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Faculty of Veterinary Medicine and Biosciences
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Effect of intermittent feeding and structural components on performance and digestive tract for broiler chickens

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Abstract

An experiment was conducted to study the effect of a diet with high structural component on the performance of ad lib and intermittently-fed broiler chickens; whether the supplemented enzymes had effect on ileal viscosity and litter quality.

Broiler chicken were given, either ad lib or intermittently, barley-oat-wheat based experimental diet in whole grains and commercial maize-wheat based diet contain less fibrous content from 11 days of age, in a 2×2 factorial arrangement. For ad lib feeding, birds got access to feed constantly for 18 hours through continuous light and 6 hours darkness in two rooms. For intermittent feeding, in one room, feed was available for three 1-h feeding bouts plus one 2-h feeding bout per day. This was completed by frequently removal of feed and switching off the light at night, from day 7 to 14. From day 14 and onward, it was changed to 5 1-h feeding bout/day until the end of the experiment. Litter quality were scored at day 22. The empty gizzard weights recorded from intermittently and ad lib fed birds at 29 and 34 &35 days of age respectively. The ileal viscosity was also measured at day 34 &35. The structural component interacted on adaptability of broiler chickens to intermittent feeding indicated by higher feed intake of diet consisting of whole grains (barley, oat and wheat) than wheat-maize based diet. For the empty gizzard weights from intermittently fed birds there was no significant difference at day 29, however the gizzard weights differed from ad lib fed birds at the end of experiment. Furthermore, the reduction of ileal viscosity due to enzyme supplementation (Wang et al., 1992), has found in birds fed barley-oat-wheat based diet.

In conclusion, broiler chickens quickly adapted to intermittent feeding through high structural component diets, without reduction of performance. With improved feed efficiency and enzyme supplementation, the ileal viscosity was not as high as when diet without enzymes (Classen, 1996)

Key word: Intermittent feeding, structural component, performance of broiler chickens, gizzard, litter quality, ileal viscosity

Acknowledgement

The thesis is devoted to my family who have always offering me unconditional support and love which is the motivation of my life and study. There is no way to express how much it meant to me and how grateful I am to them.

There are no proper words to convey my deep gratitude and respect for my supervisor, Birger Svihus who has generously helped and devoted me his precious time for guidance and support with patience, motivation, enthusiasm and immense knowledge, which are essential for completion of research and thesis. He demonstrated what a brilliant and hard-working scientist can accomplish and inspired me to realize the power of critical reasoning. It was my great honor.

Besides my supervisor, my sincere appreciation goes to Dejan Miladinovic and Ismet Nikqi for guide and support with feed processing, as well as Frank Sundby and Nina Pedersen Asper who guaranteed my laboratory work with their skilful technical assistance. I am also grateful to my fellow student parterners Qi Ji, Dzana Mrkaljevic, Adiya, Kari Borg who worked together with me for experiment and shared the experience and help with me. In the end, my thanks must goes to my teacher Li Ming encouraged me to study abroad and my friends Alima and Chana who helped me since my study in Norway. All these selfless friends created a precious memory to me.

Table of content

1. Introduction

In ad lib feeding system, feed is accessible to birds in continuous or nearly continuous lighting, often resulting in high feed intake and potential overconsumption (Svihus, 2001, Svihus et al., 2010). Researches demonstrated that the continuous light programs significantly reduce the sleeping time and induce physiological stress responses (Kliger et al., 2000, Campo and Davila, 2002). On the contrary, much less stress on leg abnormalities and significant effect on weight gain observed from intermittent regimes compared to continuous light program (Buckland et al., 1973). In addition, the mortality, ascites and severe leg problems were also associated to rapid growth due to ad lib feeding. The intermittent feeding, by both removal of feed and lighting control, might be a solution to these problems and promote feed efficiency (Decuypere et al., 1994, Buyse et al., 1996b). Light is considered a critical exogenous factor in control of chickens behavior and physiological process (Manser, 1996), and has been used as the most common method to fed chickens. The low energy consumed on maintenance due to less activity when the lights switched off. This could be a potential reason for improvement of feed efficiency of birds through intermittent programme (Buyse et al., 1996a, Summers and Leeson, 1997). The intermittent feeding, compare to continuous lighting regime, might improve feed/gain by increasing weight gain while not changing the major feed consumption (Mahmud et al., 2011). The intermittent regime might also improve feed utilization without increasing weight gain and nutrient availability of birds (Svihus et al., 2010).

The storing capacity of the anterior digestive tract of birds might be increased by intermittent feeding due to large amount of feed intake in a short time to store up feed in crop (Savory, 1980, Svihus et al., 2010, Tanha, 2012). The greater length of time from retention of ingesta has found by intermittent programme compared to ad lib. This

is due to birds storing the ingested feed in the crop and gizzard (Buyse et al., 1993). The birds' performance improved by diets diluted with hulls due to both increased holding capacity and function of gizzard (Sacranie et al., 2012). Intermittent regime might lower the crop pH due to the longer retention time and increased activity of bacterial acidification. Furthermore, the increased acidity might resulted in higher activity of exogenous enzymes (Tanha, 2012).

