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Effects of diet structure and feed availability on passage rate and nutrients digestibility

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Abstract

The purpose of the experiment was to test the following hypotheses: birds have tendency for over-consumption of feed, and the extent of over-consumption varies through the day after a starvation period. Further, the hypothesis that a developed gizzard will prevent this problem was tested. The passage flow and digestibility in anterior tract was investigated in this study.

In trial 1, 48 Ross 308 male broiler chickens were fed ad libitum with two different diets. Diet 1 was a wheat-based diet with a few structural components and diet 2 was a wheat-barley-oat-based diet with structural components. At 19 days of age, birds were fed after 6 hours starvation, and then the excreta were collected shortly after feeding. At 20 days of age, after longer starvation period birds were fed ad libitum with diet 1 and 2 both in the form of pellets and mash, and then excreta were collected. At 21 days of age, after 10 hours starvation, birds were given access to feed and dissected every hour. Contents from the small intestinal and excreta were collected. Intestinal content was analyzed for starch and titanium oxide. In the results, starch digestibility was significantly higher ($P < 0.05$) for birds fed diet with structural components than wheat-based diet. Starch digestibility varied through the day significantly caused by the underdevelopment gizzard. Moreover, no correlation was found between feed intake and starch digestibility.

In trial 2, 48 birds were randomly moved from ad libitum and intermittent feeding regime with feeding both experimental diet and commercial diet before. After 10 hours starvation, birds were fed with ad libitum and restricted. Birds were dissected after feeding 5 hours. All digestive tract content and excreta were collected for starch and titanium oxide analysis. The results from trial 2, there was no significant difference ($P>0.05$) on dry matter content and dry matter digestibility ($P> 0.05$) in each segments of small intestine. Furthermore, there was no correlation between feed intake and starch digestibility.

Key words: broiler over-consumption of feed, starch digestibility, structural components, gizzard function

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Table of Contents

1. Introduction

It is becoming increasingly difficult to ignore the overload and shorter retention time of feed in the digestive tract for broiler after a starvation period, which is the critical problem that affect the nutrients digestibility and feed availability. Svihus and Hetland (2001) have been suggested that high feed intake results in lower starch digestibility due to the overload of wheat starch in digestive tract in broiler. Similar results have been found that, after long starved period, fed diet with structural components to birds might be increase the retention time of feed in the gizzard to alleviate the over-consumption of feed (Adiya, 2013).

Recently, researchers have shown an increased interest in retention time and passage flow rate of feed in the digestive tract for broilers. Crop as the storage compartment plays an important role for moistening and softening feed, which is no effect for feed intake (Jackson and Duke, 1995). chyme transferred from crop to gizzard mainly influenced by emptying of gizzard, the particle size of the feed and the degree of moistening. It is well known that the function of gizzard is reducing the particle size of feed, controlling of feed passage rate and chemical degradation of nutrients (Svihus, 2011). It has been shown that the retention time of feed in the gizzard estimated as between 30 to 60 min, which can significantly increase when structural components were added into the diet (Svihus et al., 2010). Inclusion of structural components in broiler diets can significantly improve gizzard activity and increase the size of the gizzard, at the same time, increase the volume of gizzard to retain feed for longer time (Svihus, 2011). Furthermore, chyme can keep in small intestine as the main absorption place approximately 220 min, which calculated by Danicke et al. (1999). And the large intestine is the place for the microbial fermentation, which the rapid passage rate has been observed when components, like oat hulls, were added in the diet to reduce the time available for microbial fermentation (Choct et al., 1996).

Starch is the main energy source for broiler chicken. In this experiment, starch digestibility was determined for the over-consumption of feed for birds. There are several factors that affect the starch digestibility. First of all, smaller granules size are generally easier to digest, which is mainly depends upon the starch source (Weurding et al., 2001). Secondly, investigators have examined that the amount of amylose is negatively correlated to starch digestibility (Svihus et al., 2005). In addition, the effect between amylose and surface compound such as fatty acids is also an important issue that affects the starch digestibility (Cui and Oates, 1999, Crowe et al., 2000). Furthermore, age, feed intake, passage rate and absorption capacity of animals also the factors that influence the starch digestibility (Weurding et al., 2001).

However, the effects of feed cereal on starch digestibility should be highly considered. Wheat as the important ingredient has relatively high protein and starch level that widely used in broiler daily feed. But water-soluble fiber has been reported that decrease the nutrient digestibility by increasing the viscosity in small intestine (Edney, 1989, Yutste et al., 1991, Choct et al., 1999).

The results from Preston et al. (2000) have been indicated that whole wheat shown significant increase in apparent metabolisable energy than ground wheat. Moreover, using whole grain in the feed is the efficient way to reduce the feed price through decrease the handling, transporting and processing cost (Hetland et al., 2002), at the meantime, inclusion of whole grain in diet increase the feed availability (Kiiskinen, 1996, Olver and Jonker, 1997, Svihus et al., 1997, Preston et al., 2000). An increased starch digestibility has been reported when birds fed with the diet includes structural components, for example oat hulls (Rogel et al., 1987a, Rogel et al., 1987b). This is also consistent with reports of diet for broiler with oat hulls increase wheat starch digestibility (Rogel et al., 1987a, Hetland and Svihus, 2001). Previous evidence suggests that starch digestion have been significantly improved by added ground oat hulls into the diet for broiler, and the improvement was mainly reply on the amount of oat hulls and size of oat hulls in the diet(Rogel et al., 1987b).

The hypotheses will be tested that birds have tendency for over-consumption of feed, and the extent of over-consumption varies through the day after a starvation period. Further, the hypothesis that a developed gizzard will prevent this problem was tested. In addition, the passage flow and dry matter digestibility for birds fed with experimental diet and commercial diet in different feeding regime also investigating in this thesis.

