reported (Wu and Ravindran, 2004, Wu *et al*., 2004). In studies where whole wheat was introduced at later ages, no effect was observed on feed intake. Rose *et al*. (1995) reported decreased intake when whole wheat was introduced the 24 days of age, but clearly this cannot be attributed to physical limitations. Introduction of whole grain to chicks from day 1 may affect feed intake, particularly during the first week, but any negative effects on performance are negated by the time broilers reach market weight (Jones and Taylor, 2001). Pre-pelleting inclusion of whole grain may be a practical alternative to overcome the issue of size of whole grain in the feeding of chicks.

2.18.3 Exposure to whole grain / adaptation period before the start of trial

Whatever the age of introduction to whole grain, chickens appear to benefit from a learning period. To adjust to whole grain feeding, Cumming (1994) emphasised the importance of experience for birds given FCF with whole grains and recommended exposing pullets during rearing to grains which may be offered later in their life. Due to differences in life span of commercial broilers and layers, broilers should be introduced to whole grains from the first week of their life, although it appears that ingestion of grains during the first 3-4 days is mainly based on innate pecking behaviour rather than nutritional selection (Forbes and Covasa, 1995). Hetland *et al*. (2002) and Svihus *et al.* (2004a) pre-exposed chicks by introducing 70 g/kg whole wheat from 6-11 days of age before final inclusion of 300 and 375 g/kg whole grain, respectively, from day 11 onwards, and reported no adverse effects on performance parameters. Similar results were reported by Hetland *et al.* (2003) who had pre- exposed whole wheat at 100 g/kg from 5-11 days of age before the start of study from day 11 with inclusion level of 385 g/kg. However, in all other studies, birds were not pre-exposed to whole grains prior to the start of the trial. It is common knowledge that sudden changes in feeding systems can lead to reductions in performance.

2.18.4. Inclusion level of whole grain and the length of study

Inclusion rates of WW varied widely amongst different studies. Most studies evaluating whole wheat have used 100-200 g/kg inclusion levels (Jones and Taylor, 2001, 2002; Wu *et al*., 2004, Ravindran *et al*., 2006, Amerah and Ravindran, 2008). When inclusion levels are increased beyond 200 g/kg, it is tempting to speculate two scenarios. First, this may lead to a more developed gizzard with beneficial effects on bird performance, and second, there may be a need for more grinding in the gizzard resulting in increased energy requirements, which may have adverse effects on performance. Hetland *et al*. (2002) increased whole wheat inclusion to 300 and 440 g/kg and found more developed gizzards with no negative effects on production performance of broilers. Svihus *et al*. (2004a) further increased whole wheat inclusion to 500 g/kg and similarly found no difference in production parameters as compared lower inclusion levels (100-200 g/kg), a developed gizzard and improved broiler performance have been reported.

Conversely, Wu *et al*. (2004) and Nahas and Lefrancois (2001), included whole wheat at 200 g/kg and 100-350 g/kg, respectively, and failed to show any effect on gizzard size, but observed beneficial effects on production performance. Thus variations in the inclusion level of whole grain may be partly responsible for the inconsistency in results with whole grain feeding. The minimum amount of whole grain required enhancing the functionality and size of gizzard is not known. Studies are warranted to compare the effects of different inclusion level of whole grain under similar experimental conditions. to those fed with ground wheat. In several studies with Gizzards in young chicks are physically incapable of breaking down whole grain owing to its hardness (Covasa and Forbes, 1996). However, training or pre-exposure of birds by acclimatizing them to whole grains at an early age appears to confer benefits at later stages of growth by improving their ability to select food to meet nutritional requirements and to adopt the digestive tract for better digestion (Forbes and Covasa, 1995). Most research in this area has employed very short or virtually no dietary acclimation periods. Jones and Taylor (2001) reported that the effect of whole grain feeding may only become apparent in the grower phase (22 to 42 days) of continuously fed birds. In this study, with pre-pelleting inclusion of 200 g/kg whole wheat from 5 to 42 days, no effect on relative weight of gizzard was observed at 30 d of age, but gizzard weight was increased by 11% at 42 day of age. Wu *et al*. (2004), with the same inclusion level of whole wheat pre-pelleting in broiler starter diets, failed to show any effect on the relative weight of gizzard at 21 days of age. Svihus *et al*. (2004a), on the other hand, with 500 g/kg whole wheat inclusion from 11 to 25 days observed significant increase in gizzard weight (by 27%) as compared to birds fed ground wheat based diet. Overall these data suggest that both the inclusion level of whole wheat and length of feeding are relevant for the development of the gizzard, and to the subsequent effect on bird performance.

CHAPTER 3

MATERIALS AND METHODS

3.1 Statement of the experiment

The research work was conducted at SAU poultry farm, with 300-day-old straight run (Cobb commercial broilers for a period of 35 days from 26 December'17 to 29 January, 2018 to assess the feasibility of using Whole Wheat in commercial broiler diet on growth performance, meat yield characteristics and immune status of broilers. This research helps to make a conclusion about whole wheat.

3.2 Collection of experimental broilers

A total of 300 day-old Cobb 500 broiler chicks were collected from a renowned hatchery in Dhaka.

3.3 Experimental materials

The collected chicks were carried to the university poultry farm early in the morning. They were kept in gas brooders equally for 5 days by maintaining standard brooding protocol. During brooding period 1% whole wheat was used in four treatments except the treatment of control group. After two days 240 chicks were selected from brooders and distributed randomly in four (4) dietary treatments group where whole wheat used, another 60 chicks were distributed randomly in treatment for control. Each treatment had five (5) replications with 12 birds per replication. The total numbers of treatments were five (5) and their replications were twenty five (25).

3.4 Experimental treatments

T_{0} (Control): Basal Diets

T_1: Basal Diets + 4% of Whole Wheat

T_2: Basal Diets +8% of Whole Wheat

T_3: Basal Diets +12% of Whole Wheat

T_4: Basal Diets +16% of Whole Wheat

Table 5. Layout of the experiment

Treatment	**No. of Replications**					
Groups	**R1**	**R2**	**R3**	**R4**	**R5**	**Total**
Control (T_0)	12	12	12	12	12	60
T1	12	12	12	12	12	60
T2	12	12	12	12	12	60
T3	12	12	12	12	12	60
T4	12	12	12	12	12	60
Total	60	60	60	60	60	300

3.5 Preparation of experimental house

The experimental room was properly cleaned and washed by using tap water. Ceiling walls and floor were thoroughly cleaned and disinfected by spraying diluted Iodophor disinfectant solution (3 ml/liter water). After proper drying, the house was divided into 25 pens of equal size where using wood materials and wire net. The height of wire net was 36 cm. A group of 12 birds were randomly allocated to each pen (replication) of the 5 (five) treatments. The stocking density was $1m^2$/10 birds.

3.6 Experimental diets

Starter and grower feed were purchased from a renowned feed company from the market.

Minimum nutrients present in starter and finisher ration are presented in table 6.