In another aspect, grains such as barley, oat and wheat are commonly used as feed ingredients for poultry and have a great effect on performance. The hulls consisted in some whole grains contain a substantial amount of indigestible fiber. For example, the oat hull is water insoluble and has a strong texture that may increase grinding efficiency thus develop the gizzard muscle (Hetland et al., 2002). Supplementation of coarse oat hull has been proven to increase the size and volume of gizzards (Hetland and Svihus, 2001). In addition, the whole barley contains high fibrous content which gives a higher grinding activity and thus resulted in a bigger size of gizzards (Svihus et al., 1997a). Moreover, bigger gizzard promotes the feed consumption resulted in increased weight gain (Nir et al., 1990). The use of whole grains may also improve the welfare and health of birds, which has been proven by the findings of Elwinger et al. (1992). They demonstrated an increase of dry matter content in the litter by using whole wheat. Nevertheless, barley contain ß-glucans which have been suspected to increase the viscosity in the digestive tract of chicken (Fadel et al., 1987). This is because birds cannot synthesize the enzyme for completely hydrolyze ß-glucans (Champ et al., 1981). Enzymes are commonly added to feed when whole grains are used, which is the solution to reducing the problem of viscosity. It has been proved that the feeding value, such as feed/gain and weight gain, increased by adding enzymes to the barley-oat-wheat based diet (Svihus et al., 1997b, Svihus et al., 1997a). Additionally, most enzymes were added for diet contain barley and wheat.

The objective of this research was to investigate the interactive effect of intermittent feeding combined with high structural components diet on performance, adaptability and gizzard of broiler chickens. Also, this paper was studied the effects of diet with enzymes supplementation on ileal viscosity and further on litter quality.

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 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. All 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 were 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. In ad lib feeding system, feed is accessible to birds in continuous or nearly continuous lighting, often resulting in high feed intake and potential overconsumption (Svihus, 2001, Svihus et al., 2010). Researches demonstrated that the continuous light programs significantly reduce the sleeping time and induce physiological stress responses (Kliger et al., 2000, Campo and Davila, 2002). On the contrary, much less stress on leg abnormalities and significant effect on weight gain observed from intermittent regimes compared to continuous light

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The objective of this research was to investigate the interactive effect of intermittent feeding combined with high structural components diet on performance, adaptability and gizzard of broiler chickens. Also, this paper was studied the effects of diet with enzymes supplementation on ileal viscosity and further on litter quality.

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. Sample of the diets also taken from chicken house, which were taken from different parts and corners from the package.

Commercial diet

The commercial diet for experiment was offered from Felleskjøpet Agri (Norway) that the composition (Table 3) and chemical contents (Table 4) were shown in below. The

commercial diet was considered that no structural components were included.

Table 3. ***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 4. ***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

540 day-old male (Ross 308) broiler chickens were distributed among 12 pens (15 birds per pen) with wood shavings as litter in 3 rooms (1, 2, and 3). Diet1 were fed until 11 days of age for all rooms. From day 11, a commercial diets and an experimental diets 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 were 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 18 hours light and 6 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, 22.00 -23.00 and 03.00-04.00. Light was switched off from 23.00 to 03.00 and 04.00 to 08.00.

At 22 days of age, the photos were taken from litter (wood shavings) of pen in all 3 rooms (36 pens total) and then visually scored by 2 different persons based on these photos.

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, feed and 36 ad lib fed birds were weighed and killed by using carbon dioxide. The gizzard were weighed without contents and recorded. Additionally,

the contents from the ileum were collected for measuring the viscosity.

2.3 Chemical and statistical analyze

All the chemical analysis were 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°C ± 2°C to find the dry matter 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 jejunium, upper ileum and lower ileum were measured (day 21 and 29). Titanium dioxide equivalent to approximately 5 g for per kg feed.

Statistical analysis

The performance data from experiment were executed to a two-way ANOVA (feeding regime × diet) whereas the data (bird weight, empty gizzard weight, relative empty gizzard weight and viscosity of ileal content) from ad lib fed birds at 34 and 35 days of age were subjected to a one-way ANOVA by using SAS software SAS (2011) . Further, for pair-wise comparisons, the Ryan-Einot-Gabriel-Welsh procedure was used when appropriate, with $P<0.05$ as the significance level SAS (2011). The random variation measurement was measured by using the square root of mean square error in the analysis of variance (residual standard deviation, RSD).

2.4 Viscosity measurement

The in vitro digestion method presented by Bedford & Classen (1993) were conducted to measure in vitro viscosity. The viscosity values standardized by using the transformation recommended by Carré and Melcion (1995).

