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The effect of the grit stone on feed passage rate in broiler chickens

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Abstract

An experiment was carried out to test the hypothesis that feeding grit to broiler chickens would slower the passage rate of the feed throughout the digestive tract. At the same time, the effect of grit on the performance of broilers and gizzard development was investigated in this study.

252 one-day-old broiler chickens were randomly allocated in 4 pens. The birds were fed commercial starter from 1-10 days, grower diets from 11 to 18 days and starter diet diluted with 15% of whole wheat from 18-22 days. The experiment consisted of four treatments: one control group, one zeolite group, one granite group and one marble group.

At 5 days of age, four birds were randomly placed in each of 48 quail cages. At 5, 7 and 9 days of age, 8g, 15g and 15g of each type of grit were fed on the feed to each of 12 cages. At 18, 19 and 20 days of age, 1g of grit per bird was given. On day 5, 11, 13, 18, 21 and 22, birds were weighed either groupwise or individually for calculating the weight gain. On day 11, 13, 18 and 21, the feed and excreta were removed and collected. The feed and remaining grit stones in the feed were measured to calculating grit consumption and feed intake. The excreta were collected for observing grit excretion. On day 13, 18 and 21, randomly selected bird from each cage was killed. The crop content and gizzard content were collected and frozen for later laboratory analysis. The empty gizzard weight and full gizzard weight were measured. Small intestine was also collected and frozen for later laboratory analysis. On day 22, two birds from each treatment were killed at 30min, 60min, 90min, 120min, 150min and 180min after commencement of feeding to measure the feed flow rate.

There were three grit-fed groups in the experiment and a control group (non-grit-fed group). In the result section, the data from marble-fed group was not used.

The findings in this study showed that grit had no effect on feed passage rate ($P>0.05$). Feed intake, weight gain and feed: gain ratio of the birds were also not affected by grit supplementation ($P>0.05$). In addition, there was no significant difference in gizzard weight between grit-fed birds and non-grit-fed birds ($P>0.05$). Grit excretion and retention were significantly different in grit-fed groups.

Key words: grit stones, granite, zeolite, whole wheat, feed passage rate.

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1. Introduction

The rate of feed passage can be expressed as the amount of digesta which passes a point of the digestive tract in a given time (Almirall & Esteve-Garcia 1994; Brandt & Thacker 1958). In other words, it can be indicated as the time, referred to retention time, which takes the digesta of a meal to pass through the gastrointestinal tract and can be measured by adding a marker to the diet (Almirall & Esteve-Garcia 1994; Vergara et al. 1989).

Feed passage rate throughout the digestive tract influences nutrient utilization by determining the time available for nutrients contact with digestive enzymes, absorptive surfaces as well as microbial populations (Clemens et al. 1975; Mateos et al. 1982; Vergara et al. 1989). This fact is important in birds due to the smaller length of the intestine compared to mammals (Hill & Strachan 1975; cited by Vergara et al. 1989). It has been also suggested that feed passage rate affect the feed intake and it has been assumed an increased feed passage rate is accompanied by an increased intake of feed especially when pelleted diets are fed to the broiler chickens (Sibbald 1979; Sundu 2009; Svihus 2014).

Feed passage rate can be affected by feed intake (Ferket & Gernat 2006; Sundu 2009), the strain of and age of the bird (Shires et al. 1987; Vergara et al. 1989), fasting period (Mateos et al. 1982), high temperature (Wilson et al. 1980), genetic background (Cherry & Siegel 1978), diet type (Rochell et al. 2012), the characteristics of feed ingredients (Almirall & Esteve-Garcia 1994; Mateos & Sell 1981; Mateos et al. 1982), development of digestive tract (Svihus 2014) as well as administration.

Increased feed intake due to feeding pellets with fine particles can result in faster passage rate of the digesta (Sundu 2009). Because of the structure of the pellet integrated from the fine particles, pellets can be dissolved rapidly when moistened and ground in the crop and gizzard of the bird (Svihus 2011). In the one hand, this would cause rapid passage of the fine particles through the gizzard into the small intestine (Engberg et al. 2002). Large quantity of feed enter in the duodenum in a short time may overload this part. Besides, due to the fast disintegration of the pellets in the anterior digestive tract, the fine particles of the pellet cannot stimulate gizzard contraction and development (Engberg et al. 2002). Less-stimulating effect of the pellets would cause a poorly-developed gizzard.

The pelleted diets fed to the birds does not only result in higher feed intake, but also result in poor-developed gizzard. The underdeveloped gizzard may allow a too-fast passage of poorly degraded nutrients to be passed through (Svihus 2014). Therefore, this causes the wastage of the feed and provides nutrients for proliferation of the micro-organism living in the hind gut.

The gizzard is thought to be the feed-flow regulator or pace-maker in birds (Duke 1986; Svihus 2011). However, when the pelleted diet fed to the birds, the gizzard would be poorly developed and increase the too-fast passage of the digesta through the digestive tract (Sundu 2009). Therefore, a well-developed and well-functioned gizzard is essential to the broiler chicken.

Structural components such as coarse fibers, whole grains and grit stones are thought to stimulate gizzard development and functions by stimulating the contraction of gizzard muscle and better grinding which allows longer retention of the digessta and a better synchronized feed flow (Gionfriddo & Best 1999; Hetland et al. 2002; Hetland et al. 2005; Svihus 2011).

An experiment was carried out to test a hypothesis that feeding grit stones to broiler chickens would slower feed passage rate in the gastrointestinal tract. At the same time, the effect of grit stones on the performance of broiler chickens, gizzard development, grit consumption and disappearance were investigated as well.

2. Literature review

a. The pelleted diets

The pellet is the most common form of the feed used in broiler production. The pelleted feed can increase the handling properties of feed such as higher density, easier conveying and less dust formation during handling(Thomas & Van der Poel 1996). In addition, the pelleted diet can improve nutrient digestibility, feed intake and hence increase animal performance (Svihus & Zimonja 2011). It is possible that birds have higher growth rate when they are fed pelleted diets, because they use less energy on the grinding of the feed and therefore more energy can be used on growth (Jensen et al. 1962).

However, feeding pellets may be attributed to hyperhagia (Bolton 1960; cited by Olver & Jonker 1997), especially when they are fed ad libitum. The phenomenon is often observed in broiler production when they are fed pellets and feed intake in broiler chickens can be increased with between 10 and 20% (Engberg et al. 2002; Svihus et al. 2004b). A reason that pellets causes higher feed intake in broiler chickens is due to their higher bulk density (Choi et al. 1986).

"According to the lipostatic theory of feed intake control, the modern broiler has become hyperphagic in order to accommodate the genetic propensity for high body fat content" (Ferket & Gernat 2006). This is why the feed intake of broiler must be restricted to keep body fat at acceptable levels.

Very fast growth of broiler chickens under ad libitum feeding is sometimes contributed to increased mortality and leg problems (Adiya 2013; Su et al. 1999; Svihus et al. 2010). The increased feed intake demands a well-functioned digestive system to maintain a constant passage of feed, better regulations of feed intake and hence increase the feed efficiency. The feed intake and feed efficiency decide the broiler production.

b. Digestive tract of the bird

In the monogastric animal, the stomach is known to function as a feed storage organ and feed intake regulator. However, the crop, proventriculus and gizzard have been recognized as the organs to be responsible for this retention function in chickens. The crop is a ventral diverticulum of the esophagus, and contains longitudinal folds on the inner surface making it distensible (Adiya 2013). Although the crop is not used to its maximal capacity under ad libitum feeding, the birds under this feeding will adapt to a habit to let feed bypass the crop (Svihus 2014).