Table 6. Name and minimum percentage of nutrients present in starter ration:

Name of nutrients in starter Ration	Minimum percentage Present
Protein	21.0%
Fat	6.0%
Fiber	5.0%
Ash	8.0%
Lysine	1.20%
Methionine	0.49%
Cystine	0.40%
Tryptophan	0.19%
Threonine	0.79%
Arginine	1.26%

Source: Cobb500 manual

Table 7. Name and minimum percentage of nutrients present in finisher ration:

Name of nutrients in finisher ration	Minimum percentage Present
Protein	19.0%
Fat	6.0%
Fiber	5.0%
Ash	8.0%
Lysine	1.10%
Methionine	0.47%
Cystine	0.39%
Tryptophan	0.18%
Threonine	0.75%
Arginine	1.18%

Source: Cobb 500 manual

Feed were supplied 4 times daily by following Cobb-500 Manual and *ad libitum* drinking water 2 times daily. Appendix 1 and 2.

3.6.1 Collection of whole wheat

Whole wheat was used in commercial basal diets. This whole wheat was collected from the Savar, Dhaka . This whole wheat was dried and fresh.

Table 8. Nutrient composition of whole wheat

Nutrient Component	Amount
1. Dry matter	89%
2. Carbohydrate	14%
3. Crude protein	28%
4.Ether extract (Fat)	6%
5. Cholesterol	0%
6. Caude fiber	28%
7. Sodium 381 mg	15%
8. Potassium 230 mg	6%

Source: en.wikipedia.org/wiki/Wheat#nutrition

3.7 Management procedures

Body weight and feed intake were recorded every week and survivability was recorded for each replication up to 35 days of age. The following management procedures were followed during the whole experiment period.

3.7.1 Brooding of baby chicks

The experiment was conducted during 26th December to 29th January, 2018. The average temperature was 35°C and the RH was 60% in the poultry house. Common brooding was done for one week. After one week the chicks were distributed in the pen randomly. There were 12 chicks in each pen and the pen space was $1m^2$. Due to hot climate brooding temperature was maintained as per requirement.

Brooding temperature was adjusted (below 35°C) with house temperature. So when the environmental temperature was above the recommendation, then no extra heat was provided. At day time only an electric bulb was used to stimulate the chicks to eat and drink. In brooding extra heat was not provided at day time except mid night to morning.

3.7.2 Room temperature and relative humidity

Daily room temperature (°C) and humidity were recorded every six hours with a thermometer and a wet and dry bulb thermometer. Average room temperature and percent relative humidity for the experimental period were recorded and presented in Appendix 3 & 4.

3.7.3 Litter management

Rice husk was used as litter at a depth of 6cm. At the end of each day, litter was stirred to prevent accumulation of harmful gases and to reduce parasite infestation. At 3 weeks of age, droppings on the upper part of the litter were cleaned and for necessity fresh litter was added.

3.7.4 Feeding and watering

Feed and clean fresh water was offered to the birds *ad libitum.* One feeder and one round drinker were provided in each pen for 4 birds. Feeders were cleaned at the end of each week and drinkers were washed daily. Fed to all birds *ad libitum* throughout the experimental period.

3.7.5 Lighting

At night there was provision of light in the broiler farm for easy feed intake and body growth. For first 2 weeks 24 hours light was used. Thereafter 22 hours light and 2 hours dark was scheduled up to 28 days.

3.7.6 Bio-security measures

To keep disease away from the broiler farm recommended vaccination, sanitation program was undertaken in the farm and its premises. All groups of broiler chicks were supplied Vitamin B-Complex, Vitamin-ADEK, Vitamin-C, Ca and Vitamin-D enriched medicine and electrolytes.

3.7.7 Vaccination

The vaccines collected from medicine shop (Ceva Company) and applied to the experimental birds according to the vaccination schedule. The vaccination schedule is shown in Table 8.

Table 9. Vaccination schedule

No. of the Days	Name of Disease	Name of vaccine	Route of the Administration
3 days	IB+ND	MA-5 + Clone-30	One drop in each Eye
9 days	Gumboro	G-228E (inactivated)	Drinking Water
17 days	Gumboro	G-228E (inactivated) booster dose	Drinking Water
21 days	IB+ND	MA-5 + Clone-30	Drinking Water

3.7.8 Ventilation

The broiler shed was south facing and open-sided. Due to wire-net cross ventilation it was easy to remove polluted gases from the farm. Besides ventilation was regulated as per requirement by folding polythene screen.

3.7.9 Sanitation

Strict sanitary measures were taken during the experimental period. Disinfectant (Virkon) was used to disinfect the feeders and waterers and the house also.

3.8 Study parameters

3.8.1 Recorded parameters

Weekly body weight, feed consumption and death of chicks were recorded. FCR was calculated from final live weight and total feed consumption per bird in each replication. After slaughter gizzard, liver, spleen, intestine were measured from each broiler chicken. Dressing yield was calculated for the bird of each replication to find out dressing percentage. Blood sample was analysis from each replication to measure, complete blood count (CBC), and sugar and cholesterol level.

3.9 Data collection

3.9.1 Live weight:
The initial day-old live weight and weekly live weight of each replication was kept to get final live weight record per bird.

3.9.2 Dressing yield = Live weight- (blood + feathers + head + shank+ digestive system+ Liver+Heart)

3.9.3 Feed consumption: Daily feed consumption record of each replication was kept to get weekly and total feed consumption record per bird.

3.9.4 Mortality of chicks: Daily death record for each replication was counted up to 35 days of age to calculate mortality.

3.9.5 Dressing procedures of broiler chicken:
Three birds were picked up at random from each replicate at the 35th day of age and sacrificed to estimate dressing percent of broiler chicken. All birds to be slaughtered were weighed and fasted f by halal method or overnight (12 hours) but drinking water was provided *ad-libitum* during fasting to facilitate proper bleeding. All the live birds were weighed again prior to slaughter. Birds were slaughtered by severing jugular vein, carotid artery and the trachea by a single incision with a sharp knife and allowed to complete bleed out at least for 2 minutes. Outer skin was removed by sharp scissor and hand. Then the carcasses were washed manually to remove loose singed feathers and other foreign materials from the surface of the carcass. Afterward the carcasses were eviscerated and dissected according to the methods by Jones (1982). Heart and liver were removed from the remaining viscera by cutting them loose and then the gall bladder was removed from the liver. Cutting it loose in front of the proventiculus and then cutting with both incoming and outgoing tracts removed the gizzard. Dressing yield was found by subtracting blood, feathers, head, shank, liver, heart and digestive system from live weight.

3.9.6 Blood sample analysis

Blood samples (1 ml/bird) were collected from the wing veins. All the hematological test was measured at SAU poultry farm, SAU, maintaining standard protocol.