3. Results

The weight gain and feed intake were recorded at 11, 21, 28 and 34 days of age from 12 ad lib fed birds and 12 intermittently fed birds (24 in total). The feed/gain ratio (g/g) were also calculated based on the recorded feed intake and weight gain. The commercial diet were given to 6 birds and the experimental diet were given to rest of the 6 birds both for 12 ad lib and 12 intermittently fed birds.

Weight gain (g) per bird had extreme difference ($P<0.0001$) between ad lib and intermittently fed bird from the age period 11-21, 21-28 and 11-34 days but no significant difference ($P>0.05$) at the age period 28-34 days, which is shown in Figure 1.

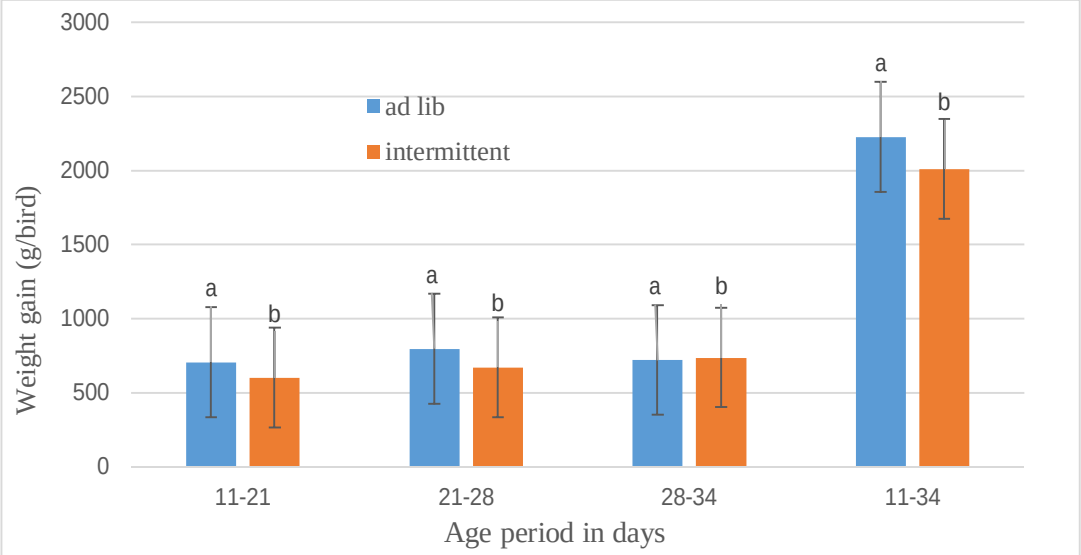


Figure 1. ***Weight gain (g) per bird in two feeding regimes at 3 different (11-21, 21-28, 28-34) and one total (11-34) age periods (from day to day) in days.***

[a-b] Means with different superscript are significantly different (p<0.05).

The interaction between diets and feeding regimes were found and demonstrated in Figure 2. The weight gain (g) of per bird on the commercial diet had responded more negatively ($P<0.05$) to intermittent feeding than that of bird on the experimental diet at

11-21, 21-28 and 11-34 days of age, but no significant difference for 28-34 days of age (P>0.05).