However, the crop is mainly thought to function as a storage organ under discontinuous feeding or intermittent feeding (Svihus et al. 2010). When stored in the crop during intermittent feeding, the feed may get enough time to be moistened (Svihus et al. 2010), softened and fermented by microflora mainly lactic acid bacteria and produce lactic acid and thereafter reduce the pH of the crop (Bayer et al. 1978; Hilmi et al. 2007). The increased retention time and reduced pH in the crop is thought to increase the efficiency of exogenous enzymes (Svihus et al. 2002; Svihus et al. 2010).

The proventriculus and gizzard are the true stomach of the chicken. In the proventriculus, hydrochloric acid and pepsinogen are secreted and mixed with contents because of muscular activity of the gizzard. The proventriculus of the chicken is too small to store the digesta longer time (Dibner & Richards 2004) and hence the retention time of digesta in this part is very short. The chemical digestion of proventriculus is mainly aided by the gizzard.

However, the gizzard is the main organ to grind coarser particles and control feed passage rate (Ji 2014; Scott & Heuser 1957; Svihus 2011). Due to the contraction of the gizzard muscles, the gizzard content is refluxed into the proventriculus and stimulate more secretion of hydrochloric acid and pepsinogen to be added on the content (Duke 1992). Gizzard contraction may affect the flow of digesta in the duodenum, because the contractions of the duodenum, gizzard and proventriculus are coordinated (Duke 1986). The grinding activity of the gizzard is aided by its two thick, opposed lateral muscles and two thin, anterior and posterior muscles (Svihus 2011).

The grinding activity has been described in detail by Svihus (2011) and Duke (1992) and will be briefly mentioned here. "The grinding cycle begins with contraction of two thin muscles, followed by opening of the pylorus and a powerful peristaltic contraction in the duodenum. Immediately after the starting of the duodenal contraction, the pair of two thick muscles contracts and leads to some gastric material being pushed into the duodenum and some are entering the proventriculus. This contraction cycle takes place up to 4 times per minute".

The digesta in the gizzard is rubbing against with the koilin layer, a thick layer of glycol-protein, inside the gizzard and meanwhile against other particles in the gizzard during the contraction. Feed particles need to be reduced to a critical particle size before leaving the gizzard (Moore 1999). The gizzard is thought to be analogous to the rumen where particles are retained until degraded to certain critical particle size (Clemens et al. 1975).

The retention time of chyme in the proventriculus and gizzard has been estimated to vary between 30min to 60min in a standard commercial diets with few structural components, but this time can approach to 2h or more if feed contain structural component (Svihus 2014). This is because the inclusion of structural component in broiler diets can increase the gizzard activity, gizzard size and volume and hence to retain the digesta for longer time in the gizzard (Hetland et al. 2003; Ravindran et al. 2006).

The gizzard is the main retention organ of the solid components of the diet and the main purpose of this is to make them suitable for intestinal digestion (Vergara et al. 1989). The increased retention time and better grinding in the gizzard may give a synchronized feed flow which increases the retention time of digesta in small intestine and results in higher digestion and absorption.

c. Structural components in the feed

Coarser particles in the diet is thought to increase gizzard contraction, gizzard development as well as increase retention time of the digesta in the gizzard (Amerah et al. 2009; Hetland & Svihus 2001; Nir et al. 1994a; Sundu 2009). Pellets consisted of bigger particles can stimulate gizzard and increase gizzard weight and gizzard size (Sundu et al. 2008).

Many structural components have been tested with regard to their stimulating effects on the gizzard development, functions and feed flow rate. The developed- and well-functioned gizzard can be explained as the gizzard with increased weight, increased holding capacity and stronger muscular contractions. The weight of the gizzard is reduced in chickens when they are fed pellets compared to those fed mash diets (Choi et al. 1986). The coarser ingredients is thought to be responsible for more developed gizzard that ensures a complete grinding and a well- regulated feed flow and secretion of digestive juices (Svihus et al. 2010).

The gizzard weight of the broilers were larger in treatments where they are fed whole grains than that of the broiler fed mash or pellets (Olver & Jonker 1997; Svihus et al. 2010). This is in agreement with the finding of Munt et al. (1995) and Mastika and Cumming (1985). The reason to use whole grain is twofold in poultry production. One is to reduce feed cost by saving handling and processing cost of the grain (Hetland et al. 2002; Svihus et al. 2004a). Another most important role of whole grains has been associated with their physical structure to stimulate the activities of the gizzard (Hetland et al. 2002; Hetland et al. 2005; Svihus & Hetland 2001).

Some studies have found feeding whole wheat to chickens can stimulate gizzard function, increase gizzard weight and reduce the passage rate (Olver & Jonker 1997). Oat hulls and litter materials fed to poultry have been observed to increase feed utilization by stimulating gizzard functions (Amerah et al. 2009; Hetland & Svihus 2001; Hetland et al. 2005). Whole sorghum fed with grit increased feed efficiency and weight gain compared to the mash fed with grit (Nir et al. 1994b).

Grinding grain sorghum was not improving weight gain or feed conversion of birds when grit was fed (Balloun & Phillips 1956). When whole grain fed to chickens with grit, feed efficiency and weight gains were improved 12.5% and 16.5%, respectively (McIntosh et al. 1962).

d. Grit stones

The grit is defined as stones and rock fragments ingested by birds, excluding very fine particles such as dust, ash, and clay (Gionfriddo & Best 1999). Feeding grit to poultry is generally considered as a wise choice for optimum feed utilization and health which is mainly accomplished by stimulating gizzard and improving functions of the gizzard (Gionfriddo & Best 1999).

It has been accepted that gizzard grit is an essential aid for grinding food in many birds (Franson et al. 2001; Lee et al. 2004; Norris et al. 1975). Grit may also provide supplementary minerals, especially calcium (Gionfriddo & Best 1996; Korschgen 1964; Norris et al. 1975). In some species, grit consumption is driven primarily by the requirement of calcium and secondarily as a grinding material (McCann 1939), because calcium is a crucial nutrient for egg shell and skeleton formation. McIntosh et al. (1962) also concluded that grit has an action in enhancing energy availability in addition to that of grinding feed in the gizzard.

Elevated mortality is observed in wild birds when they are deprived from grit (McCann 1939; Norris et al. 1975). Elevated mortality is also caused by one factor. In the wild birds, the toxic particle such as lead shot pellets and pesticide pellets potentially mistaken as grit and ingested by birds (Best & Gionfriddo 1991; Fisher et al. 2006; Trost 1981).

Grit is consumed higher and excreted faster in the birds fed coarser feed compared to pellets (Norris et al. 1975). At the same time, consumption of grit is influenced by avian preference and aversions (Best & Gionfriddo 1994), the availability of grit particles with different characteristics (Norris et al. 1975) and rates of breakdown and passage of grit from the gizzard (Gionfriddo & Best 1995; Norris et al. 1975; Vance 1971).

3. Material and Methods

A feeding experiment was carried out from 12th of November to 4th of December 2015 at the Animal Production Experimental Centre, NMBU, Ås, Norway.

a. Chicken experiment

On 12th of November, 252 one-day-old male broiler chickens (Ross 308) were randomly allocated in four equally sized pens (72cm x145cm) covered with wood shaving. Each pen contained a bell drinker and a plastic bucket feeder. Feed and water were available ad libitum. Room temperature was kept around 28℃ at first week. Extra heating was provided by heat lamps over the pens in the first 5 days to ensure the temperature around the pens 30℃. Room temperature was reduced to 2℃ in the following three weeks. The birds were exposed to continuous lightning due to no possibility for complete darkness.