3.10 Calculations

3.10.1 Live weight gain

The average body weight gain of each replication was calculated by deducting initial body weight from the final body weight of the birds. Body weight gain = Final weight – Initial weight

3.10.2 Feed intake

Feed intake was calculated as the total feed consumption in a replication divided by number of birds in each replication.

$$\text{Feed intake (g/bird)} = \frac{\text{Feed intake in a replication}}{\text{No. of birds in a replication}}$$

3.10.3 Feed conversion ratio

Feed conversion ratio (FCR) was calculated as the total feed consumption divided by weight gain in each replication.

$$\text{FCR} = \frac{\text{Feed intake (kg)}}{\text{Weight gain (kg)}}$$

3.10.1 Statistical analysis

The data was subjected to statistical analysis by applying one way ANOVA using statistical package for social sciences (SPSS) version 16. Differences between means were tested using Duncan‟s multiple comparison test, LSD and significance was set at P<0.05.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Production performances of broiler chicken

4.1.1 Final live weight

Final live weight of broiler (g/bird) fed different level of whole wheat containing diets comparison basal diet was presented to table-10. The live weight of broiler in the dietary group Control (T_0), T_1 (4%), T_2 (8%) T_3 (12%) and T_4 (16%) were 2125.40 ± 15.34, 2231.40 ± 8.82, 2258.40 ± 21.47, 2191.20 ± 21.45 and 2229.10 ± 31.65 respectively. Here, significantly ($P<0.05$) higher body weight found in all treated groups T_1 (4%), T_2 (8%) T_3 (12%) and T_4 (16%) compared to control ($T_{0)}$ group. But among the treated groups were showed insignificant ($P>0.05$) difference. The highest body weight was found in 8% whole wheat Supplemented group T_2 (2258.40 ± 21.47) group whereas lowest in T_0 (2125.40 ± 15.34) group of broiler. However, final live weight of broiler fed whole wheat based diets was significantly ($P<0.05$) higher compared with control group.

In contrast, whole wheat feeding has reported to increase digesta viscosity but improved feed per gain (Engberg *et al*., 2004; Wu *et al*., 2004). However, birds supplemented with whole wheat had higher body weight and feed efficiency. These beneficial effects have been attributed to the influence of whole grain feeding on the development and functionality of the gizzard. Similar observation was found in the study of Manwar *et al.* (2005) who supplemented whole wheat in feed and reported significant increase body weight of broilers in the whole wheat group compared with basal feed. An ability to maintain growth rates while consuming diets containing high amounts of whole wheat has been found by other researchers (Rose and Michie 1982; Leeson and Caston 1993; Covasa and Forbes 1994). Some previous research has shown that early growth rates were depressed with whole wheat feeding but in these previous cases the birds were very quickly exposed to high levels of whole wheat

The above findings were in contrast to Yuben and VelmuruguRavindran (2004), reported that whole wheat inclusion had no effect on weight gain of broiler chickens that agrees with obtained result in present study, but in contrast reduced feed intake and improved feed efficiency. In agreement with present study, Amerah *et a*l (2011) observed that in whole 35 day of trial period, whole wheat inclusion had no effect on weight gain or feed intake, but tended to improve feed per gain

Table 10: Production performance of broiler treated with whole wheat

Parameters	T_0	T_1	T_2	T_3	T_4	Mean ± SE	Level of significance
Final Live weight (g)/bird	2125.40 ± 15.34^{b}	2231.40 ± 8.82^{a}	2258.40 ± 21.47^{a}	2191.20 ± 21.45^{a}	2229.10 ± 31.65^{a}	2207.10 ± 12.77	*
Feed Consumption (g)/bird	3220.40 ± 27.29^{a}	3103.50 ± 22.38^{b}	3036.10 ± 22.24^{b}	3237.40 ± 51.03^{a}	3268.90 ± 47.59^{a}	3173.26 ± 23.38	*
FCR	1.52 ± 0.01^{a}	1.39 ± 0.01^{b}	1.34 ± 0.01^{b}	1.48 ± 0.01^{a}	1.47 ± 0.03^{a}	1.44 ± 0.02	*
Dressing percentage (%)	66.40 ± 0.51	67.40 ± 0.68	68.20 ± 0.74	67.40 ± 0.68	67.00 ± 0.71	67.28 ± 0.29	NS
Livability (%)	98.33 ± 1.67	95.00 ± 2.04	96.67 ± 2.04	96.67 ± 2.04	96.67 ± 2.04	96.67 ± 0.83	NS

[ab], values with different superscripts in the same row differ significantly (P<0.05).
Here, T_0 = (Control), T_1 = (4% whole wheat Supplementation), T_2 = (8% whole wheat Supplementation), T_3 = (12% whole wheat Supplementation) and T_4 = (16% whole wheat Supplementation).
Values are Mean ± SE (n=25) one way ANOVA (SPSS, Duncan method)
SE= Standard Error
NS =Non Significant
*** means significant at 5% level of significance (p<0.05)**

4.1.2 Feed consumption (FC)

Different treatment groups (table12) showed significant ($P<0.05$) differences in FC of broiler chicken. The mean feed consumption (FC) of broiler (g/birds) at the end of 5^{th} week in different dietary groups Control (T_0), T_1 (4%), T_2 (8%), T_3 (12%) and T_4 (16%) were 3220.40 ± 27.29, 3103.50 ± 22.38, 3036.10 ± 22.24, 3237.40 ± 51.03 and 3268.90 ± 47.59 correspondingly (table-12). Significantly ($P<0.05$) lower feed intake found in T_1 (3103.50 ± 22.38) and T_2 (3036.10 ± 22.24) groups compared to T_0 (3220.40 ± 27.29), T_3 (3237.40 ± 51.03), T_4 (3268.90 ± 47.59) groups. Significantly ($P<0.05$) 16% whole wheat supplied group T_4 (3268.90 ± 47.59) consumed higher amount of feed and 8% whole wheat treated group T_2 (3036.10 ± 22.24) consumed lower amount of feed. The observation was that of increasing feed consumption as the level of supplementation is increased. This might be attributed to the whole nature of the wheat which reduced of the feed intake. This is in consonance with the observations reported reduced feed consumption among the broiler on the test diets. Improvement in feed efficiency was because of whole wheat inclusion that largely reduced feed intake (Uddin *et al*, 1996; Hetland *et al*, 2002).

4.1.3 Feed conversion ratio (FCR)

The mean Feed conversion ratio (FCR) of broiler in different dietary groups Control (T_0), T_1 (4%), T_2 (8%), T_3 (12%) and T_4 (16%) were 1.52 ± 0.01, 1.39 ± 0.01, 1.34 ± 0.01, 1.48 ± 0.01, and 1.47 ± 0.03 respectively correspondingly (table-12). Significantly ($P<0.05$) better FCR found in T_1 (1.39 ± 0.01) and T_2 (1.34 ± 0.01) groups compared to T_0 (1.52 ± 0.01), T_3 (1.48 ± 0.01), T_4 (1.47 ± 0.03) groups. Lowest FCR found in 8% whole wheat Supplemented group T_2 (1.34 ± 0.01) and highest in T_0 (1.52 ± 0.01) groups.

Uddin *et al.* (1996) found identical non-significant FCR in all Whole wheat treated groups compared to that of control group of broilers. Watson *et al.* (2003) also got no significant effect of WW decoctions on feed conversion efficiency. But Williams *et al.* (2005) found contrary result and reported that at 28 days birds fed diets supplemented with 2.5 g/kg of meal had significantly greater better FCR than those fed diets with 1.25, 5.0 g/kg of *WW* and controls.

4.1.4 Dressing percentage (DP)

The dressing percent (Table 10) data of broiler were affected by whole wheat. The treatment groups T_0 (66.40 ± 0.51), T_1 (67.40 ± 0.68), T_2 (68.20 ± 0.74), T_3 (67.40 ± 0.68) and T_4 (67.00 ± 0.71) showed no significance ($P>0.05$) difference in dressing percent of broiler chicken. Numerically better DP was found in 8% whole wheat Supplemented group T_2 (68.20 ± 0.74). Skillman *et al.* (2015) also found that polyherbal (including whole wheat) extract did not exhibit any effect on the dressing percentage values of broiler. Dressing percentage was lower by 8.5% in relation with control bird (rutkowski 2000).