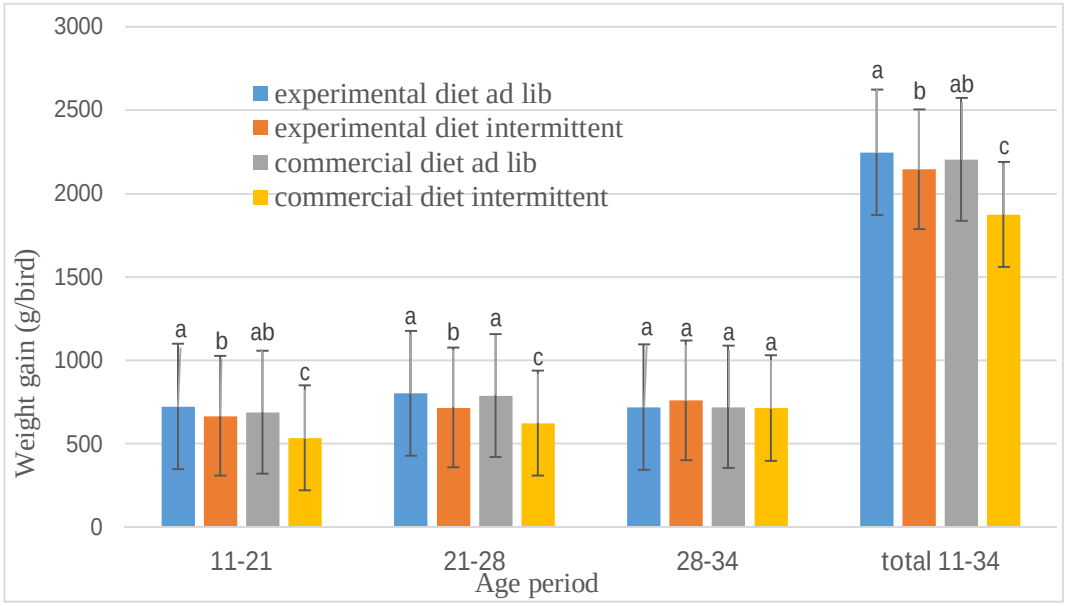
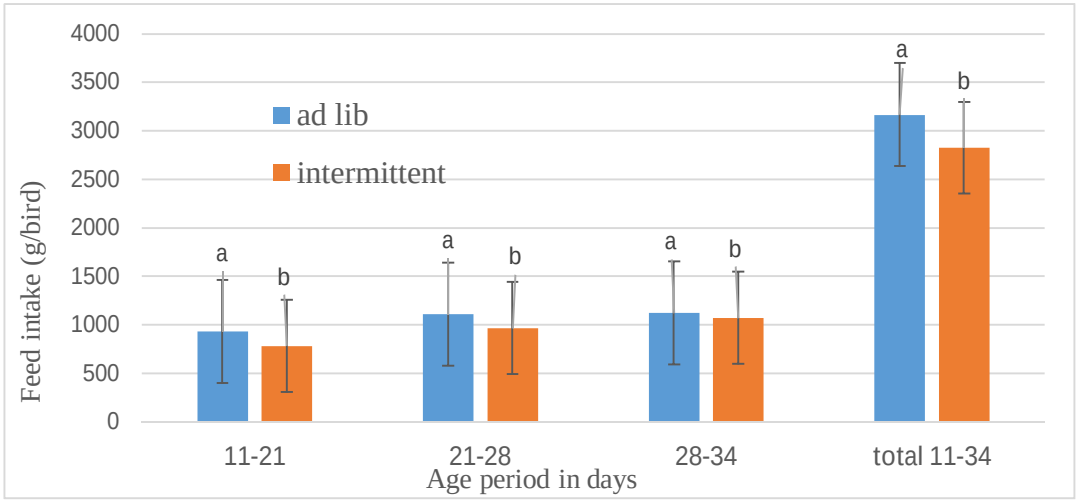


Figure 2. ***Weight gain (g) per bird in two feeding regimes and two diets at 3 different (11-21, 21-28, 28-34) and one total (11-34) age periods (from day to day) in days.***

[a-b-c] Means with different superscript are significantly different (p<0.05).

Feed intake (g) per bird had extreme difference (P<0.0001) between ad lib and intermittently fed bird which is shown in Figure 3.



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[a-b] Means with different superscript are significantly different (p<0.05).

For feed intake (g), the interaction between commercial diets and intermittent feeding regimes were found and shown in Figure 4. The bird on the commercial diet had poorer performance (P<0.0001) in intermittent feeding than bird on the experimental diet in general.

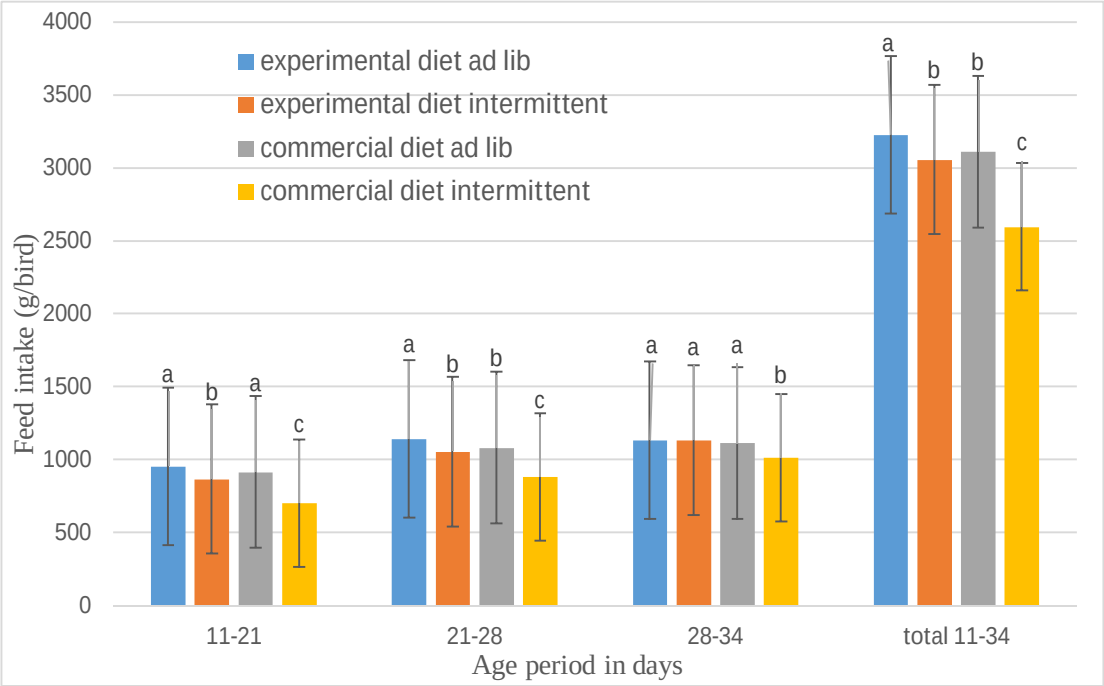

Figure 4. ***Feed intake (g) per bird in two feeding regimes and two diets at 3 different (11-21, 21-28, 28-34) and one total (11-34) age periods (from day to day) in days.***

[a-b-c] Means with different superscript are significantly different (p<0.05).