All birds were fed commercial starter diet from day 1-11, grower diet from day 11-18. From 18 to 22 days of age, the remaining birds were fed a mixed diet consisting of 15% whole wheat and 85% starter diet, except on day 21, when half the birds were given 50 g of whole wheat and the remaining birds were given 50 g of the grower diet. Coccidostats were included in the diet. Commercial diets were bought from the Norwegian feed company Norgesfôr. The whole wheat was supplied by Felleskjøpet. The birds got access to both feed and water ad libitum throughout the experiment time, with exception of the period when the effect of whole wheat and passage rate were examined. From 1 to 5 days, all the birds were kept in the pen and fed commercial starter diets in bucket feeders.

At 5 days of age, 4 randomly selected birds were weighed and housed in each of 48 quail cages (50cm×35cm×20cm) with floor of wire mesh. Two racks of cage were used and each rack consisted of 24 cages and each side 12 cages. The feeder and water container were suspended outside each cage and accessible through windows in the cage. The cage is equipped with a tray for collecting excreta. The bird with a weight below 130 grams was excluded from the experiment. The birds left in the pen were not used in the experiment. The trial consisted of 1 control (without grit) and 3 treatment groups (with grit). Grit-fed groups were zeolite-fed group, granite-fed group and marble-fed group. Each group was including 12 cages and totally 48 birds. From 5 days of age, different grit stones were given to the birds according to their treatment and cage numbers.

At 5 days of age, 8 grams of each type of grit were fed to each of 12 cages (2g/bird). The feed (fed to the birds from 5 to 11 days of age) also was prepared and weighed in the bucket for each cage in order to make the calculation of feed intake easier. The grit was given on top of the feed. At 7 days of age, 15 grams of each type of grit were fed to each of 12 cages (3.75g/bird) and at 9 days of age, 15 grams of each type of grit were also fed to each of 12 cages (3.75g/bird). Grit stones were given on top of the feed. Birds were weighed groupwise at day 5 and at day 11. At 11 days of age, feed was removed and remaining grit in the feed was measured. The remaining feed in the bucket and feeder was put together and weighed. Simultaneously, the excreta in the tray from day 5 to 11 was collected and stored in the freezer for later analysis. Clean trays were placed into the cages again.

From 11 days of age, grower diet was used and weighed in each bucket corresponding to each cage. At 13 days of age, the feed in the bucket and feeder also put together and weighed. The birds in each cage also were weighed groupwise. At the same time, the excreta also were collected and clean trays were placed back into the cages. At 13 days of age, one bird picked randomly from each cage was killed and dissected (in total 48 birds). After dissection, the gizzard was weighed full and empty, and the gizzard content was put in to a container and frozen.

At 18 days of age, the same process was repeated again as it has performed at 13 days of age. Additionally, trays were cleaned at 15 days, 16 days and 17 days of age and pooled with the excreta taken at 18 days of age, because the excreta were piled.

From 18 days of age, the grower diet was switched to a starter diet containing 15% of whole wheat. Meanwhile, 1 gram of grit was fed to per bird on 18 days, 19 days and 20 days of age, respectively.

On day 21 feed was taken away at 21:00 and the birds were starved to 07:00 on day 21. From 07:00 to 09:00, birds were weighed and trays were removed and cleaned. One bird from each cage was marked with cage number and put into the corresponding pen. The remaining 48 birds in the cage were fed whole wheat and pellets (24 birds were fed whole wheat and other 24 birds were fed pellets) in order to test the effect of whole wheat. After feeding 2 hours, the trays were put into the cages. After feeding 5 hours, the birds were killed and dissected. The whole digestive tract including the crop was collected. The crop and gizzard contents were put into separate containers and the gizzard weight was weighed full and empty. The excreta were collected.

After killing all the birds in the cages, the remaining birds in the pens were placed back to the cages and was given access to starter diet with 15% of whole wheat. At 21:00, the feed was taken away and the birds was starved until 07:00 on day 22. At 07:00, 50 g of feed (starter diet + 15% whole wheat) was given to the birds for 30 minutes. After 30 minutes, feed was taken away and collected in small plastic bags for further analysis. Two birds from each treatment were killed by a cranial blow followed by a cervical dislocation at 30, 60, 90, 120, 150 and 180 minutes after commencement of feeding (6 killing times × 2 replicates). Whole digestive tract was collected. The crop and gizzard content were also collected and the empty gizzard weight and full gizzard weight were recorded. The intestinal tract was put in the liquid nitrogen and then put into bag and frozen. On 22 days of age, there were actually 46 birds left, because one was dead during the experiment another one was intentionally killed duo to its lower body weight.

The feed consumption, weight gain and feed: gain ratio were calculated at 11, 13, 18 and 21 days of age according to the data recorded in each dissection day.

b. Grit composition

i. Granite

The granit grit was ordered from Sibelco Nordic AB, a supplier of industrial minerals. The grit stones were produced at Woldstad Sandforreting in Norway, and had a dimension of 2.0 to 3.5 mm.

Table 1. Chemical composition of granite grit (Sibelco Nordic)

SiO_2	**Silicon dioxide**	**79.50 %**
Al_2O_3	Aluminium oxide	9.57%
K_2O	Potassium oxide	3.62%
Na_2O	Sodium oxide	2.55%
Fe_2O_3	Iron (III) oxide	2.04%
CaO	Calcium oxide	1.66%
MgO	Magnesium oxide	0.67%
TiO_2	Titanium dioxide	0.28%

ii. Zeolite

The zeolite with 1mm to 2.5mm dimension were ordered from ZEOCEM, A.s. The chemical composition of the zeolite was provided in table 2 by EL spol.s.r.o. The lab analysed 34 types of different chemical composition and only main elements are illustrated here.

Table 2. Average values for chemical composition of zeolite grit (Rehakova et al. 2004).

SiO_2	Silicon dioxide	68.5%
Al_2O_3	Aluminium oxide	12.9%
TiO_2	Titanium dioxide	0.2%
Fe_2O_3	Iron(III)oxide	1.5%
CaO	Calcium oxide	3.3%
MgO	Magnesium oxide	1.1%
MnO_2	Manganosite	<0.1%
P_2O_5	Phosphorus pentoxide	<0.1%
Na_2O	Sodium oxide	1.3%
K_2O	Potassium oxide	2.9%
Ba	Barium	0.1%
Sr	Strontium	0.02%

iii. Marble

The marble grit/gritstone was produced by Visnes Kalk AS in Lyngstad of Norway. The dimension of the gritstone was 0.5-2 mm. The chemical composition of the gritstones is shown in table 2. The chemical name of the gritstone is calcium carbonate (CaCO3)

Table 3. Average values for the chemical composition of marble gritstone.

CaCO3	Calcium carbonate	98%
MgCO3	Magnesium carbonate	1%
Fe2O3	Iron(III)oxide	0.1%
SiO2	Silica (quartz)	0.6%

c. Laboratory work

All the samples were first thawed then homogenized, respectively.

Dry matter content of feed, faeces, gizzard, crop content, duodenum + jejunum and ileum were all determined with the procedure below:

A representative sample was taken out, wet weight registered, and then dried in the oven at temperature 105 ± 2°C overnight. The sample was placed in a desiccator until cool the dry weight was measured. Tare weight of crucible was subtracted from the gross weight of the sample to calculate net weight of wet/dry sample (equation 1).

After measured dry matter content of each digestive tract segment and faeces from day 21, intact whole-wheat were picked out manually. To achieve this, the samples were diluted with water over night. The whole wheat was then dried again to find dry matter content. This was only done for the birds that were given access to whole wheat for two hours.

$$\frac{net\ weight\ of\ dry\ sample\ (g)}{net\ weight\ of\ wet\ sample\ (g)} \times 100\% = Dry\ matter\ (\%) \tag{1}$$

i. Separation of gritstones from the gizzard content and faeces

Due to a relatively small amount gizzard content, the whole sample had to be used for dry matter determination. Thus, the particles had to be dissolved in water before using the floating method. The method consisted of holding the bowl under a slow running faucet with water rinsing through at a steady pace distributing the particles. As a result, the low density particles float up and were washed out, while the high density particles, the gritstones, are left in the bottom of the bowl. The grit stones were then dried in room temperature overnight and weighed and saved for further analysis.