4.1.5 Livability

The livability rate showed on (table 10) different group was not significant (P>0.05). The survivability rate of different treatment groups T_0, T_1, T_2, T_3 and T_4 were 98.33 ± 1.67, 95.00 ± 2.04, 96.67 ± 2.04, 96.67 ± 2.04 and 96.67 ± 2.04. Treatment had no significant (P>0.05) effect on livability rate.

4.1.6 Weekly body weight gains

Table 11. Effects of feeding different level whole wheat on body weight gain (g/bird) of broiler at different week.

Treatments	1st week	2nd week	3rd week	4th week	5th week
T_0	172.60 ± 3.42	383.00 ± 19.27	525.80 ± 17.97	469.60 ± 18.35	574.40 ± 13.81^{b}
T_1	174.50 ± 3.15	404.10 ± 4.49	538.40 ± 18.24	490.20 ± 24.86	624.20 ± 6.29^{a}
T_2	173.70 ± .86	402.20 ± 12.58	560.30 ± 8.43	494.80 ± 17.25	627.40 ± 5.29^{a}
T_3	174.50 ± 3.63	386.00 ± 19.84	550.00 ± 10.99	479.70 ± 18.64	601.00 ± 10.23^{ab}
T_4	174.50 ± 2.73	404.00 ± 14.24	549.10 ± 9.58	506.30 ± 19.26	595.20 ± 16.81^{ab}
Mean ± SE	173.96 ± 1.21	395.86 ± 6.47	544.72 ± 6.09	488.12 ± 8.50	604.44 ± 6.12
Level of significance	NS	NS	NS	NS	*

^{ab}, values with different superscripts in the same column differ significantly (P<0.05).
Here, T_0 = (Control), T_1 = (4% whole wheat Supplementation), T_2 = (8% whole wheat Supplementation), T_3 = (12% whole wheat Supplementation) and T_4 = (16% whole wheat Supplementation). Values are Mean ± SE (n=25) one way ANOVA (SPSS, Duncan method), SE= Standard Error, NS =Non Significant

The mean body weight gains (g) of broiler at the end of 5th week in different dietary groups Control (T_0), T_1 (4%), T_2 (8%) T_3 (12%) and T_4 (16%) were 574.40 ± 13.81, 624.20 ± 6.29, 627.40 ± 5.29, 601.00 ± 10.23 and 595.20 ± 16.81 respectively (Table 11and Figure: 2).The overall mean body weight gain of different groups showed that there were significant differences (P< 0.05) among the groups. Significantly higher body weight found in T_1 (624.20 ± 6.29) group and T_2 (627.40 ± 5.29) group compared to control group T_0 (574.40 ± 13.81).

This mode of feeding has not only shown positive effects on the performance of broilers, gut development and utilization of feed nutrients but also meets consumer demands for a ‘natural’ feeding system and improved bird welfare (Gabriel *et al.*, 2008). Previously, researchers have demonstrated that feeding up to 30% whole wheat (or 60% whole wheat (Rose et al., 1995) would not reduce growth rates compared to pelleted diet.

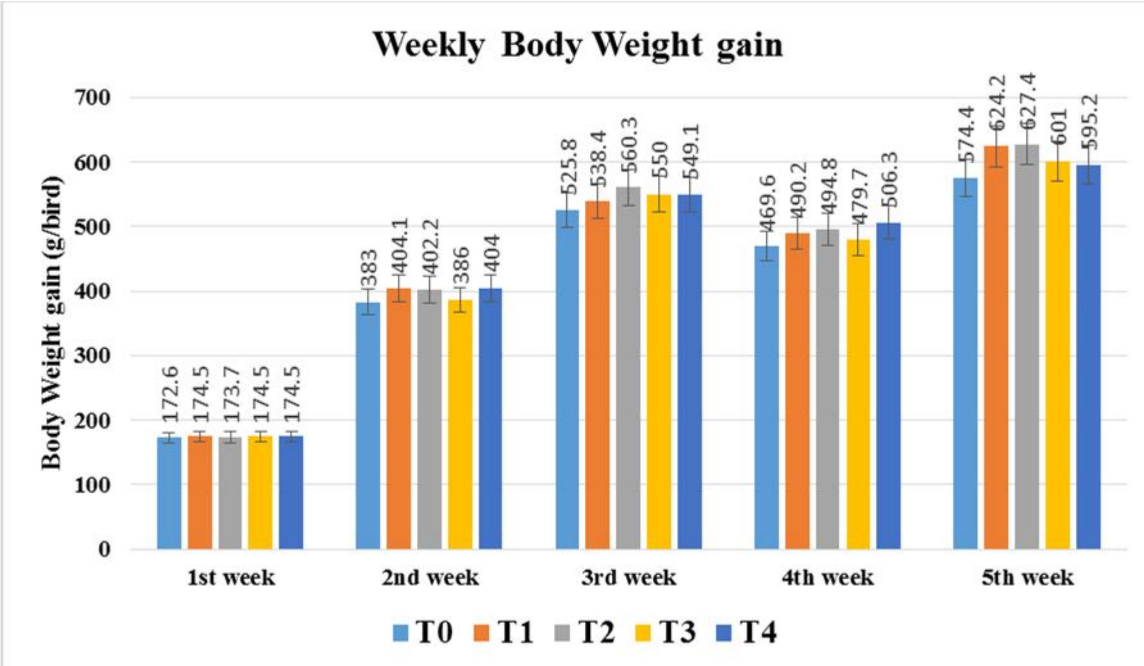

Figure 2: Effects of feeding different level of supplemented whole wheat on body weight gain (g/bird) of broiler at different week

4.1.7 Weekly feed consumption

Table12. Effects of feeding different level of whole wheat on feed consumption (g/bird) of broiler at different week.

Treatments	1st week	2nd week	3rd week	4th week	5th week
T_0	185.20 ± 3.48	328.40 ± 13.71	629.00 ± 5.79	978.60 ±19.67^{a}	1099.20 ± 11.17^{a}
T_1	183.20 ± 2.22	335.60 ± 12.94	617.00 ± 28.62	963.90 ± 19.08^{ab}	1003.80 ± 5.87^{b}
T_2	186.70 ± 1.48	341.40 ± 10.09	609.00 ± 3.32	916.20 ± 9.00^{b}	982.80 ± 23.98^{b}
T_3	187.00 ± 0.55	341.00 ± 9.30	653.90 ± 26.83	987.30 ± 11.02^{a}	1068.20 ± 6.72^{a}
T_4	186.30 ± 1.38	352.20 ± 11.02	650.60 ± 28.55	982.60 ± 21.57^{a}	1097.20 ± 17.71^{a}
Mean±SE	185.68 ± 0.89	339.72 ± 4.97	631.90 ± 9.65	965.72 ± 8.68	1050.24 ± 11.55
Level of significance	NS	NS	NS	*	*

^{ab}, values with different superscripts in the same column differ significantly (P<0.05).