No significant differences (P>0.05) were found from feed/gain ratio (g/g) (feed intake/weight gain) in two feeding regimes in general. However, at the age period 28-34 days, feed/gain ratio for bird is lower (P=0.0007) in intermittent feeding than ad lib as shown in table 5.

The feed/gain ratio (g/g) of birds were no significant differences (P>0.05) in total and from 11 days until 28 days of age. But at the age period 28-34 days, in intermittent feeding regime, the commercial diet gives better (P=0.4845) feed/gain ratio on bird than experimental diet (Table 6.).

Table 5. ***Feed/gain ratio (g/g) by different feeding regimes at total and different age period in days***

Feeding regime \ Age period in days	11-21	21-28	28-34	Total 11-34
ad lib	1.322 ± 0.041	1.394 ± 0.049	1.560[a] ± 0.054	1.424 ± 0.033
intermittent	1.304 ± 0.020	1.440 ± 0.069	1.457[b] ± 0.076	1.404 ± 0.042

[a-b] Means with different superscript are significantly different (p<0.05).

Table 6. ***Feed/gain (g/g) by two feeding regimes and two diets at total and different age periods***

Feeding regime \ Age period in days	11-21	21-28	28-34	Total 11-34
experimental diet ad lib	1.318 ± 0.010	1.419 ± 0.017	1.575 ± 0.070	1.436 ± 0.024
experimental diet intermittent	1.299 ± 0.018	1.471 ± 0.090	1.491 ± 0.037	1.424 ± 0.039
commercial diet ad lib	1.326 ± 0.060	1.369 ± 0.060	1.544[a] ± 0.031	1.412 ± 0.038
commercial diet intermittent	1.308 ± 0.022	1.409 ± 0.010	1.423[b] ± 0.093	1.384 ± 0.038

[a-b] Means with different superscript are significantly different (p<0.05).

The (performance data) weight gain (g), feed intake (g) and feed/gain (g/g) by experimental and commercial diet at different (11-21, 21-28 and 28-34) and total (11-34) age periods in days were demonstrated below (Table 7). Except 28-34 days of age (P>0.05), the rest age periods of weight gain (11-21, 21-28 and 11-34) and all age periods (11-21, 21-28, 28-34 and 11-34) of feed intake were significantly higher (P<0.0001) in experimental diet than commercial diet. Feed/gain showed significant differences (P<0.05) at 21-28 and 11-34 days of age and no significant differences (P>0.05) for the rest (11-21 and 28-34 days of age) by two diets.

At 22 days of age, the 36 litter (wood shavings) in pens (24 ad lib from room 1 & 2 and 12 intermittent from room 3) were visually scored.

The intermittent and ad lib feeding regime showed significant affect (P<0.05) on litter quality (Figure 5) whereas neither of experimental and commercial diet had no effect (P>0.05) on litter score (Figure 6). No interaction between diet and feeding regime was found (P>0.05).

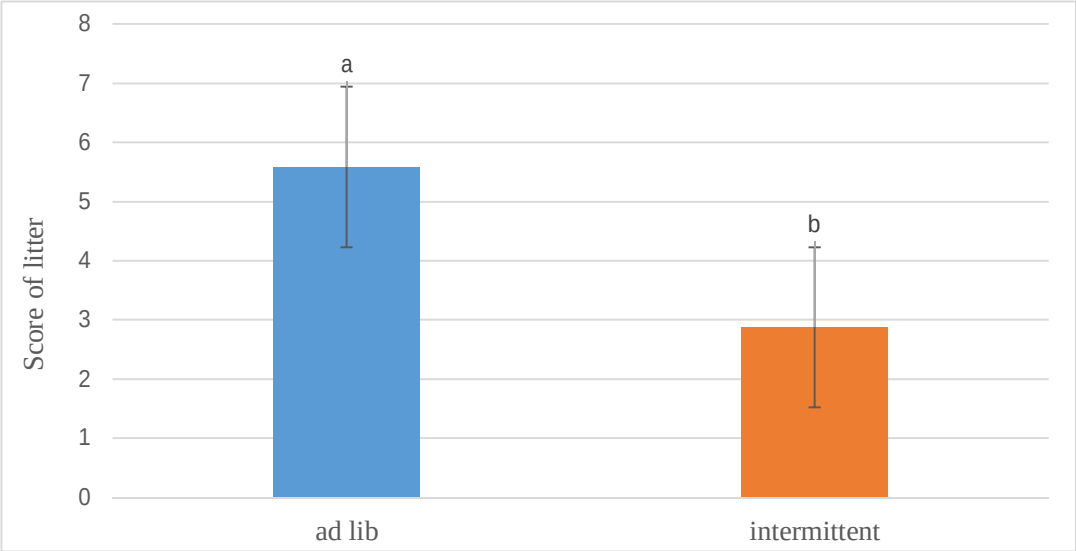

Figure 5. ***Score of litter by ad lib and intermittent feeding regime at 22 days of age.***

[a-b] Means with different superscript are significantly different (p<0.05).