The same process was used for faeces collected from 5-11 days of age. The faeces from each cage was homogenized, and a 250g sample were soaked in enough water to dissolve the particles. For faeces samples collected on 11-13, 13-18 and 18-21 days of age, the amount of grit stones were collected with the wet sieving procedure, as described below.

ii. Wet sieving procedure

Wet sieving of faeces was done to determine the particle size distribution on dry matter basis. Faeces from 11-13, 13-18 and 18-21 days of ages were first homogenized and analysed for dry matter content. According to the Standard Wet Sieving Analysis

Procedure from The Centre of Feed Technology/Fôrtek at NMBU, the samples should have been dried in the sieves for minimum 4 hours to determine the dry matter, but due to practicalities and limited time, an alternative method was created to determine dry matter of the particle distribution.

100 grams of sample were dissolved in water for 10 minutes with the assistance of a magnet stirrer (IKA C MAG HS7) before wet sieved in a Retsch sieve shaker (AS 200 Control) with amplitude 1.50 mm/g. Some additional water was used to rinse out the container with the sample to make sure all the particles were emptied into the sieves. Sieves size were 1.4, 0.8, 0.5 and 0.2 mm, and water pressure was at maximum. Sieving time were set to 2 min. with water, and 1 min. without water to shake off excess water. Each sieve was then weighed. Form 4 replicas per treatment for all sample sets, a sample of approximately 2.5 grams were taken out to determine dry matter of respective particle size in the sieve. The average dry matter content was further used to calculate the particle distribution of the faeces on dry matter basis. To estimate a "wet tare sieve weight", empty sieves were shaken as mentioned and weighed. The average of 11 registrations was used when subtracting the tare weigh from the gross registration of the wet sample. The content left in the sieves were washed out in a bowl and rinsed for grit stones as described above, and the grit stones were collected and saved for further analysis.

iii. Particle distribution of grit stones

Three representative samples from the original grit stones were dry sieved to find the actual particle size distribution of grit given to the birds. The tare of the sieve was first registered before about 100 grams of the initial grit stones were dry sieved for 1 minute on amplitude 1.00 mm/g on the Retsch sieve shaker (AS 200 Control), each sieve was then weighed and registered again before emptying the content of the sieves. All steps where repeated between each sample.

Each type of grit stones was sieved 4 replicates to get an average particle distribution. Similar procedure was conducted for grit stones that were found in the faeces and gizzard. Since the samples of gritstones from the gizzard content was very small, the samples where pooled together from 12 replicas to 3 replicas so that the total sample were approximately evenly distributed within the treatments. Only zeolite and granite was detected in the gizzard content.

The percentage particle distribution was calculated with the equation shown below.

$$\% \text{ of particle of nth Size} = \frac{\text{weight of sieve full (g)- weight of sieve empty (g)}}{\text{weight of sample (g)}} \times \qquad (2)$$

Due to personal error, the particle distribution of initial grit stones was measured of the remaining grit stones in the bag, after the birds were fed. However, the particle distribution was assumed to be equal in the bag. A previous sieving had been done beforehand to get a quick picture of the actual particle size, but with a 500 g and no replicates.

iv. The amount of feed passed through the crop and gizzard

Crop (g) = feed intake (dry matter) – crop content (dry matter)

Gizzard (g) = feed intake – (crop content + gizzard content)

d. Data analysis

ANOVA in Excel 2016 was used to test P-value, standard deviation and regression analysis.

4. Results

a. General performance

According to the cumulative performance data from 5 to 21 days of feeding period, the performance parameters weight gain (*P*=0.1574), feed intake (*P*=0.2761) and feed: gain ratio (*P*=0.5743), were not significantly different between grit-fed birds and non-grit-fed birds as illustrated in Table 1.

Table 4. Growth performance, feed intake, feed efficiency in broiler chickens during 5 to 21 days of age, fed commercial diet with grit, zeolite and granite, or without grit. The values are illustrated as mean value ± standard deviation.

5-21 days of age

Treatment	Weight gain, g	Feed intake, g	F:G[1]
Control	882.1 ± 56.6	1201.1 ± 71.1	1.36 ± 0.04
Zeolite	921.1 ± 41.7	1237.5 ± 44.0	1.34 ± 0.03
Granite	896.7 ± 46.8	1214.4 ± 46.0	1.36 ± 0.05
P-value	0.1574	0.2761	0.5743

[1]feed: gain ratio

b. Gizzard data from different dissection days

Table 2 illustrates the relative weight of full gizzard and empty gizzard decreased with increased body weight between grit-fed broilers and non-grit-fed broilers. When it comes to grit content in the gizzard, zeolite took up 12% of gizzard content at 13 days of age and this number decreased to 7.9% at 22 days. However, granite was accounting for one third of gizzard content at 13 days of age and decreased to one fourth of gizzard content at 22 days of age. According to the Table 2, more granite grit remained in the gizzard than zeolite from 13 to 22 days ($P<0.05$).

Table 5. The data from each dissection day

	Weight	Bird (g)	GW (full), g	Gizz[1] full (%)[2]	GW (empty), g	Gizz empty (%)[2]	GC[3] (g)	GS[4] (g)	%[5] of GS in GC
13 days	Control	495.1 ± 37.0	17.5 ± 2.8	3.6 ± 0.7	10.5 ± 1.2	2.1 ± 0.3	7.0 ± 1.9	0	0
	Zeolite	497.0 ± 27.6	17.5 ± 2.4	3.5 ± 0.5	11.0 ± 0.8	2.2 ± 0.2	6.6 ± 2.1	0.9 ± 0.7	12.1 ± 8.6
	Granite	517.8 ± 28.7	20.6 ± 1.6	4.0 ± 0.2	11.7 ± 1.2	2.3 ± 0.2	8.9 ± 1.0	3.1 ± 0.7	35.4 ± 8.4
	P - Value	0.162	0.0024	0.0754	0.026	0.4787	0.0044	< 0.001	< 0.001
18 days	Control	898.3 ± 55.1	22.8 ± 9.5	2.5 ± 1.0	14.0 ± 2.5	1.6 ± 0.3	7.0 ± 1.9	0	0
	Zeolite	897.5 ± 87.9	21.9 ± 5.0	2.4 ± 0.5	14.0 ± 2.4	1.6 ± 0.3	6.6 ± 2.1	0.1 ± 0.1	1.3 ± 2.1
	Granite	894.3 ± 71.9	22.6 ± 5.6	2.5 ± 0.7	13.8 ± 1.8	2.3 ± 0.2	8.9 ± 1.0	1.6 ± 1.6	17.2 ± 12.5
	P - Value	0.9903	0.9520	0.9566	0.9555	0.9528	0.0044	0.0032	0.0002
21 days	Control	1043.3 ± 115.5	25.1 ± 4.0	2.4 ± 0.4	16.5 ± 1.9	1.6 ± 0.2	8.6 ± 2.8	0	0
	Zeolite	1106.5 ± 100.9	27.3 ± 4.1	2.5 ± 0.3	16.8 ± 1.7	1.5 ± 0.1	10.5 ± 2.8	0.5 ± 0.4	5.6 ± 4.7
	Granite	1070.1 ± 109.5	27.6 ± 5.5	2.6 ± 0.3	16.7 ± 2.3	1.6 ± 0.3	10.9 ± 4.3	2.9 ± 1.7	26.3 ± 14.8
	P - Value	0.3722	0.3441	0.5694	0.9213	0.6633	0.2234	0.0002	0.0001
22 days	Control	1102.1 ± 105.3	24.5 ± 4.5	2.2 ± 0.4	15.8 ± 1.3	1.4 ± 0.1	8.7 ± 4.0	0	0
	Zeolite	1153 ± 70.6	26.3 ± 3.7	2.3 ± 0.3	16.4 ± 1.8	1.4 ± 0.2	9.8 ± 2.2	0.8 ± 0.6	7.9 ± 5.6
	Granite	1130 ± 90.2	27.2 ± 4.3	2.4 ± 0.4	17.2 ± 2.5	1.5 ± 0.3	10.0 ± 2.9	2.6 ± 1.2	26.6 ± 12.9
	P - Value	0.3841	0.2796	0.4216	0.2012	0.2855	0.5377	< 0.0001	0.0002