Here, T_0 = (Control), T_1 = (4% whole wheat Supplementation), T_2 = (8% whole wheat Supplementation), T_3 = (12% whole wheat Supplementation) and T_4 = (16% whole wheat Supplementation).

Values are Mean ± SE (n=25) one way ANOVA (SPSS, Duncan method), SE= Standard Error, NS =Non Significant

The mean feed consumption (FC) of broiler (g/birds) at the end of 5th week in different dietary groups Control (T_0), T_1 (4%), T_2 (8%), T_3 (12%) and T_4 (16%) were 1099.20 ± 11.17, 1003.80 ± 5.87, 982.80 ± 23.98, 1068.20 ± 6.72 and 1097.20 ± 17.71 correspondingly (table-12 and Figure: 3). Significantly ($P<0.05$) lower feed intake found in T_1 (1003.80 ± 5.87) and T_2 (982.80 ± 23.98) groups compared to T_0 (1099.20 ± 11.17), T_3 (1068.20 ± 6.72), T_4 (1097.20 ± 17.71) groups. Lowest feed intake found in **8**% whole wheat Supplemented group T_2 (982.80 ± 23.98) and highest in T_0 (1099.20 ± 11.17) groups. Improvement in feed efficiency was because of whole wheat inclusion that largely reduced feed intake (Uddin *et al*, 1996; Hetland *et al*, 2002).

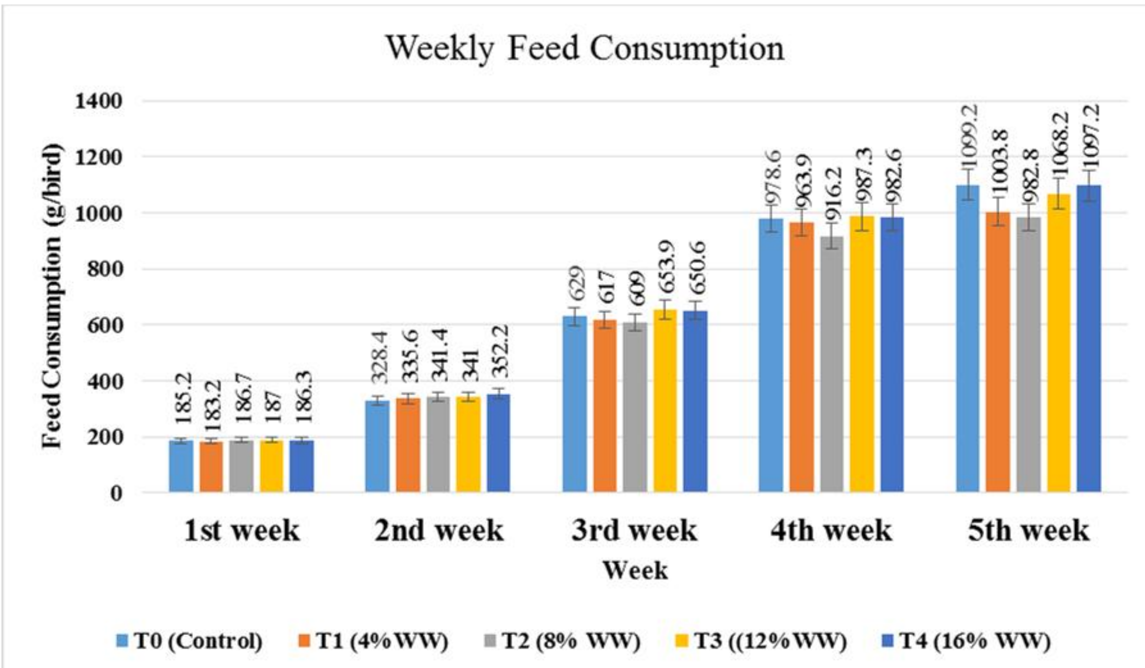

Figure 3: Effects of feeding different level of supplemented whole wheat on feed consumption (g/bird) of broiler at different week.

4.1.8 Weekly feed conversion ratio

Table 13. Effects of feeding different level of whole wheat on FCR of broiler at different week.

Treatments	1st week	2nd week	3rd week	4th week	5th week
T_0	1.07 ± 0.03	0.87 ± 0.07	1.20 ± 0.05	2.09 ± 0.07	1.92 ± 0.06^a
T_1	1.05 ± 0.02	0.83 ± 0.03	1.16 ± 0.10	1.99 ± 0.12	1.61 ± 0.02^c
T_2	1.07 ± 0.01	0.85 ± 0.02	1.09 ± 0.02	1.86 ± 0.07	1.57 ± 0.05^c
T_3	1.07 ± 0.03	0.89 ± 0.02	1.19 ± 0.07	2.07 ± 0.05	1.78 ± 0.04^b
T_4	1.07 ± 0.02	0.87 ± 0.03	1.19 ± 0.05	1.95 ± 0.09	1.85 ± 0.04^{ab}
Mean ± SE	1.07± 0.01	0.86 ± 0.02	1.17 ± 0.03	1.99 ± 0.04	1.74 ± 0.03
Level of significance	NS	NS	NS	NS	*

The mean FCR of broiler at the end of 5th week in different dietary groups Control (T_0), T_1 (4%), T_2 (8%) T_3 (12%) and T_4 (16%) were 1.92 ± 0.06, 1.61 ± 0.02, 1.57 ± 0.05, 1.78 ± 0.04 and 1.85 ± 0.04 respectively. The overall mean FCR of different groups showed that there was significant ($P<0.05$) differences among the groups. Significantly better FCR was found in **8**% whole wheat Supplemented group T_2 (1.57 ± 0.05) compared to T_0 (1.92 ± 0.06), T3 (1.78 ± 0.04), T4 (1.85 ± 0.04) groups. (Table 13 and Figure 4). But Tester *et al.* (2012) found contrary result and reported that at 28 days age birds fed diets supplemented with 2.5 g/kg of meal had significantly better FCR than those fed diets with 1.25, 5.0 g/kg of Whole wheat meal and controls.

Similar improvements in FCR from whole grain feeding have been reported by Gabriel et al. (2008).