2. Material and Methods

2.1 Diet

Experimental diets

Two experimental diets were produced in FôrTek (Center of Feed Technology) owned by Norwegian University of Life Sciences. Diet 1 was a wheat-based diet with a few structural components and had smaller particle size. On the other hand, diet 2 was a barley-oat-wheat-based diet with structural components, as shown in Table 1. Both the diets went through the same feed producing line.

Table 1. *Composition of Experimental Diets (g/kg)*

Ingredients	Diet 1	Diet 2
Barley	-	200
Oat	-	200
Wheat	660	260
Fish Meal	60	60
Rapeseed Oil	30	30
Soybean Meal	212	212
Lime stone	10	10
Monocalcium Phosphates	10	10
L-Lysine HCL	2.0	2.0
DL-Methionine	2.0	2.0
L-Threonine	1.0	1.0
Salt	2.5	2.5
Mineral Premix	1.5	1.5
Vitamin A	0.5	0.5
Vitamin ADKB	1.0	1.0
Vitamin D_3	0.8	0.8
Vitamin E	0.5	0.5

Choline Chloride	1.2	1.2
Titanium Oxide	5.0	5.0
Phytase	0.2	0.2
Rovabio XL APT Flex	2.0	2.0

According to the composition of feed, macro materials were weighed automatically by computer and separately ground by hammer mill (E-22115 TF, Muench - Wuppertal, Germany) through a 3mm sieve. Ground ingredients were transported to the pre-bin for waiting next processing step.

Raw ingredients were mixed by a twin-shaft paddle mixer (400 liter Tatham, Model 1992 OB-1078) and rapeseed oil was added by a nozzle (65 degree angle) with 2.3 kg/min flow into the mixer chamber. 1 kg representative sample from each diet were taken from different places and corners after the mixing process.

After mixing process, the raw ingredients passed through the double continuous conditioner (Twin Pass, Muench, Germany, 1.2t/h) where the steam were added and they were then sent to the pellet press (RPM 350.100 Muench - Wupertal, Germany). Conditioner and pelleting parameter are shown in Table 2. For diet 1, there was used a 2.5mm die compared with a 3mm die for diet 2.

Table 2. *Processing Parameter*

Parameter	Unit	Diet 1	Diet 2
Conditioner temperature	℃	81.3	76.8
Die diameter	mm	2.5	3.0
Die length	mm	42.0	42.0
Capacity	Kg/h	450	450
Motor load	%	19.0	23.0

Amperes motor 1	amp	13.0	16.0
Amperes motor 2	amp	12.0	15.0
SUM Amperes motor	amp	25.0	31.0
Energy consumption	kW	15.38	19.07
Specific energy consumption	kWh/kg	0.0342	0.0424
Damp	Kg/h	52.0	47.0
ISO-box	℃	75.7	81.0

At the end, pellets were sent to the counter flow cooler (Miltenz, New Zealand, capacity 1.2 t/h) to lower the temperature and the moisture content for 30 minutes. When the cold pellets fell down from the cooler chamber into the package, representative samples were taken in different intervals. There were also taken pellets samples from different parts from the package. The pellet samples were pooled and distributed into plastic sample bags. Samples also were taken from chicken house, which were taken from different parts and corners from the package. Both samples from FôrTek and chicken house were analyzed the starch content, as shown in table 3.

Table 3. *Chemical content (%)of experimental diets*

	Diet 1	Diet 2
Dry matter	90	90
Starch	43.850	41.350

Commercial diet

The commercial diet for trial 2 was offered from Felleskjøpet Agri (Norway) that the composition and chemical contents were exhibited in Table 4 and Table 5, respectively. The commercial diet was considered that no structural components were included.

Table 4. *Composition of the Commercial Diet*

	Ingredients
Macro ingredients in decreasing order	Wheat, Soybean Meal, Maize grits, Maize gluten, Soy oil, Dehulled Oats and Rapeseeds
vitamins	Vitamin A, Vitamin D3, Vitamin E
Minerals	Iron, iodine, copper, manganese, zinc, selenium
Enzymes	6-Phytase, Endo-1,4-beta-xylanase, Endo-1,3 (4)- beta-glucanase

Table 5. *Chemical Contents (%) of the Commercial Diets*

Crude Protein	21.2
Crude Fat	4.8
Crude Ash	5.1
Sodium	0.14

2.2 Chicken experiment

Trial 1

48 day-old male broiler chickens (Ross 308) were randomly selected and placed in 4 battery cages where they were given feed and water ad libitum, with a six-hour dark period (00:00 to 06:00). In two cages the birds were given diet 1, while the two others were given diet 2. The room temperature was 33 ℃. The temperature was reduced to 29 ℃ when the chickens were 7 days of age, and reduced again to 27 ℃ at 14 days of age.

At 14 days of age the birds were weighed, and distributed one bird in each 48 quail cages. Birds were placed in cages in relation to which diet previous given. Birds eating diet 1 where placed in odd numbered cages and birds eating diet 2 were placed in even numbered cages. The same feeding and light regime lasted until 18 days of age.

At day 19, feed were removed and lights were switched off at 00.00. After a 6 hours starvation period and 5 hours darkness, birds got access to feed ad libitum in the morning at 06.00. The feed intake was measured at 09:00, 13:00, 17:00 and 22:00. After 1 hour feeding, clean trays were placed under each cage and excreta were collected at 11.00. Further, after 9 hours feeding, trays were cleaned. Excreta were collected from each tray at 19.00 (after feeding 13 hours). Feed was removed at 22.00.