[1]Gizzard, [2]% of body weight, [3]Gizzard content, [4]Gizzard stone, [5]% of grit stone in gizzard content.

c. Grit consumption, excretion and retention

Table 3 shows the grit consumption, disappearance and retention in the gizzard from 5 to 18 days of age. Averagely, 9.5g of grit was fed to each bird on day 5, 7 and 9. The grit consumption was identical in zeolite-fed birds and granite-fed birds. On day 11, 3,6 grams of granite and 4.2 grams of zeolite were excreted. However, the higher amount of zeolite was found in the feces than granite grit on day 13 (P<0.05). As to the retention of grit, 0.9-gram of the zeolite and 3.1-gram of granite were remained in the gizzard on day 13. Thereafter, these numbers fell down to 0.09 gram and 1.6 gram at 18 days of age. The amount of grit excreted at 13 days of age was 1.63 gram for the zeolite-fed bird and 1.08 gram for the granite-fed bird. At 18 days of age, these numbers were 0.97 for zeolite group and 1.44 for granite group.

Table 6. Grit consumption, excretion and retention from 5-18 days of age. The values illustrated in the table are mean values.

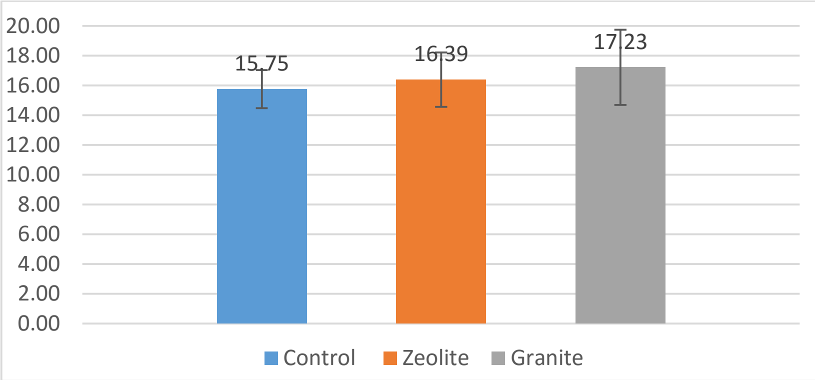
Grit consumption, excretion and retention						
	GE[1]	GF[2] 11d[3]	GG[4] 13d	GF 13d	GG18d	GF18d
Zeolite	9.34	3.60	0.86	1.63	0.09	0.97
Granite	9.35	4.24	3.13	1.08	1.64	1.44
P-value	0.9115	0.0836	< 0.0001	0.0006	0.0032	0.088

[1]Grit eaten, [2]grit in feces, [3]11 days of age, [4]grit in the gizzard.

d. Gizzard weight of the birds at 22 days of age

Figure 1 shows that empty gizzard weight of grit-fed birds was higher than that of non-grit-fed birds at 22 days of age, but the difference was not significant (P=0.2012).

Figure 1. Empty gizzard weight (g) of the bird at 22 days of age.



e. Empty gizzard weight and amount of grit in the gizzard at 22 days of age

Figure 2 and figure 3 illustrates the relationship between amount of the grit in the gizzard and empty gizzard weight at 22 days of age. It is not obvious that there is any large effect of zeolite and granite content on the empty gizzard weight as shown in the figures.

Figure 2. The relationship between amount of zeolite grit in the gizzard and empty gizzard weight at 22 days of age.

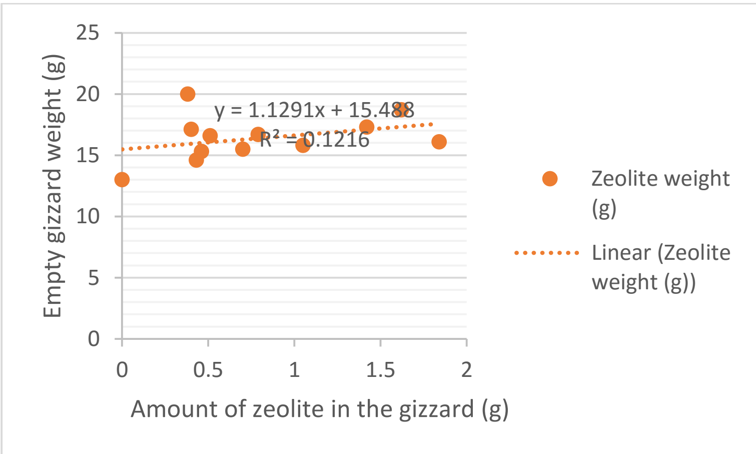
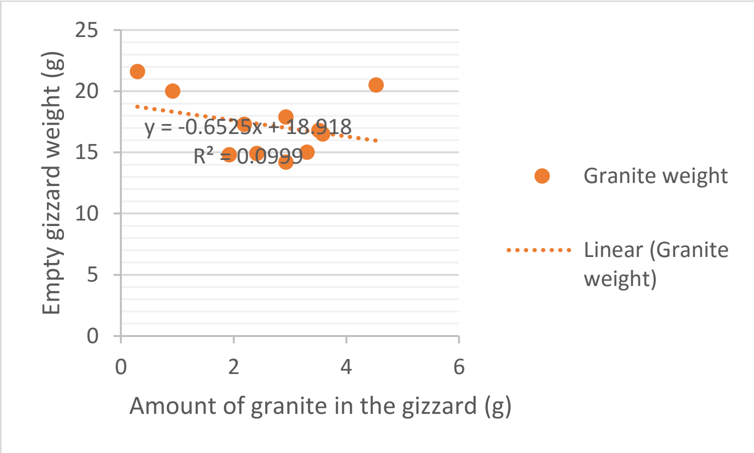


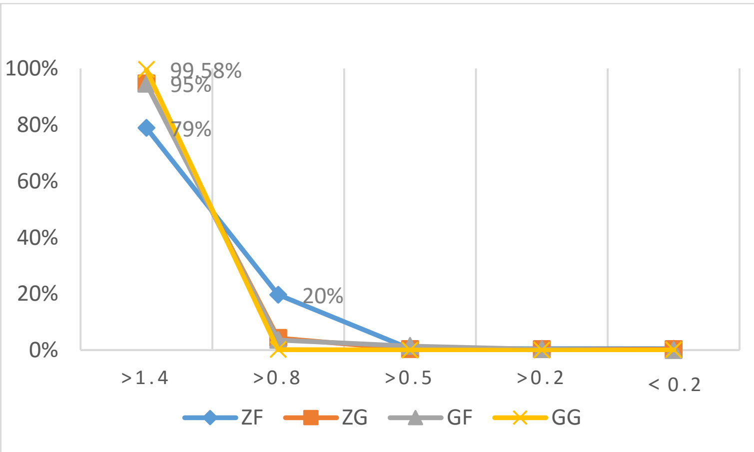
Figure 3. The relationship between amount of granite grit in the gizzard and empty gizzard weight at 22 days of age.



f. Particle size distribution of the grit in the feed and gizzard

Figure 4 shows the particle size distribution of the grit fed to the bird at 5 days of age as well as that of the grit found in the gizzard at 22 days of age. The graph shows that 79% of zeolite and 95% of granite fed to the bird was coarser than 1.4mm and 20% of zeolite was fall within the range from 0.8mm to 1.4mm. As to the size of the grit found in the gizzard at 22 days of age, 95% of zeolite and 99.5% of granite were coarser than 1.4mm. This means that grit remained in the gizzard was coarser than 1.4mm.