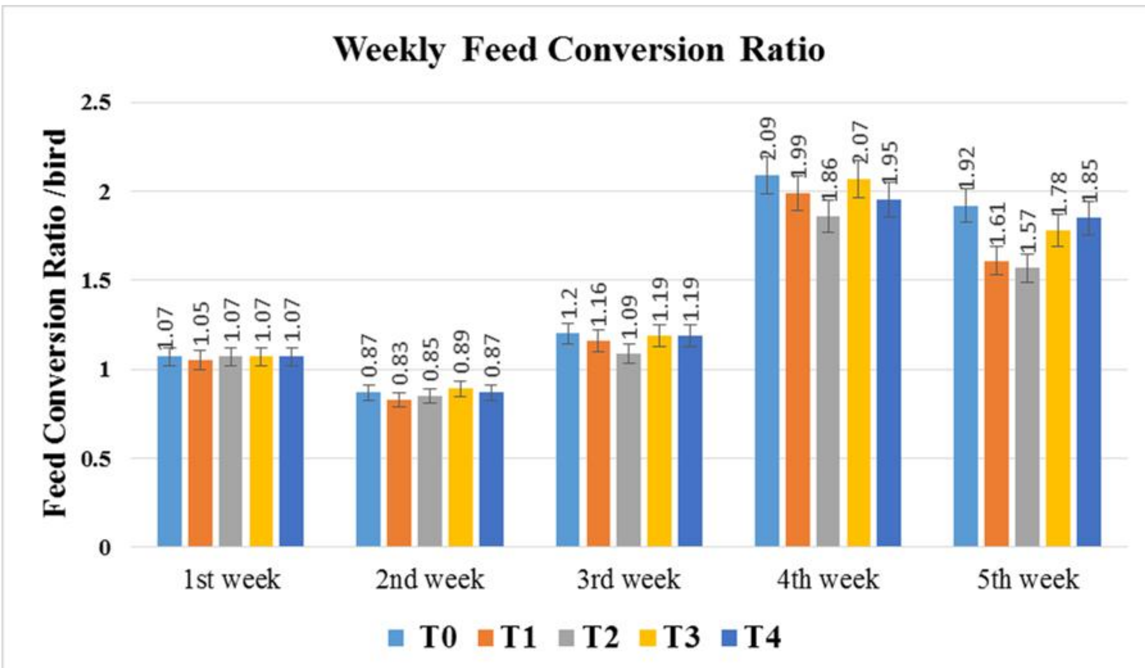

Figure 4: Effects of feeding different level of supplemented whole wheat on feed conversion ratio of broiler at different week.

4.1.9 Visceral organs (Gizzard & Intestine) and Immune organs (Spleen)

Table 14. Effect of dietary supplementation of whole wheat on some visceral organs and immune organ:

Treatment group	**Gizzard/bird (g)**	**Intestine/bird (g)**	**Spleen /bird(g)**
T_0	40.30 ± 1.068	100.60 ± 7.541	1.90 ± .187
T_1	41.20 ± 1.901	108.20 ± 4.969	2.10 ± .187
T_2	42.30 ± 1.715	111.10 ± 5.548	2.30 ± .200
T_3	40.90 ± 1.435	108.60 ± 4.343	2.00 ± .224
T_4	41.60 ± 2.556	107.80 ± 7.121	1.90 ± .292
Mean± SE	41.26 ± .750	107.26 ± 2.565	2.04 ± .095
Level of significance	NS	NS	NS

Here,
T_0 = (Control), T_1 = (4% whole wheat Supplementation), T_2 = (8% whole wheat Supplementation), T_3 = (12% whole wheat Supplementation) and T_4 = (16% whole wheat Supplementation). Values are Mean ± SE (n=25) one way ANOVA (SPSS, Duncan method), SE= Standard Error, NS =Non Significant

Effect of dried WW supplementation on immune organs of Cobb 500 strain broiler during the period from 0 to 35 days of age are summarized in Table 14.
The comparative weight of gizzard (g) of broiler in the dietary group Control, T_0, T_1, T_2, T_3 and T4 were 40.30 ± 1.068, 41.20 ± 1.901, 42.30 ± 1.715, 40.90 ± 1.435 and 41.60 ± 2.556 respectively. The highest value was recorded in 8% whole wheat Supplemented group T_2 (42.30 ± 1.715) and lowest value was control group (40.30 ± 1.068).

The comparative weight of intestine (g) of broiler in the dietary group Control, T0, T1, T2, T_3 and T4 were 100.60 ± 7.541, 108.20 ± 4.969, 111.10 ± 5.548, 108.60 ± 4.343 and 107.80 ± 7.121 respectively. The highest value was recorded in 8% whole wheat Supplemented group T_2 (111.10 ± 5.548) and lowest value was control group (1.90 ± .187).

Form of wheat had no effects ($P > 0.05$) on the relative weights of crop, proventriculus, and pancreas. The relative weight of liver was found to be heavier at 14 days in birds fed the whole-wheat diet, but the biological significance of this finding is unclear. Whole wheat feeding induced no changes ($P > 0.05$) in the relative weight and relative length of the duodenum, jejunum, ileum, small intestine and caeca. The lack of effects of whole wheat feeding on the weight of the gastrointestinal tract is consistent with previous data (Preston et al. 2000; Jones and Taylor 2001. The comparative weight of spleen (g) of broiler in the dietary group Control, T_0, T_1, T_2, T_3 and T_4 were 1.90 ± .187, 2.10 ± .187, 2.30 ± .200 , 2.00 ± .224 and 1.90 ± .292 respectively. The highest value was recorded in 8% whole wheat Supplemented group T_2 (2.23±1.10) and lowest value was control group (1.90 ± .187).

However, the relative weight of gizzard, intestine & spleen of different groups showed non-significant ($P>0.05$) difference among the groups.

Supplementation of in broiler diets did not exert any effect on the mean relative values of visceral organs weights of the broilers used in this study. But relatively higher organs weight was found in whole wheat groups than control groups. Whole wheat given in FCF resulted in increased relative weight of the gizzard, irrespective of the form of other feed (pellet or mash). Gabriel *et al*. (2003a).

4.2 Hematological parameters

Table 15. Effect of supplementation of whole wheat to broiler diets on blood parameters.

Parameters	**T_0**	**T_1**	**T_2**	**T_3**	**T_4**	**Mean ± SE**	**Level of significance**
Glucose (mg/dl)	275.20± .25	284.00±3.89	281.20±9.36	280.60±2.54	270.00±6.01	278.20±2.61	NS
Cholesterol (mg/dl)	190.00±6.27	193.00±.83	186.40±4.76	201.20±3.51	202.20± .66	194.56±.36	NS
Hemoglobin (g/dl)	8.70 ± 0.36	9.52 ±. 0.61	9.60 ± 0.62	9.50 ± 0.79	9.08 ± 0.75	9.28 ± 0.27	NS

Here, T_0 = (Control), T_1 = (4% whole wheat Supplementation), T_2 = (8% whole wheat Supplementation), T_3 = (12% whole wheat Supplementation) and T_4 = (16% whole wheat Supplementation). Values are Mean ± SE (n=25) one way ANOVA (SPSS, Duncan method), SE= Standard Error, NS =Non Significant

Table 15 show the effect of dietary levels of whole wheat (4%, 8%, 12% and 16%) in feed, and their impact on some blood parameters. Concerning the treatment effect on blood constituents, the results indicated no significant differences due to supplementation of whole wheat.

4.2.1 Glucose

Effects of dietary whole wheat supplementation on concentration of glucose (mg/dl) of broiler chickens are presented in Table 15. Different treatment groups of broiler chicken treated with whole wheat showed no significance (P>0.05) difference in blood glucose in broiler chicken. The blood glucose data in different treatment groups are T_0, $T_{1,}$ $T_{2,}$ T_3 & T_4 275.20 ± 5.25, 284.00 ± 3.89, 281.20 ± 9.36, 280.60 ± 2.54 and 270.00 ± 6.01 respectively. Highest result is found in T_1 (284.00±3.89) and Lowest result is found in T_4 (270.00±6.01) where 4% & 16% WW were provided.

The above result was supported Janka et al. (2018) who found that the blood glucose level was decreased by the wheat based diet at the age of 3 weeks broiler chicken. This result also supported Anna et al. (2016) who reported that no significant differences were found in blood glucose concentration between the experimental groups (Wheat based and maize based diet).