At day 20, the lights were switched off from 00.00 to 06.00. After a 10 hours starvation period (22.00-08.00), birds got access to feed ad libitum. Mash diets crashed by motor-ground were given to half of the birds on each diet while pelleted diets were given the other half. Feed intake was measured at 10:00, 12.00, 13.00 and mash diet were changed back to normal pellet diets at 13.00 that all feed intake were recorded. Clean trays were placed under each cage after 1 hour feeding. Excreta were collected at 09.30, 10.30, 11.30 and 13.30. Feed was removed at 22.00.

At day 21, the light was switched off from 00.00-06.00. The birds were killed and dissected 8 birds each hour (08:00, 09:00, 10:00, 11:00, 12:00, and 13:00). The remaining birds were given access to feed at 08:00. At 09:00 all the clean trays were placed beneath the cages. The birds were killed by a cranial blow, followed by cervical dislocation. The weight of the birds, crop weight and weight of the gizzard full and empty were recorded. The content of the jejunum, upper part of the ileum and lower part of the ileum were collected and frozen at -20 degree. The excreta from all the cages were collected after all the birds were killed and dissected. Feed intake was measured from 08.00.

Trial 2

540 day-old male (Ross 308) broiler chickens were distributed among 12 pens (15 birds per pen) in 3 rooms (1, 2, and 3). Diet1 were fed until 11 days of age for all rooms. From day 11, commercial diet and an experimental diet were fed. In each room, the commercial diets were given to 6 pens while the experimental diets were given the rest of pens. Weight gain and feed intake were recorded at day 11, 14, 19, 28 and 34. The daily temperature was constantly around 24 ℃ from day 7 to day 14, and around 28 ℃ from day 14 to day 21.

The birds in room 1 and 2 were fed ad libitum with a six hours dark period (00.00-06.00), while the birds in room 3 were fed by intermittent feeding regime. From 7 to 14 days, feed for birds in room 3 were available at 08.00-09.00, 12.00-13.00, 16.30-17.30 and 21.00-23.00. From 14 to 35 days, feed for birds in room 3 were changed to be available at 08.00-09.00, 12.30-13.30, 17.30-18.30 and 22.00 -23.00. Light was switched off from 23.00 to 03.00 and 04.00 to 08.00.

At 28 days of age, two birds from each pen in all 3 rooms were weighed and distributed in individual cages. They were fed ad libitum with the same diet as earlier that made birds adapt to environment. Feed was taken away at 22.00 and lights were switched off from 00.00 to 06.00.

At 29 days of age, after 10 hours starvation, all feeds changed to be the experimental diets and given at 08.00. Odd number birds were fed with ad libitum and even numbers were fed with restricted which 10g were fed at first hour and 5g were added in each following 4 hours. Feed intake were recorded at every hour from 08.00-12.00. Clean trays were placed under each cage at 08.00 and excreta were collected at 08.00, 09.00, 10.00, 11.00, 12.00 and 14.30. Due to ad libitum fed birds did not eat normally, only 24 birds with intermittent feeding history were dissected. All birds were weighed and killed using a strap and cervical dislocation. All materials in the digestive tract (crop, gizzard, jejunum, upper ileum, lower ileum and colon) were collected and empty gizzard was weighed.

At 34 and 35 days of age, 36 ad libitum fed birds were killed by using carbon dioxide. The empty gizzards weight and remaining feed were recorded.

2.3 Chemical and statistical analyze

All the chemical analysis was executed at the Department of Animal and Aquaculture Sciences at the Norwegian University of Life Science, Ås, Norway. All the samples were dried overnight with at temperature at 103 ℃ ± 2 ℃ to find the dry matter content.

Starch

Feed samples from FôrTek and the chicken house were ground by ultra-centrifugal mill (RPM 18000, Retsch ZM 1000, Germany) through 0.5mm sieve. The excreta samples from day 19 (11.00 and 19.00) were analyzed for the starch percentage based on the AACCI-method 76-11. Due to the small amount of samples content after drying (dry matter < 0.25g) at 09.30 and 10.30, in this experiment, only samples from 11.30 and 13.30 used to analyze the starch content. For trial 2, digestive tract samples from jejunum, upper ileum and lower ileum were analyzed the starch content.

Titanium

Feed samples from FôrTek and the chicken house were measured for titanium dioxide according to (Short et al., 1996). The excreta samples (day 19 and 20) and the samples from jejunum, upper ileum and lower ileum were measured (day 21 and 29).

Statistical analyze

In trial 1, data from day 19 and day 21 were measured by a two-way ANOVA (diet × starch digestibility; diet × gizzard weight). For the data in day 20, a three-way ANOVA were used to test not only the correlation between diet, diet form and starch digestibility; also diet, diet form and feed intake of birds as well (SAS, 2011). In trial 2, a two-way ANOVA were used to test the difference of empty gizzard weight and relative gizzard weight between birds fed with experimental diet and commercial diet (SAS, 2011). The significance of differences between treatments was determined by using Ryan-Einot-Gabriel-Welsh multiple F test (SAS, 2011).

3. Results

Trial 1

At 19 days of age, there was a significant difference (P=0.038) in starch digestibility between birds fed with wheat-based diet and barley-oat-wheat-based diet at 11.00 after feeding 5 hours. In addition, no significant difference was found on starch digestibility for both groups of birds at 19.00 between these two different diets, which are shown in table 6.

Table 6. *Starch digestibility (% of birds) for birds fed with 2 different diet at 11.00 and 19.00*

Diet / Time	11.00	19.00
Wheat-based diet	$0.987^{a} \pm 0.009$	$0.986^{a} \pm 0.011$
Barley-oat-wheat-based diet	$0.991^{b} \pm 0.002$	$0.989^{ab} \pm 0.004$

^{ab} Means in a row with same superscript are no significant different (P>0.05)
Values presented as Mean $\pm$ Standard deviation

At 20 days of age, after 10 hours starvation period, feed intake (from 08.00-10.00, 10.00-12.00 and 12.00-13.00) for each group of birds fed with wheat-based diet (diet 1) and barley-oat-wheat-based diet (diet 2) both in the form of pellets and mash was shown in figure 1 below. According to the statistical analysis, feed intake was greater (P<0.0001) on both diets on pellet form than on mash form during the feeding period of 08.00-10.00 and 12.00-13.00. Moreover, this was no significant difference on feed intake from 10.00 to 12.00 for all types of diets. However, no significant effect was found between feed intake and diet grain in this experiment.