Figure 4. Particle size distribution of the grit fed to birds and found in the gizzard.



ZF= zeolite fed to birds, ZG=zeolite found in gizzard, GF=granite fed to birds, GG=granite in the gizzard.

g. Dry matter of feed passing through the crop and gizzard at different times

Table 7 illustrates the dry matter content of feed intake and the dry matter content of each segment at different times.

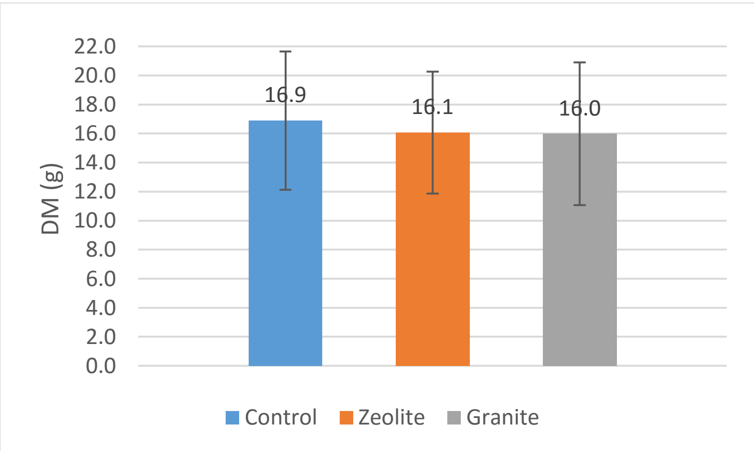
Table 7. Dry matter of feed intake in 30 minutes and dry matter content in each segment at different time.

DM of feed intake and content of each segment (g)						
Time	30min	60min	90min	120min	150min	180min
Control group						
Feed intake	14.37	13.75	17.77	21.15	13.49	20.02
Crop	8.40	6.78	7.35	5.81	1.17	2.88
Gizzard	2.51	3.23	3.22	2.30	2.72	2.19
Duo + Jej[1]	1.28	2.33	1.98	3.14	2.93	2.29
Ile[2]	0.58	0.77	1.57	1.76	1.45	1.02
Zeolite group						
Feed intake	14.31	20.36	17.42	17.73	11.48	15.13
Crop	10.41	12.00	4.87	6.33	0.39	1.68
Gizzard	2.08	4.10	2.81	2.89	1.94	2.36
Duo+ Jej	2.09	3.10	3.10	3.34	2.27	1.84
Ile	0.34	1.29	1.48	1.63	0.92	1.49
Granite group						
Feed intake	18.50	17.30	17.50	14.73	11.29	15.94
Crop	13.33	9.34	9.60	3.60	0.00	1.28
Gizzard	2.89	2.40	2.31	2.61	1.75	2.32
Duo+ Jej	3.27	2.88	2.69	2.22	1.95	1.99
Ile	0.91	0.92	1.16	1.19	0.75	1.15

[1]Duodenum + Jejunum, [2]ileum

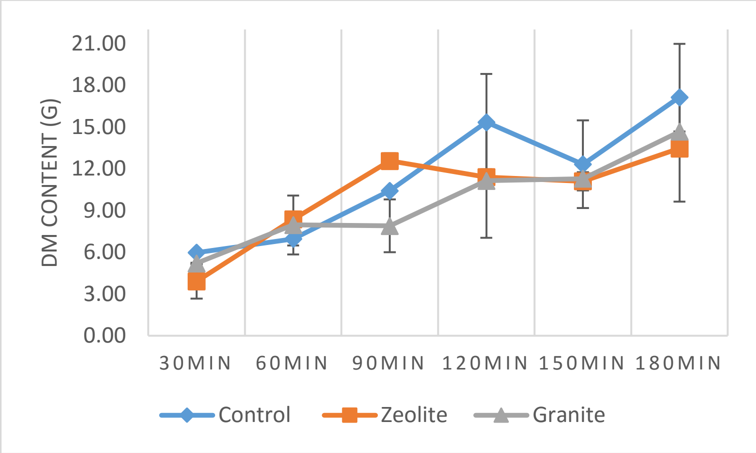
Figure 5 shows dry matter of feed intake was not different between grit-fed birds and non-grit-fed birds during 30 minutes feeding (P=0.8868).

Figure 5. Dry matter of feed intake at 22 days of age.



The amounts of feed have passed through the crop (figure 6) at different times were similar between grit- and non-grit-fed birds (P>0.05).

Figure 6. Dry matter of the feed has passed the crop at different time. Bars indicate standard deviation for each plot.



In Figure 7, the amounts of DM content which has passed through the gizzard at different times were not different in grit-fed group and non-grit-fed group, but there was higher amount of DM content passed through the gizzard in control group than granite group at 120min (P<0.05).

Figure 7. Feed passage rate through the gizzard at different time. Bars indicate standard deviation for each plot.

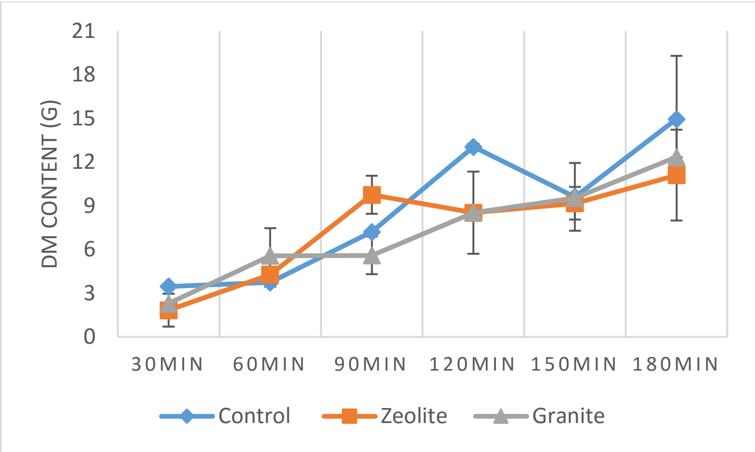


Figure 8 shows the dry matter of duodenal and jejunal content at different times. In general, there is no large difference between dry matter content of duodenum and jejunum in grit-fed birds and non-grit-fed birds at different times after commencement of feeding (P>0.05). From 30min, the dry matter content of the duodenum and jejunum gradually increased and reached to the highest point at 120min in both groups, and then decreased slowly.

Figure 8. Dry matter content of duodenum + jejunum at different times.