4.2.2 Total cholesterol

Total cholesterol concentration (mg/dL) in the blood of different groups ranged from (186.40 ± 4.76) to (202.20 ± 4.66). Statistical analysis revealed a non significant (P>0.05) deference among the group. The cholesterol level of different treatments were Control (T_0) (190.00 ± 6.27), T1 (193.00 ± 4.83), T2 (186.40 ± 4.76), T3 (201.20±3.51) and T_4 (202.20±4.66) correspondingly. Numerically lower cholesterol was found in whole wheat Supplemented group T_2 (186.40 ± 4.76) (Table 15) Schalm *et al*. (2012) found contrary results by investigating the serum cholesterol. They reported that serum cholesterol progressively increased if dietary levels whole wheat is increased.

4.2.3 Hemoglobin

The hemoglobin data (Table 15) of broiler chicken were increase treated by whole wheat. The whole wheat Supplemented treated group T_2 (9.60 ± 0.62) showed the highest hemoglobin level than other treatment groups of T_1, T_3, T_4, and Control respectively, but no significant (P>0.05) difference was found among most of whole wheat and control treatment.

CHAPTER 5

SUMMARY AND CONCLUSION

The present data suggest that, the grain is added as whole post-pelleting, a larger diameter pellet is beneficial. On the other hand, when WW is added pre-pelleting, a smaller diameter pellet results in improved weight and feed per gain in broiler performance. WW Inclusion and larger pellet diameter improved AME and ileum digestibility of starch. However, gizzard size differed depending on the method of inclusion and the present data suggest that improvements in nutrient utilization cannot be always explained on the basis of gizzard development alone. The hypothesis that a well-developed gizzard will improve nutrient utilization is relevant for post-pellet inclusion of WW, but not for pre-pellet inclusion of WW, indicating the involvement of other factors. The experiment was conducted at SAU poultry farm. The effects of supplementation of WW were measured. Production performance findings indicate that dietary inclusion of different treatment (Control (T_0), T_1 (4% WW), T_2 (8%WW) T_3 (12%WW) and T_4 (16%WW)) groups showed significant ($P<0.05$) effect on weekly FC, body weight gain , FCR and total FC, LW and FCR during 35 days of marketing.

Significantly ($P<0.05$) higher weekly body weight gain and final live weight found in 8% WW treated group. In case of weekly and total feed consumption 8% WW treated group significantly ($P<0.05$) consumed lower amount of feed. Significantly ($P < 0.05$) better FCR found in 8% whole wheat Supplemented group than control group. In case of weekly FCR at end of 5th week Significantly ($P < 0.05$) better FCR was found in 8% whole wheat Supplemented group compared to control, 12% WW and 16% WW groups. Dressing percentage and livability (%) was insignificant ($P>0.05$) in different dietary groups. Gizzard and intestine weight was insignificant ($P>0.05$) in different dietary groups. Insignificant ($P>0.05$) spleen weight found in different dietary groups but numerically higher weight found in 8% whole wheat Supplemented group. Different dietary group showed Insignificant ($P>0.05$) effect on glucose (mg/dl), cholesterol (mg/dl) and hemoglobin (g/dl) value. But numerically lower cholesterol was found in 8% whole wheat Supplemented group.

Analyzing the above research result it can be concluded that final live weight, total feed consumption and FCR was significantly ($P<0.05$) superior in 8 % WW treated groups. The study therefore recommends conducting field trial on commercial poultry farm to fix up inclusion level of whole wheat.

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APPENDICES

Appendix 01. Recommended level of nutrients for broiler

Components	Starter	Grower
ME (kcal/kg)	3000	3100
% CP	22	20
% Ca	1.0	0.85
% P (Available)	0.5	0.4
% Lysine	1.2	1.0
% Methionine	0.5	0.45
% Tryptophane	0.21	0.18

Source: Cobb500 Broiler Management Guide, 2016

Appendix 02. Nutrient composition of the ingredients used to formulate experimental diets

Ingredients	DM (%)	ME (K. Cal/kg)	CP (%)	CF (%)	Ca (%)	P (%)	Lys (%)	Meth (%)	Tryp (%)
Soybean meal	90	2710	44.50	7.5	0.26	0.23	2.57	0.76	0.57
Maize	89.5	3309	9.2	2.4	0.25	0.40	0.18	0.15	0.09
DCP					22	17.21			
Soybean oil	100	8800							
Protein concentrate (Jeso-prot)	91.64	2860	63.30	8.1	6.37	3.24	3.87	1.78	.53
Meat and Bone meal	95.5	1044	14.6	2.5	7.0	12.11	.66	0.24	0.12

Source: Cobb500 Broiler Management Guide, 2016

Appendix 03. Feed consumption (g/bird) of 1st, 2nd, 3rd, 4th & 5thweek under different treatments.

Treatment	Replications	1st week FC	2nd week FC	3rd week FC	4th week FC	5th week FC
T_o	R_1	197	301	635	1010	1096
	R_2	176	359	645	1037	1101
	R_3	181	364	630	950	1075
	R_4	186	304	610	930	1140
	R_5	186	314	625	966	1084
T_1	R_1	189	379	725	890	990
	R_2	184	309	590	975	994
	R_3	176	342	560	971	1015
	R_4	181	339	590	985	1000
	R_5	186	309	620	998.5	1020
T_2	R_1	189	381	620	900	998
	R_2	187	329	600	923	930
	R_3	186	329	610	900	1050
	R_4	181.5	339	605	910	1010
	R_5	190	329	610	948	926
T_3	R_1	187	374	752	1025	1090
	R_2	186	339	640	998.5	1077
	R_3	189	319	603	978	1056
	R_4	187	329	610.5	965	1063
	R_5	186	344	664	970	1055
T_4	R_1	181.5	378	676	1005	1112
	R_2	190	329	610	900	1100
	R_3	187	355	605	995	1145
	R_4	186	374	610	988	1036
	R_5	187	325	752	1025	1093

Appendix 04. Body weight gain (BWG) (g/bird) of 1st, 2nd, 3rd, 4th and 5th week under different treatments.

Treatment	Replications	1st week BWG	2nd week BWG	3rd week BWG	4th week BWG	5th week BWG
T_0	R_1	173	451	456	537	548
	R_2	168	356	548	447	619
	R_3	183	342	554	455	570
	R_4	176	397	528	432	545
	R_5	163	369	543	477	590
T_1	R_1	170	418	467	587	610
	R_2	180.5	410	550	455	625
	R_3	171	400	557.5	465	610
	R_4	167.5	400.5	569.5	457	640
	R_5	183.5	392	548	487	636
T_2	R_1	173.5	448	532	562	620
	R_2	177	402	551	488.5	635
	R_3	172	402.5	571.5	472	615
	R_4	173	376.5	568	467	623
	R_5	173	382	579	484.5	644
T_3	R_1	183	462	509	553	565
	R_2	176	357	573.5	463.5	593
	R_3	163	352	551.5	472.5	610
	R_4	170	377	563	457.5	623
	R_5	180.5	382	553	452	614
T_4	R_1	171	457	523	562	590
	R_2	167.5	402	532	542	630
	R_3	183.5	402.5	551	488.5	635
	R_4	173.5	376.5	571.5	472	575
	R_5	177	382	568	467	546

Appendix 05. Weight of internal organs (gizzard and intestine) and immune organ (spleen) of broiler chicken under different treatment groups (g/bird).