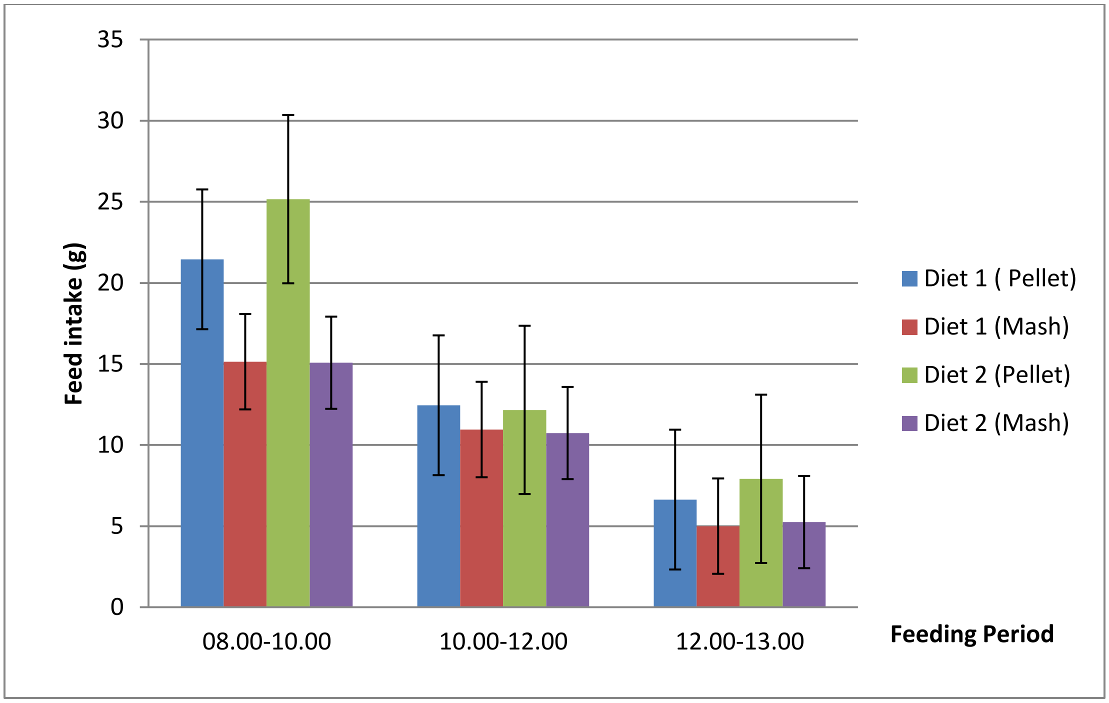

Figure 1 . *Feed intake(g) for birds fed with pellet and mash form for both diets at different feeding periods. Diet 1 was a wheat-based diet and diet 2 was a wheat-barley-oat-based diet*

Furthermore, starch digestibility of birds fed with 2 diets in the form of pellet and mash at 11.00 and 13.00 were presented in figure 2. Further statistical tests revealed that birds fed with barley-oat-wheat-based diet had significant higher ($P=0.020$) starch digestibility at 11.00 than that of birds fed with wheat-based diet. No significant differences ($P>0.05$) were found from starch digestibility of birds fed with these 2 different diets in the form of pellets or mash at 13.00, however, the wheat-based diet shown the lower starch digestibility at this moment. As shown in figure 2, a significant increase ($P<0.01$) in starch digestibility was found in the wheat-based diet both for pellets and mash form during the period of 11.00 to 13.00. In addition, starch digestibility for diet 2 were no significant difference from 11.00 to 13.00. According to the results from statistical analysis, there was no interaction ($P>0.05$) found between starch digestibility and diet form (pellet or mash) at both 11.00 and 13.00.

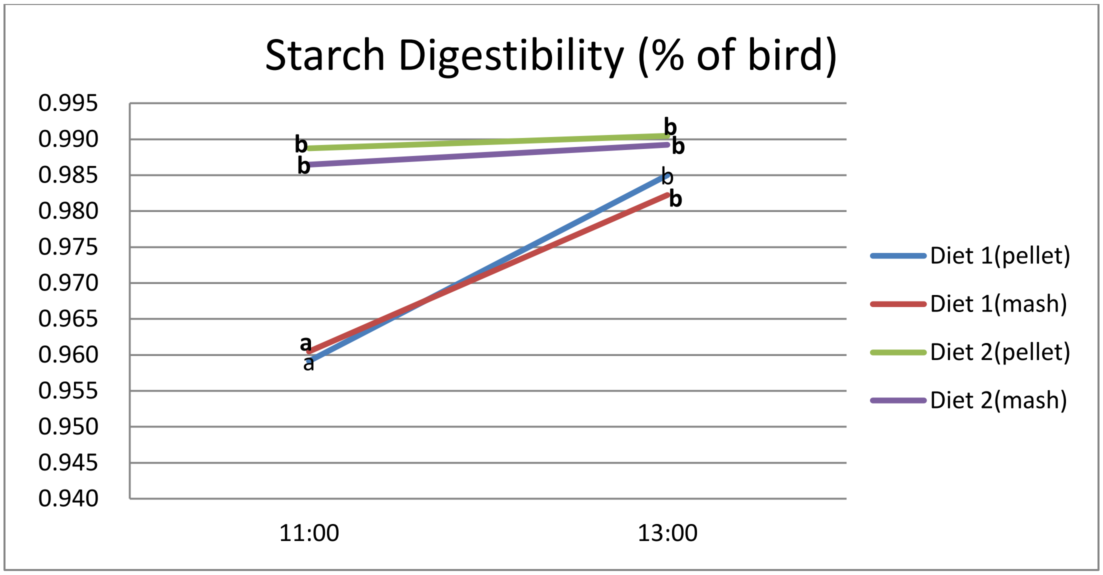

Figure 2. *Starch digestibility(% of birds) for different diet in the form of pellet and mash at 11.00 and 13.00. Diet 1 was a wheat-based diet and diet 2 was a wheat-barley-oat-based diet. Points with same letters mean no significant difference(P>0.05)*