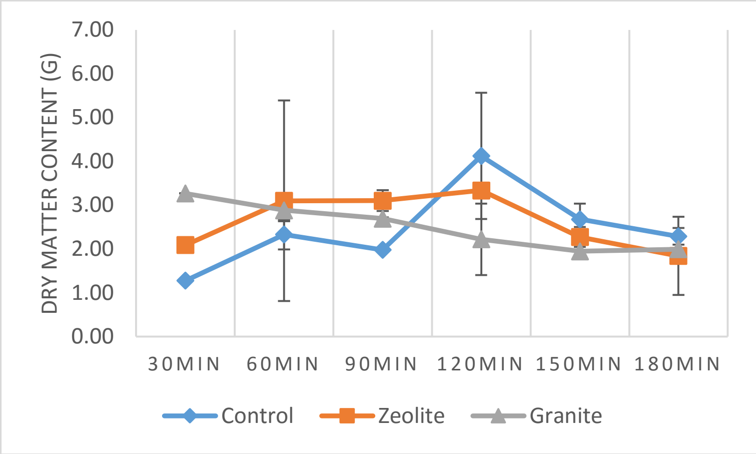
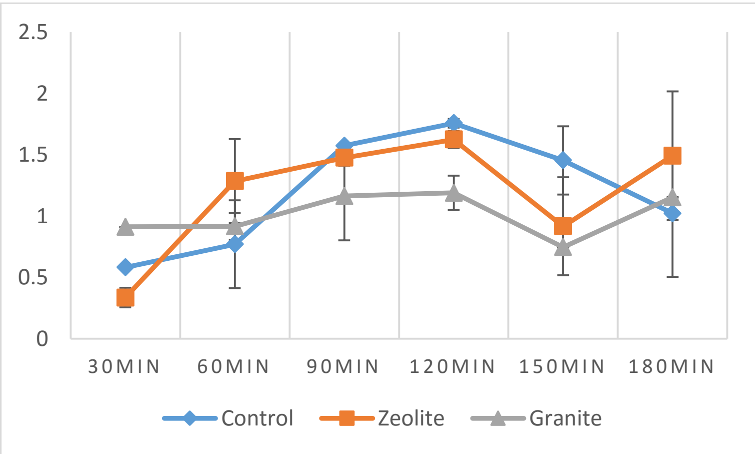


Figure 9 shows the dry matter content of the ileum at different times. There is also no much difference between dry matter of ileum content in grit-fed birds and non-grit-fed birds. The dry matter content was slowly increasing from 30min and reaching to the highest point at 120min and then decreasing.

Figure 9. Dry matter content of ileum at different times.



5. Discussion

a. Birds performance

In this experiment, the differences in weight gains and feed intakes were not statistically significant between grit-fed birds and non-grit-fed birds. This is in agreement with the findings of Arscott et al. (1955) and Majewska et al. (2009) in which they have shown that grit fed to the chicken and turkey has no significant effect on the weight gain and feed: gain ratio.

One possible reason that performance parameters were not different much between grit-fed birds and non-grit-fed birds is maybe that both group of birds ate identical pelleted diets without whole grains in our experiment from 1 to 18 days of age. After 18 days of age, they were fed the diet containing 15% of whole wheat.

Even though the feed diluted with whole wheat was fed to the birds after 18 days of age, there were no significant differences between the weight gain, feed intake and feed: gain ratio of grit-fed birds and those of non-grit-fed birds.

No interaction between whole wheat and grit was found in this study. However, many studies have shown that a need for grit when poultry are fed whole grains or feed with coarser particles (Balloun & Phillips 1956; Heuser & Norris 1946; Scott & Heuser 1957). Furthermore, the grit fed with whole grains or coarsely ground grains improved digestibility and energy availability of whole grains or coarsely ground grains(McIntosh et al. 1962; Smith & MacIntyre 1959).

The value of grit is somewhat controversial when all-mash or pelleted diet is fed to poultry. Pellet granule disintegrates rapidly inside the upper digestive tract when they are moistened and its fine particles pass quickly down the digestive tract (Engberg et al. 2002; Svihus 2006). Therefore, there is no much interaction between the grit and pellets. Whereas, coarse ground mash or whole grains would occupy the gizzard for a longer time because extensive grinding is needed to reduce the particle size of the mash or whole grains to a critical size before leave the gizzard.

The feed is the most important factor affecting the performance of broiler chickens. Modern broiler chickens are selected for rapid growth and efficient utilization of the feed with high digestibility (Almirall & Esteve-Garcia 1994). Ferket and Gernat (2006) reported that "modern commercial broilers and turkey will not grow to their full genetic potential unless they consume their full nutritional requirement each and every day”. It is possible that the feed used in this study was not meet the nutritional requirement of the broilers. It may be also caused by the changes of the feed in different period. In this study, the commercial starter diet was fed from 1 to 10 days of age and 11-18 days of age grower diet was fed, from 18-21 days of age, starter diet diluted with whole wheat was fed. The broiler is very sensitive to the changes of feed and nutrients as well as the changes of feed shape (Ferket & Gernat 2006).

However, Balloun and Phillips (1956), Heuser and Norris (1946), Slinger et al. (1962), Scott and Heuser (1957) found that grit feeding increases weight gains, feed efficiencies as well as egg production. The grit, as some other structural components such as insoluble fiber and whole grains does, stimulates the gizzard development and functions (Amerah et al. 2011; Svihus et al. 2004a). Gizzard size and weight would increase and the muscular activity would be stronger when these materials fed to the bird.

Well-developed gizzard would grind feed more efficiently, increase the proportion of finer particles (Hetland et al. 2003) and give a synchronized feed flow (Svihus 2014). Increased fine particles would present a greater surface to contact with digestive juices.

Additionally, the grit also induce the excretion of gastric juice from proventriculus, which would increase feed digestibility and inhibit bacteria proliferation in the gut (González-Alvarado et al. 2007; Mateos et al. 2012; Svihus 2011). “The oscillation of digesta between the gizzard and duodenum may increase the efficiency of digestion by exposing the digesta longer to digestive enzymes and bile, but it slows the rate of passage of digesta through these segments” (Shires et al. 1987). Furthermore, the presence of the grit slows down the passage rate of the digesta in the digestive tract and thus allowing more complete digestion (McIntosh et al. 1962).

Nevertheless, some researchers have found that grit had adverse effects on the performance of poultry (Bennett & Classen 2003; Garipoglu et al. 2006; Walter & Aitken 1961). There are some reasons that can cause the adverse effects. One of them is that grit in the gizzard possibly compete with the feed for gizzard space and impede normal nutrient absorption rate as feed intake reduced and holding capacity decreased (Hinners & Elliott 1972).

In this study, it might be possible that grit especially the granite grit competes for gizzard space with the feed. As shown in table 5, the granite grit was accounting for one third of the gizzard content on 13 days of age. There were still considerable amounts of granite found in the gizzard for example at 18 days of age, even though the birds were deprived from grit for many days in this time. However, the belief was not proved in the finding of Itani (2015), where grit neither reduced feed intake nor impede nutrient absorption.

The most likely reason that grit results in poor performance is that grit as a structural components in the gizzard promotes the grinding activity of the gizzard and thus increases smaller particles and increases the passage rate (Hetland et al. 2003; Nir et al. 1994a).

b. Gizzard weight

When it comes to the dissection data, the weight of empty gizzard was not significantly different between grit-fed group and non-grit-fed group. No interactions between the grit and the pelleted feed may be the reason, because of the fast integration of the pellets in the crop and gizzard as mentioned earlier. Even after the pelleted feed diluted with whole wheat and grit were fed to the birds from 18 days of age, there were no difference between the gizzard weight of the grit-fed birds and that of non-grit fed birds.

The increased weight of the gizzard was observed in many researches when using different structural components in the poultry feed (Bennett et al. 1995; Engberg et al. 2004; Hetland & Svihus 2001; Rowland & Hooge 1980; Scott & Heuser 1957). However, increased gizzard weight and size was not guiding criterion of the efficiency of feed utilization (Scott & Heuser 1957).

c. Grit consumption, retention and disappearance

The amount of the grit stone in the gizzard decreased from 13 to 18 days of age, but the amount increased at 21 days of age after the bird getting access to the grit at 18, 19 and 20 days of age totally 3 grams of grit to each bird. The retention of the grit in the gizzard is affected by many factors.