Treatments	Replications	Gizzard weight (g)	Intestine weight (g)	Spleen weight (g)
T_0	R_1	42	115	1.5
	R_2	37	79	2
	R_3	39	120	2.5
	R_4	43	92	2
	R_5	40.5	97	1.5
T_1	R_1	35	95	1.5
	R_2	41.5	110.5	2
	R_3	47	98.5	2.5
	R_4	41.5	120.5	2
	R_5	41	116.5	2.5
T_2	R_1	48	93.5	2
	R_2	44	115	2
	R_3	38	103.5	2.5
	R_4	40.5	123.5	3
	R_5	41	120	2
T_3	R_1	37	99.5	2.5
	R_2	44	110.5	2
	R_3	38	97.5	1.5
	R_4	42	118	1.5
	R_5	43.5	117.5	2.5
T_4	R_1	42.5	101.5	2
	R_2	49	94	1.5
	R_3	33	96	1.5
	R_4	42.5	132	1.5
	R_5	41	115.5	3

Appendix06. Hematological data in different treatment groups

Treatments	Replications	Glucose (mg/dl)	Cholesterol (mg/dl)	Haemoglobin (g/dl)
T_0	R_1	280	193	9.1
	R_2	285	210	8.3
	R_3	276	186	7.7
	R_4	280	190	9.8
	R_5	255	171	8.6
T_1	R_1	286	203	9.8
	R_2	290	189	10.4
	R_3	292	198	8.9
	R_4	270	176	7.5
	R_5	282	199	11
T_2	R_1	295	184	11.3
	R_2	269	197	10.6
	R_3	250	198	7.9
	R_4	295	178	8.7
	R_5	297	175	9.5
T_3	R_1	276	205	8.7
	R_2	283	190	12.5
	R_3	289	207	7.9
	R_4	275	208	9.6
	R_5	280	196	8.8
T_4	R_1	254	211	8.4
	R_2	274	203	11.9
	R_3	269	202	7.5
	R_4	290	210	8.9
	R_5	263	185	8.7

Appendix 07. Average Live weight, Eviscerated Weight and Dressing Percentage of different replication of broiler chicken under different treatment

Treatment	Replications	live weight (g)	Eviscerated weight (g)	Dressing Percentage (%)
T_o	R_1	2165	1428.9	66
	R_2	2138	1432.46	67
	R_3	2104	1430.72	68
	R_4	2078	1350.7	65
	R_5	2142	1413.72	66
T_1	R_1	2252	1531.36	68
	R_2	2220.5	1487.735	67
	R_3	2203.5	1498.38	68
	R_4	2234.5	1452.425	65
	R_5	2246.5	1550.085	69
T_2	R_1	2335.5	1611.495	69
	R_2	2253.5	1509.845	67
	R_3	2233	1473.78	66
	R_4	2207.5	1545.25	70
	R_5	2262.5	1561.125	69
T_3	R_1	2272	1544.96	68
	R_2	2163	1449.21	67
	R_3	2149	1396.85	65
	R_4	2190.5	1511.445	69
	R_5	2181.5	1483.42	68
T_4	R_1	2303	1543.01	67
	R_2	2273.5	1477.775	65
	R_3	2260.5	1537.14	68
	R_4	2168.5	1431.21	66
	R_5	2140	1476.6	69

Appendix 08. Recorded temperature (°C) during experiment

Age in weeks	Period	Room temperature (°C)						
		8 A.M.	12 P.M.	4 P.M.	8 P.M.	12 A.M.	4 A.M.	Average
1st	26.12.17-01.01.18	29.1	29.5	30.0	30.5	29.5	29.0	29.66
2nd	02.01.18 - 08.01.18	28.5	29.0	29.5	29.2	27.1	26.0	28.21
3rd	09.01.18 - 15.01.18	25.0	25.2	25.8	25.2	24.0	24.2	24.90
4th	16.01.18 - 22.01.18	24.8	25.5	25.8	24.0	24.4	23.2	24.61
5th	23.01.18 - 29.01.18	24.2	24.5	25.8	24.0	23.4	22.2	24.01

Appendix 09. Relative humidity (%) during experiment

Age in weeks	Relative humidity (%)							
	Period (day)	8 A.M	12A.M	4 P.M.	8 P.M.	12 P.M.	4 A.M	Average
1st	11.05.17-17.05.17	48	49	50	48	47	78	53.3
2nd	28.05.17-24.05.17	47	45	50	45	44	44	45.83
3rd	25.05.17-31.05.17	46	46	48	47	45	44	46
4th	01.06.17-07.06.17	56	57	60	65	61	59	59.66
5th	01.06.17-07.06.17	63	66	67	66	63	61	64.33

Appendix 10: Mortality of broilers under different treatments up to 5 weeks of age.

Day no.	Date	Mortality
Day 0	26.12.2017	0
Day 1	27.12.2017	0
Day 2	28.12.2017	0
Day 3	29.12.2017	0
Day 4	30.12.2017	0
Day 5	31.12.2017	01
Day 6	01.01.2018	0
Day 7	02.01.2018	01
Day 8	03.01.2018	0
Day 9	04.01.2018	01 (T_1R_1)
Day 10	05.01.2018	0
Day 11	06.01.2018	0
Day 12	07.01.2018	1 (T_0R_1)
Day 13	08.01.2018	0
Day 14	09.01.2018	0
Day 15	10.01.2018	0
Day 16	11.01.2018	1 (T_1R_2)
Day 17	12.01.2018	0
Day 18	13.01.2018	0
Day 19	14.01.2018	0
Day 20	15.01.2018	1 (T_3R_1)
Day 21	16.01.2018	2(T_1R_5,T_2R_3)
Day 22	17.01.2018	0
Day 23	18.01.2018	0
Day 24	19.01.2018	1(T_3R_2)
Day 25	20.01.2018	0
Day 26	21.01.2018	0
Day 27	22.01.2018	1 (T_4R_1)
Day 28	23.01.2018	0
Day 29	24.01.2018	0
Day 30	25.01.2018	1(T_2R_2)
Day 31	25.01.2018	0
Day 32	26.01.2018	0
Day 33	27.01.2018	1(T_4R_3)
Day 34	28.01.2018	0
Day 35	29.01.2018	0

APPENDIX-11

Pictorial view of this experiment.

Fig: Receiving DOC

Fig: Gas Brooder

Fig: Vaccine preparation for DOC

Fig: Taking DOC weight

APPENDIX-11(continued)

Fig: Placing DOC in Brooder

Fig: DOC in brooder

Fig: Treatment & Replication chamber

Fig: Treatment & Replication chamber

APPENDIX-11(continued)

Fig: Whole Wheat mixing in Broiler ration

Fig: Taking Daily Records

Fig: Supervisor observing my research activity

Fig: Taking blood parameter

APPENDIX-11(continued)

Fig: Taking blood from wing vein

Fig: Taking blood parameter

Fig: Working in farm

Fig: Slaughtering bird following Halal method

Fig: Desectioning bird