The performance data from day 14 to 21 in trial 1 were summarized in table 7. Weight gain, feed consumption and bird weight (21 days) for birds fed with wheat-based diet was significantly lower (P<0.01) than that for diet with structural components. As shown in table below, no significant difference (P>0.05) was found on feed per gain for 2 diets.

Table 7. *Effect of wheat-based diet and wheat-barley-oat-based diet on performance from day 14-21*

	Wheat-based diet	Wheat-barley-oat-based diet
Weight gain (g)	$426^{a} \pm 54.288$	$478^{b} \pm 53.084$
Feed consumption (g)	$589^{a} \pm 62.692$	$682^{b} \pm 62.183$
Feed per gain (g/g)	$1.39^{a} \pm 0.136$	$1.43^{a} \pm 0.092$
Bird weight (21 day) (g)	$948^{a} \pm 77.046$	$1024^{b} \pm 72.063$

[ab] Means in a row with same superscript are no significant difference (P>0.05)
Values presented as Mean ±Standard deviation

At 21 days of age, empty gizzard weight of birds fed with barley-oat-wheat based diet from the first day was significantly higher (P<0.01) than another group fed with wheat-based diet, which is shown in figure 3. Further analysis showed that there was a significant difference (P<0.01) in relative gizzard weight (% of birds) between birds fed with 2 different diets, which barley-oat-wheat-based diet had higher relative gizzard weight.

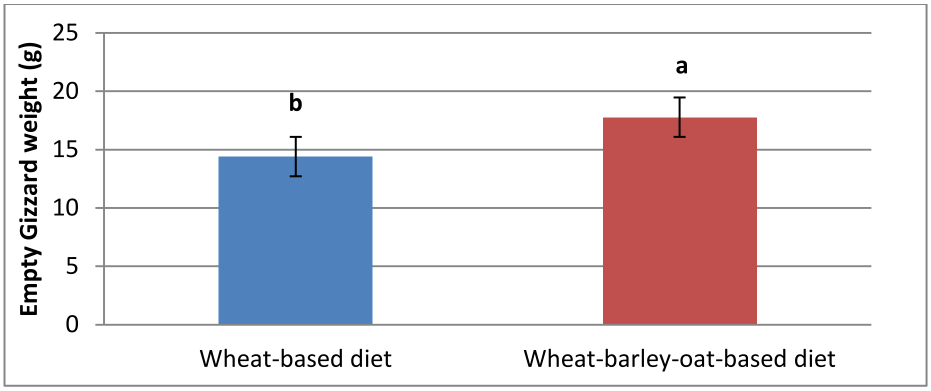

Figure 3. *Empty gizzard weight (g) of birds fed the diet with or without structural components at 21days of age. Points with different letters existed a significant difference(P<0.05)*

There were 3 birds identified from total 48 birds in trial 1 that shown considerably smaller gizzard, at the meantime, as shown in table 8, there also had lower starch digestibility than others. These three birds were all given the feed without structural components.

Table 8. *Individual birds with smaller gizzard weigh and lower starch digestibility than others*

Cage number	Given Diet	Structural component	Gizzard weight (g)	Starch digestibility in excreta at 11.00 (% of birds)	Starch digestibility in excreta at 13.00 (% of birds)
1	Wheat-based	No	13.3	0.885	0.963
11	Wheat-based	No	8.5	0.913	0.943
33	Wheat-based	No	16.6	0.918	0.962

Trial 2

At 29 days of age, feed intakes for birds fed with ad libitum and restricted were exhibited in figure 4 below. It was clearly shown in figure 4 that feed intake for an ad libitum feeding group was more than 2 times higher than that for restricted feeding.

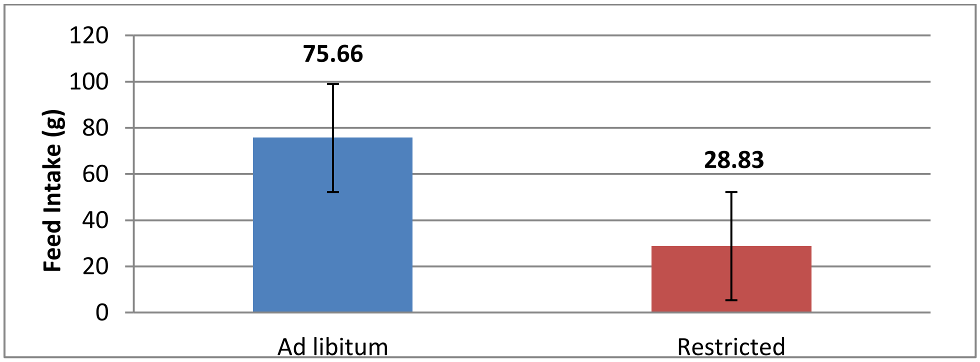

Figure 4. *Feed intake (g) of two groups of birds fed with different feeding regime*

In addition, starch digestibility for both groups of birds were no significant difference (P>0.05) in each segments of small intestinal as shown in figure 5. Further statistical analysis revealed that no interaction was found between feeding regime and starch digestibility.