The availability is a main factor affecting the retention of the grit in the gizzard. When the grit is available to birds, they will consume and eliminate considerable amount daily (Gionfriddo & Best 1996; Gionfriddo & Best 1999). In our experiment, there was higher content of the grit collected from the feces at 11 days of age as shown in table 3. This is reasonable that they excreted considerable amount of grit in the feces because they were getting access to the grit at 5, 7 and 9 days of age and per bird consumed around 9 grams of grit during these days.

However, when birds are deprived from grit suddenly, their excretion of the grit would decrease and retain them in the gizzard for a longer period (Walter & Aitken 1961). This can be observed in this study that amounts of grit in the feces collected at 18 days of age was lower, because the grit was not available to the bird from 10 to 18 days of age.

Diet characteristic is also a factor that affect grit retention and elimination. Coarse and hard food accelerate the disintegration and elimination of the grit because there is more abrasion between hard food and the grit (Norris et al. 1975; Trost 1981). This is less affective in this study before the bird getting access to whole wheat at 18 days of age, since the birds were eating pellets before 18 days of age and after this day they were eating pellets diluted with 15% of whole wheat.

d. Particle size of the grit

According to the particle size distribution of grit in the feed and gizzard, more than 80% percent of the zeolite and 95% of the granite in the feed had a particle size larger than 1.4 mm. However, more than 95% of zeolite and 99 % of granite in the gizzard was falling on the sieve with a size of 1.4mm. This is in agreement with the finding of Tagami (1971) as cited in Gionfriddo and Best (1999), who observed that domestic chicks retained more medium-sized (1.7-2.4mm) grit than large (2.4-3.4 mm), and they retained very few small (0.6-1.7 mm) particles. Grit could pass through the gizzard after it has been reduced to a certain size no longer able to aid the grinding of the coarse particles of food (Scott & Heuser 1957).

e. Feed passage rate

The passage rate of the digesta through the digestive tract is one measure of gastrointestinal function and the best measure of rate of passage is mean retention time (MRT) for the entire tract or segment of it (Shires et al. 1987; Warner 1981).

Many factors affect the feed passage rate as mentioned in introduction. In addition, different results can be obtained when different methods are used to measure the passage rate of the feed through digestive tract. Using inert markers is one of the most common ways to decide feed passage rate. However, using the time required for a feed to pass through the specific segment of digestive tract is also a method to test feed passage rate. In this study, the latter one was used.

Rate of passage is a limiting factor for feed intake and it is generally considered that faster passage rate of feed results in increased feed intake. Increased excretion of dry matter was observed when larger amounts of feed were forced-fed to the rooster (Sibbald 1979). This suggests that passage rate of the digesta can be determined by the quantity of feed consumed.

In this study, the birds were getting access to feed for 30 minutes at 22 days of age. Feed consumption in control group and grit-fed groups was not different. It is reasonable that they had similar feed consumption in 30 minutes, because they were starved in same period of time, fed same amounts of feed and fed in same length of time. Furthermore, their daily feed intake and weight gain were also similar to both grit and non-grit group.

Long time starvation allows the larger feed intake and the shorter transit time as Mateos et al. (1982) claimed. But it is hard to say which one has eaten much in this study, they consumed similar amounts of feed. Generally, the pellets give a higher feed intake because of their high bulk density. In addition, the birds spend less time and less energy on eating pelleted diets (Jensen et al. 1962), due to their structure and energy content.

The passage rate of the ingesta was faster in the bird with higher body weight than that in the bird with lower body weight (Cherry & Siegel 1978). The author also mentioned that faster feed transit time is an indicator of efficient feed utilization and rapid growth rate in chickens with higher body weight. This cannot be proved in this study, because the body weight and feed flow rate throughout the digestive tract were similar between grit-fed birds and non-grit-fed birds.

The amount of the feed passed through the crop at different times was not significantly different in control group and grit-fed group. This can reveal that grit and whole wheat have no effect on the passage rate of the crop. Some studies have shown that structural components like grit and whole wheat can affect the passage by stimulating the contraction of gizzard muscles (Amerah et al. 2009). The contraction of the gizzard is coordinated with the contraction of proventriculus and duodenum (Duke 1986). Gizzard contraction may manipulate the release of feed from the crop.

From figure 6, it can be observed that crop passage rate increased with time. In the one hand, it indicates that crop release the digesta slowly. Besides, considerable amounts of the feed retained in the crop when the birds were getting access to the feed, even though the birds were starved overnight. Empty crop results the feed directly moving into the proventriculus and if not, the presence of feed in the crop result in storage (Wilson et al. 1980). This statement was not supported in this study, because there were considerable amounts of feed left in the crop even the birds were fasted overnight. The crop or whole digestive tract except the ceca was assumed to be empty after overnight fast in this study.

Wilson et al. (1980) also reported "the restriction of feed intake in Peking ducks for 6 hours led to a reduced passage rate of the digesta compared to the full-fed ducks". This is possible in this study that birds were adapted to the feed restriction more or less. Even though the birds were not under the intermittent feeding in this study, they were starved overnight at their 20 and 21 days. The birds in this study stored some feed and released them slowly (figure 6), though the observation lasted only 180min in each group. The broilers have a habit to store large amounts of the feed in the crop and release the feed from the slowly (Adiya 2013).

Gizzard is thought to the main organ to manipulate feed passage in poultry as mentioned in introduction. The amounts of feed passed through the gizzard at different times was also not different between control group and grit-fed groups, but there was higher amount of the digesta passed thought the gizzard in control group than that in zeolite group at 120min.

As shown in figure 7, the amount of the feed passed through the gizzard increased with time. Many factors affect the feed passage rate through the gizzard. The feed intake and crop passage rate are the main factors. In this study, feed intake was same in each group. The crop passage rate was also similar to each group. It has been pointed out that as long as the crop contains feed, the gizzard also contains feed (Heuser 1945). The author also mentioned that feed passage rate from the crop is related to that from the gizzard. In addition, the gizzard passage rate is mainly decided by the grinding of the gizzard.

The grit is considered to aid gizzard development and grinding activity by stimulating the contraction of gizzard muscle and by providing coarse surface to the feed to be abraded (Gionfriddo & Best 1999; Scott & Heuser 1957). The well-developed gizzard is thought to give a synchronized feed flow. However, feeding grit to the broilers in this study did not take any difference between the feed passage rate of the birds fed with grit and birds fed without grit, even though the whole wheat was fed to them. Svihus (2011) concluded " surprisingly enough when considering that genetic selection most probably have taken place on a finely ground diet, the gizzard of modern broiler chickens therefor appears to have a very high capacity to grind large cereal particles and fibrous material down to a very small, and that gizzard stones are not required for this to happen".

The dry matter content of the small intestine for grit-fed birds were not different from that for non-grit-fed birds. The dry matter content of the small intestine is decided by the gizzard passage rate and duodena and jejunal absorption of the nutrients. The movement of the duodenum is also influencing the dry matter content in the small intestine. The more digest passed out the gizzard the more digesta will go in to the duodenum. Duodenal fullness reduces gastric motility (Duke 1986). This may be a reason that the birds empty the crop and gizzard step by step.

Jackson and Duke (1995) reported that feed bypassed the empty gizzard in a short time and filled in the small intestine with feed within 30 minutes. Svihus et al. (2002) also reported that considerable quantities of the feed had passed the gizzard within 30 minutes feeding. In this study, there was no much dry matter content at 30min, and the duodenal and jejunal content increased gradually and reached the highest point at 120min.

6. Conclusion

What can be concluded from the study is that feeding grit to the broiler chickens, neither slower the passage rate nor improve the gizzard weight and the performance of the broiler chickens. Further studies are needed to test the interactions between pellet, grit and whole wheat. Or answer a question: is the grit essential in modern broiler chickens?

7. References

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