Table 7. ***Weight gain, Feed intake and Feed/gain (g/g) by experimental and commercial diet at different and total age periods in days***

Performance by Diet / Age period in days		11-21	21-28	28-34	Total11-34
Weight gain	experimental diet	695.639[a] ± 38.774	760.798[a] ± 52.089	740.851 ± 35.827	2197.288[a] ± 79.666
	commercial diet	613.343[b] ± 84.838	708.323[b] ± 88.691	718.604 ± 40.777	2040.271[b] ± 181.447
Feed intake	experimental diet	910.328[a] ± 53.469	1097.743[a] ± 64.410	1133.906[a] ± 31.996	3141.977[a] ± 115.646
	commercial diet	807.867[b] ± 115.217	981.428[b] ± 107.429	1063.939[b] ± 59.766	2853.234[b] ± 276.331
Feed/gain	experimental diet	1.309 ± 0.017	1.445[a] ± 0.067	1.533 ± 0.069	1.430[a] ± 0.031
	commercial diet	1.317 ± 0.044	1.389[b] ± 0.046	1.483 ± 0.091	1.398[b] ± 0.039

[a-b] Means with different superscript are significantly different (p<0.05)

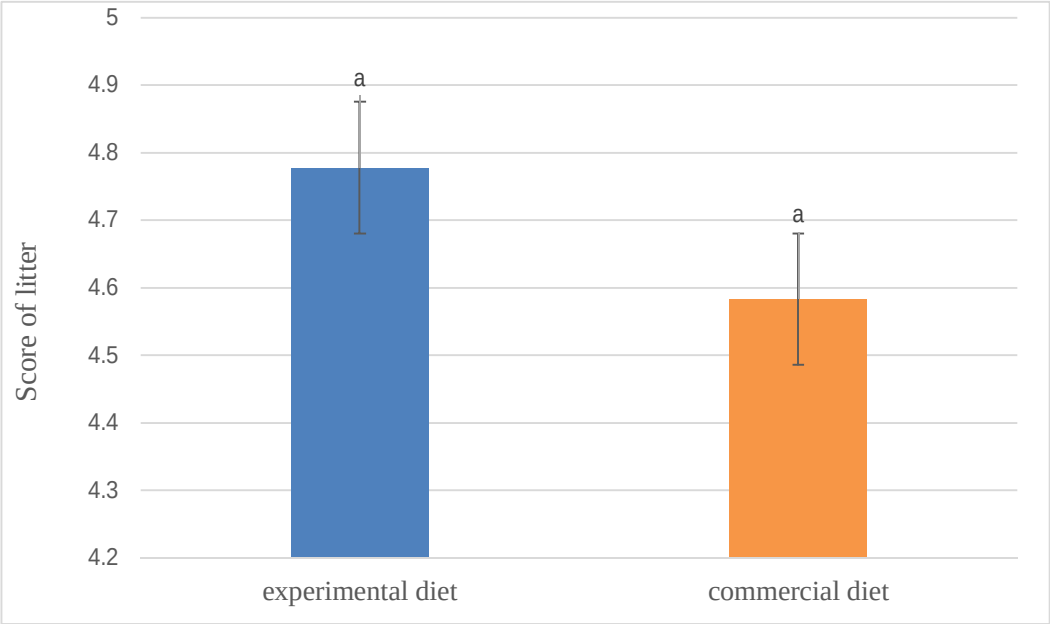

Figure 6. ***Score of litter by experimental and commercial diet at 22 days of age.***

[a-b] Means with different superscript are significantly different (p<0.05).

At 29 days of age, all 24 birds were dissected and the empty gizzard weight (g) as well as relative empty gizzard weight (%) were weighed and calculated. No significant difference were found (P>0.05) both from empty gizzard weight and relative empty gizzard weight depending on experimental diet and commercial diet that was exhibited in the following Figure 7.