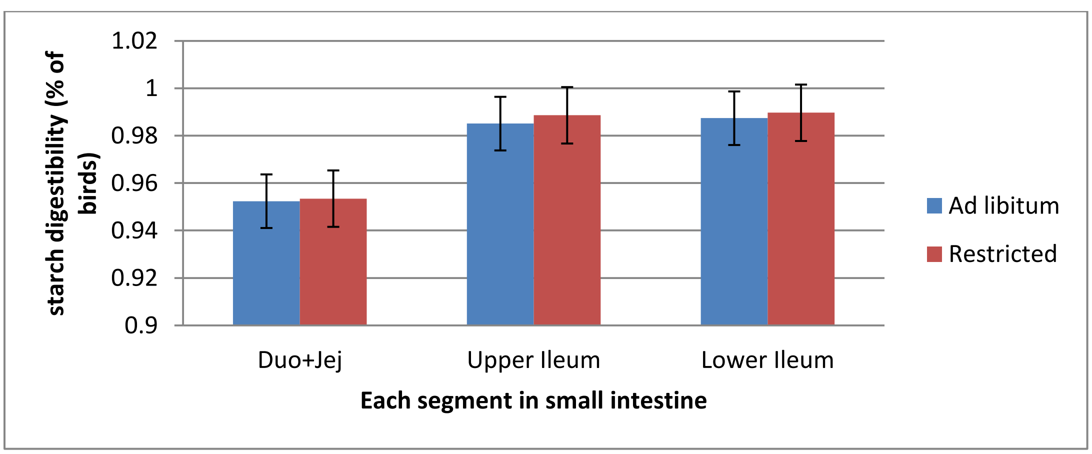

Figure 5. *Starch digestibility (% of birds) in each segment of small intestine for birds fed with different feeding regime*

At 29 days of age, 24 birds with intermittent feeding history fed with experiment diet or commercial diet were dissected. The empty gizzard weight were exhibited in the following figure 6, which was no significant difference (P>0.05) between the birds fed with experimental diet and commercial diet. Moreover, no significant difference (P>0.05) in relative gizzard weight (% of birds).

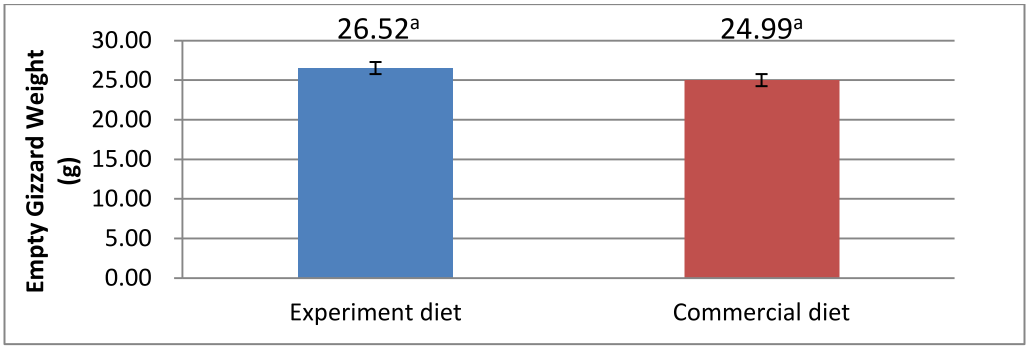

Figure 6. *Empty gizzard weight(g) for birds fed with experimental diet and commercial diet at 29 days of age.Points with same letters are no significant difference (P>0.05)*

Dry matter content in whole digestive tract were shown in figure 7 below. As shown in figure, there was significantly amount of dry matter retaining in the crop after 5 hours feeding.

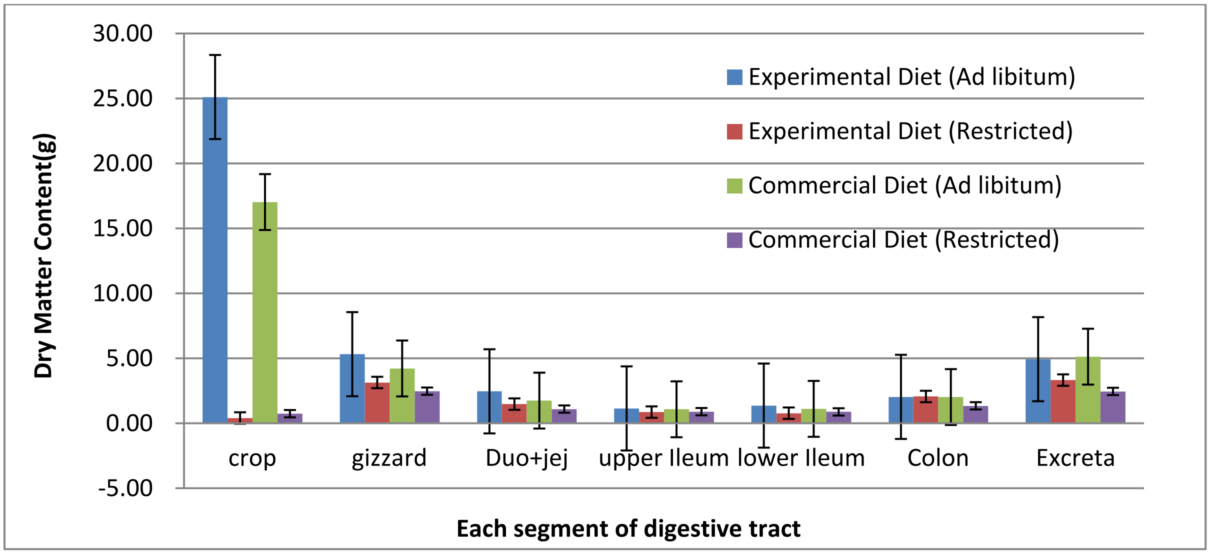

Figure 7. *Dry matter content(g) in each segment of digestive tract and excreta from birds fed with experimental diet or commercial diet feeing through ad libitum or restricted after feeding 5 hours. Duo+Jej means the content of duodenum and jejunum*

In 29 days of age, after 5 hours feeding, dry matter digestibility in small intestine of birds fed with experimental diet and commercial diet both with ad libitum and restricted feeding regime was detected through titanium analysis as shown in figure 8. On the basis of results from statistical analysis, no significant differences (P>0.05) were found on dry matter digestibility in different part of digestive tract either feeding ad libitum or restricted for birds which had experimental diet or commercial diet before. Individual variation between birds should be highly considered on dry matter digestibility in duo+jej. Two individual birds were identified from birds fed restricted that had lower dry matter digestibility in duo+ jej, which is -0.47 for experimental diet and -1.65 for commercial diet.

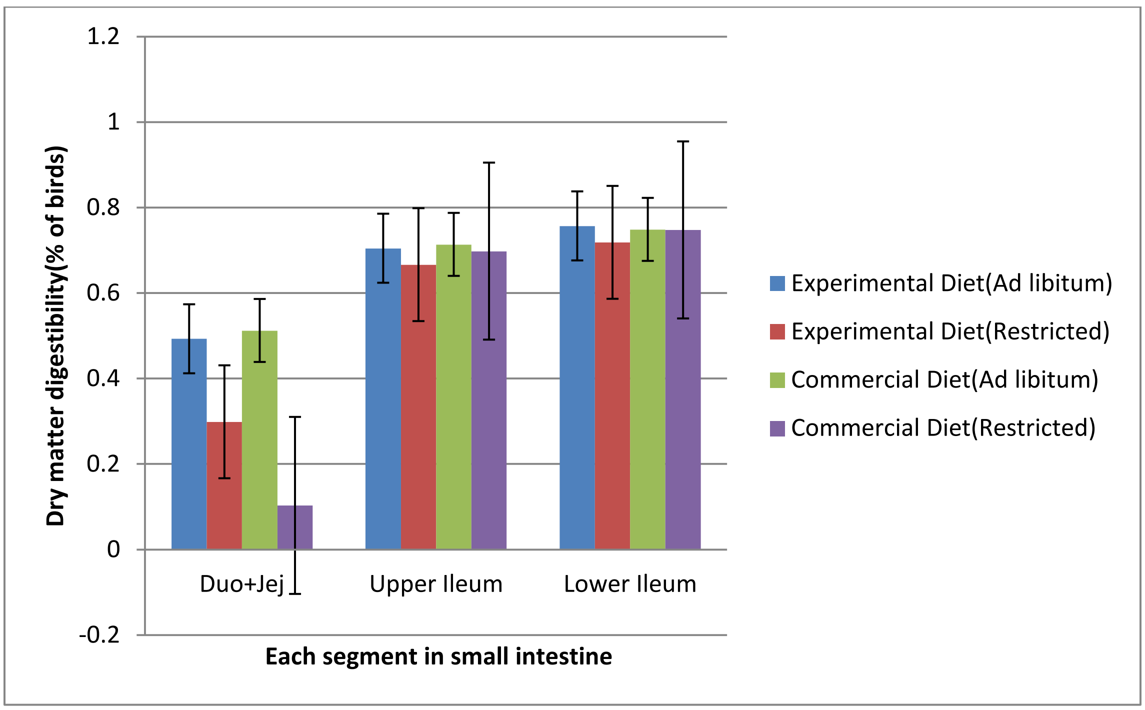

Figure 8. *Dry matter digestibility (% of birds) in small intestine from birds fed with experimental diet and commercial diet feeing through ad libitum or restricted after feeding 5 hours.*
Duo+Jej means the digestibility in duodenum and jejunum

At 34 and 35 days of age, after dissection, there was significant difference (P=0.0038) on empty gizzard weight between birds fed with experimental diet and commercial diet that fed experimental diet had significantly bigger size of gizzard, as shown in figure 9. The relative gizzard weight for birds fed experimental diet was also significantly higher (P=0.0340) than commercial diet.

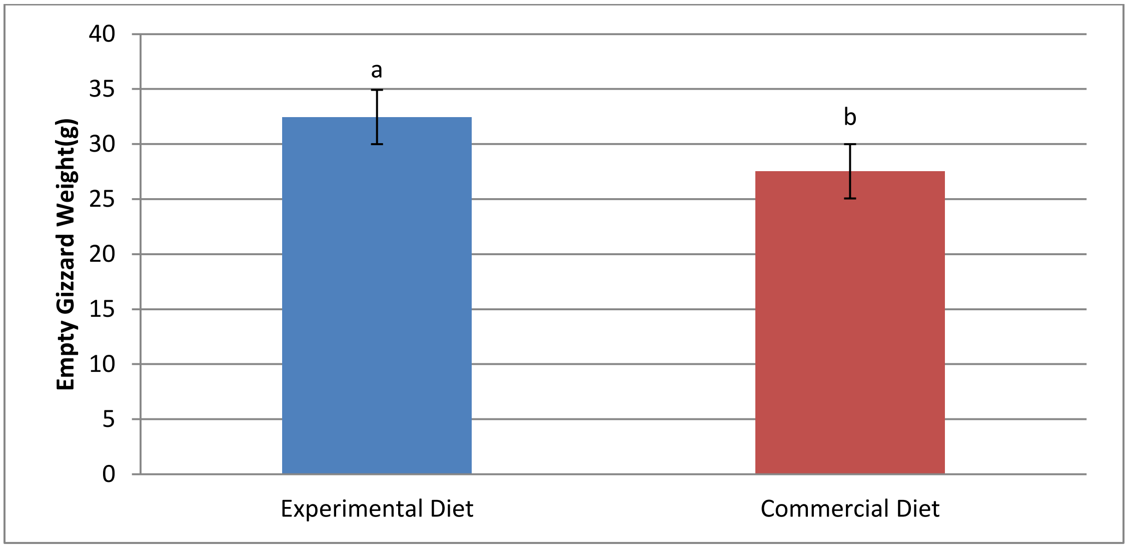

Figure 9. Empty gizzard weight (g) for birds fed with experimental diet or commercial diet at 34 and 35 days of age. Points with different letters are significant difference (P<0.05)