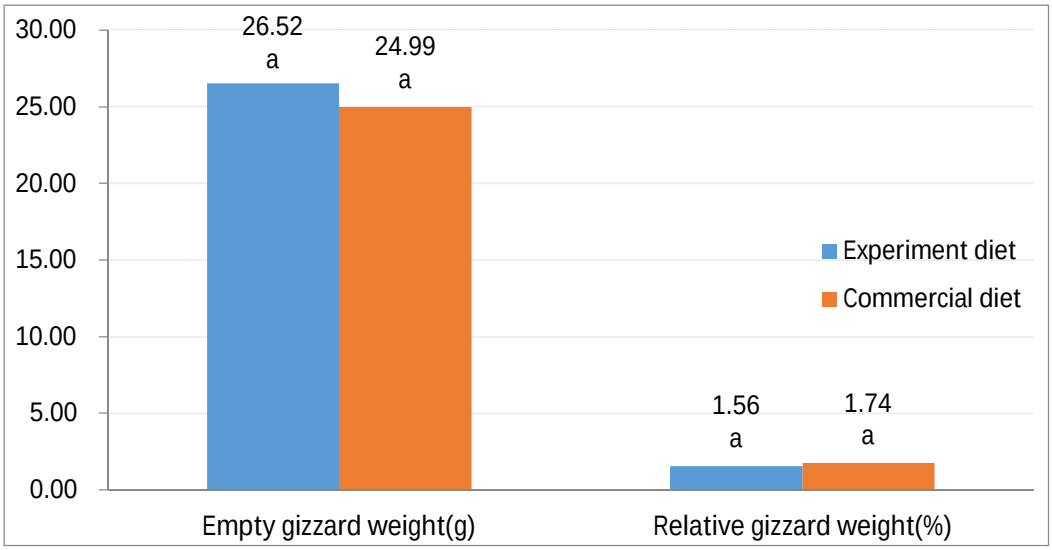

Figure 7. ***Empty gizzard weight (g) and relative empty gizzard weight (%) for two diets***

[a] means with same superscript are no significant difference (P>0.05)

At 34 and 35 days of age, the other group of 36 ad lib fed birds were weighed and dissected. The gizzard were weighed without contents and recorded. Additionally, the contents from the ileum were collected for measuring the viscosity.

Bird weight (g/bird) from experimental and commercial diet were no significant difference (P>0.05) as shown in Figure 8**.**

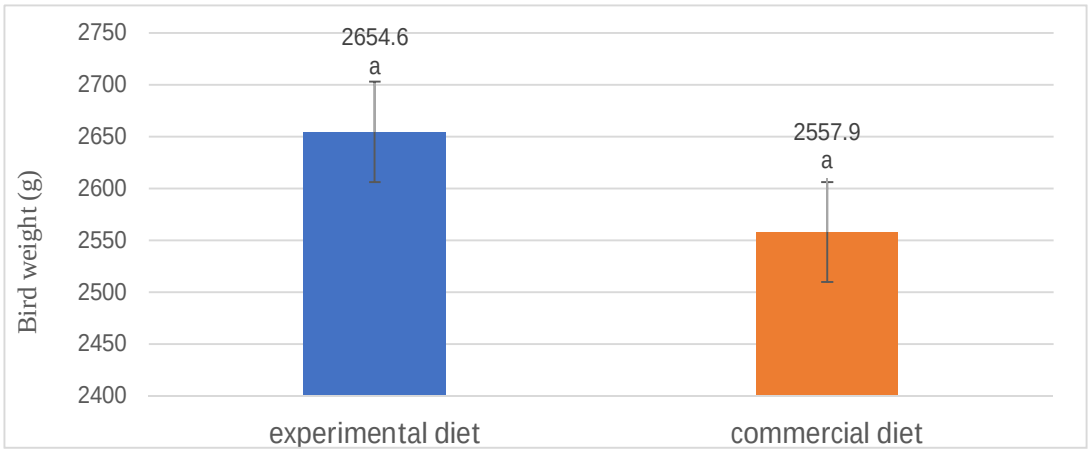

Figure 8. ***Bird weight (g/bird) from experimental and commercial diet in ad lib feeding regime at 34 days of age.***

[a-b] Means with different superscript are significantly different (p<0.05)

The empty gizzard (g) (P=0.0038) weight and relative empty gizzard weight (%) (P=0.0340) were both smaller for commercial diet than experimental diet from ad lib fed birds at 34&35 days of age as shown in the Figure 9**.**