4. Discussion

Trial 1

Comparing with the wheat-based diet, birds fed diet containing structural components (wheat-barley-oat-based diet) exhibited a higher starch digestibility. This also accords with earlier studies, which birds fed diet with oat hulls shown high starch digestibility (Rogel et al., 1987a, Hetland and Svihus, 2001).

In addition, starch digestibility for birds fed with wheat-based diet was varied through the day significantly. On the opposite, starch digestibility was changed only slightly when birds fed diet with structural components. These findings supports the hypothesis of this experiment that developed gizzard is not only increase the volume of the gizzard, but also improve the regulation of feed flow to avoid the over-load of feed in the digestive tract.

Regarding to the data of empty gizzard weight, birds fed with the diet inclusion of oat hulls had significantly larger size of gizzard. It leads to the birds shown higher starch digestibility, and this finding confirms one of the hypotheses in this study that well functioning gizzard will control the over-consumption of feed. This finding corroborates the ideas of Hetland et al. (2002), who suggested that inclusion of high fibrous ingredients in the daily diet could increase the gizzard size which might positively affect the starch digestibility. There is also another finding that when insoluble fibrous ingredients contain in broiler diet, such as oat hulls, the increasing secretion of pancreatic enzyme break down the nutrients and concentration of bile salt causes the strong emulsifiers, which could improve the solubilisation of nutrients in the gizzard, therefore increase the feed utilization (Hetland et al., 2003, Svihus et al., 2004).

The results of three individual birds indicated the variation in gizzard development and starch digestibility, which birds may have different abilities of starch digestion. Also, it could illustrate that undeveloped gizzard may responsible for the low starch digestibility when birds were in the situation of over-comsumption of feed. Additionally, diet containing high amounts of structural components could positively affect the reduction of feed particles size entering into the samll intestine (Hetland et al., 2002, Hetland et al., 2003). And the well- functioning gizzard could prolong the retaining time of mateirals in the gizzard to reduce the particle size wherefore increase the nutrients digestibility (Svihus, 2011).

The most intresting finding was that this experiment did not find the relevance between feed intake and starch digestibility. Although, a study has been observed that the crushed or mash diet can significantly increase the starch digestibility through reducing the feed intake (Svihus and Hetland, 2001). It is difficult to explain this result, but it is supported in trial 2 again.

Besides, data in this study indicate that when birds fed diet inclusion of structural components had higher feed consumption. This finding corroborates the ideas of Hetland and Svihus (2001), who has been reported that inclusion of oat hulls can increase feed consumption for broiler, which was affected by the particle size of oat hulls. But, our data seem to indicate that low nutrient concentration in diets containing high amounts of structural components caused the high feed consumption for birds.

The suprising results is that weight gain was significantly higher for birds fed low nutrient concentration diet, which is containing high amounts of structural components. However, it supports previous findings that inclusion of oat hulls in the broiler diet have positive effect on performance and digestibility (Hetland and Svihus, 2001, Svihus and Hetland, 2001).

Trial 2

In terms of the results from different feeding regime and starch digestibility in each segments of small intestine, this study did not detect any evidence that starch digestibility is affected by the feed intake. Besides, starch digestibility did not affected by the high feed intake for birds fed ad libitum. A hypotheses leading from these results is that low starch digestibility after a longer starvation is not caused by the over-consumption of feed, which might be too rapid flow of feed that passed through the gizzard region entering into the small intestine. Moreover, no individual variation was detected between gizzard weight and starch digestibility whether fed experimental diet or commercial diet in ad libitum and restricted feeding regime.

A comparison of the empty gizzard weight for experimental diet and commercial diet reveal no difference between these 2 diets, but the gizzard weight was slightly higher for birds fed with experimental diet at 29 days of age. The one possible explanation is that dissected birds were fed intermittent and used the litter in cages since 14 days of age. It may because gizzards were stimulated by litter as structural components. However, the dissection data from 34 and 35 days indicate that experimental diet significantly improve the development of gizzard.

After dissection, the data of dry matter content in whole digestive tract indicate that, even after feeding 5 hours, there was still high amounts of dry matter retaining in the crop for ad libitum feeding. Taking into the consideration of the feeding history, all of the birds from intermittent feeding groups adapted to have a habit of retaining feed in the crop, which corroborate the findings from Svihus et al. (2010) that holding capacity of digestive tract might be improved by birds fed with intermittent feeding. Moreover, dry matter content in small intestine was lower for birds fed restricted than fed ad libitum. And the dry matter digestibility of small intestine shown that there was no significant difference between experimental diet and commercial diet whether feeding ad libitum or restricted.

5. Conclusion

It can be concluded that inclusion of structural components can stimulate the gizzard activities to avoid too rapid flow of feed in the samll intestine, further, to prevent the decrease of digestibility. To summarize the results from trial 1 and 2 is that feed intake does not affect feed flow. A hypothesis should be considered that after longer starved time, lower starch digestibility may not caused by the over-consumption of feed, it may due to too rapid flow of feed in the anterior digestive tract, which should be tested in the future research.

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