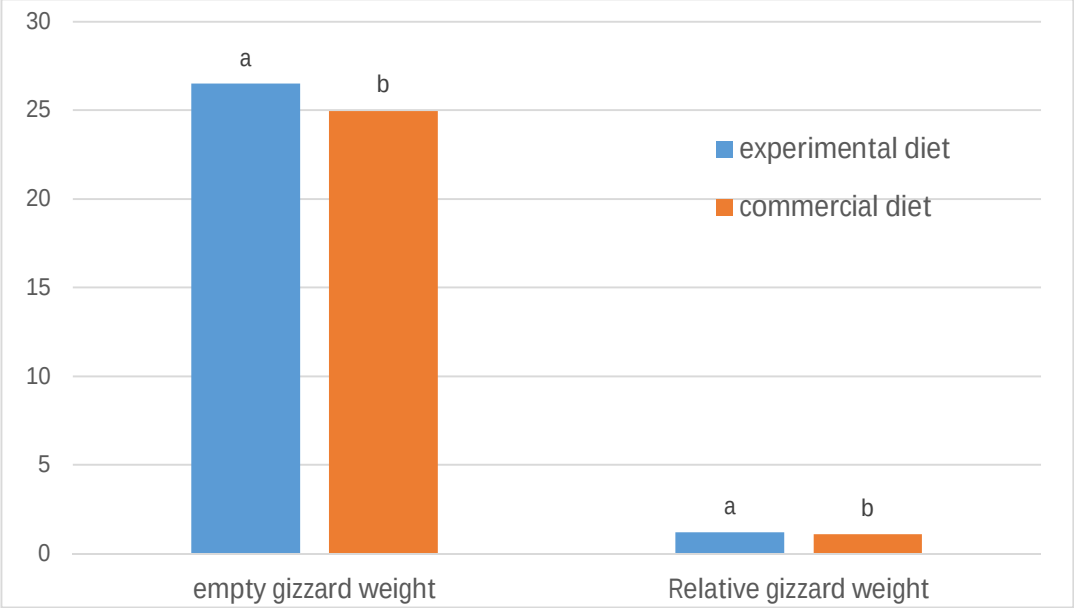

Figure 9. ***The empty gizzard weight (g) and relative empty gizzard weight (%) from the ad lib fed birds at 34&35 days of age***

[a-b] Means with different superscript are significantly different (p<0.05)

The viscosity of ileal content from ad lib fed birds were measured at 35 days of age and showed higher (P=0.0361) viscosity from birds fed with experimental diet than the birds fed with commercial diet (Figure 10.).

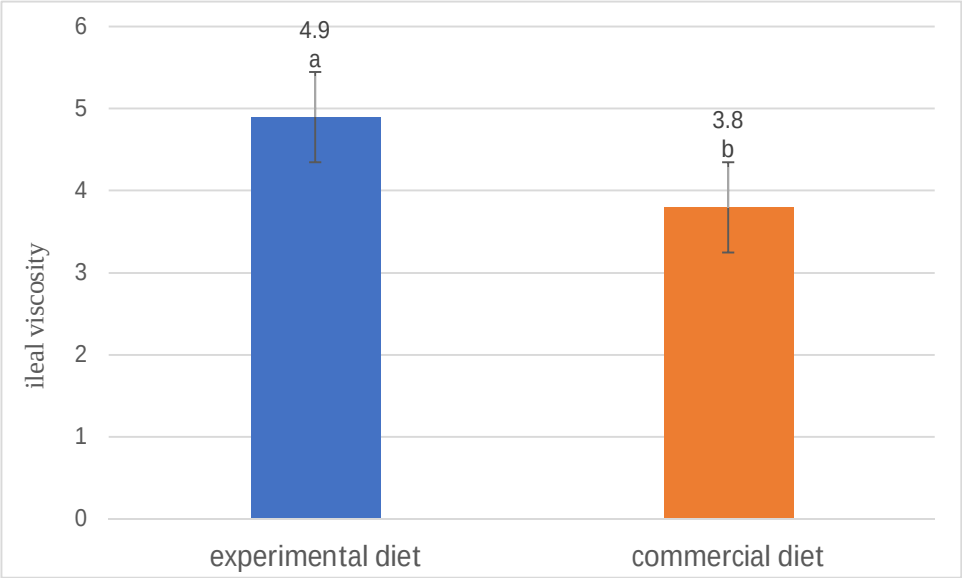

Figure 10. ***The viscosity of ileal content from ad lib fed birds in experimental and commercial diet at 35 days of age.***

[a-b] Means with different superscript are significantly different (p<0.05)

4. Discussion

The weight gain of intermittently fed birds, after an adaption period to this feeding regime, observed similarly to that of ad lib fed bird, although the access of the feed reduced to only 5-hour from 18-hour continuously in ad lib. This could be explained by the dramatically increase of feed-storing capacity both in crop and gizzard due to intermittent feeding, as observed by Barash et al. (1993), although not all the former researches have agreed on it (Svihus et al., 2010, Sacranie et al., 2012). Additionally, this finding seems to be consistent with previous research which found that birds had the ability to adapt quickly through intermittent feeding system. (Svihus et al., 2010). This was proved by similar birds weight gain as ad lib fed birds in this research. For intermittently fed birds, diets did not have any effect on body weight in the later period of experiment and there was no significant difference of weight gains between feeding regimes.

The feed intake was significantly lower in intermittent feeding than ad libitum until 28-days of age but since then the discrepancy was lessened until end of the experiment. The reason for this result is same with previous explanation for weight gain that discussed above, which is after a period of feeding, birds were gradually adapted to cope with intermittent feeding. Ad lib feeding ensures high feed intake, but birds could use the crop as an intermediary storage organ for feed when adapted to intermittent feeding after a periods of food deprivation (Svihus et al., 2010). In addition, birds were able to retain the feed in crop and gizzard, as shown here and previously (Svihus et al., 2010) that corroborates the result of feed intake in current experiment. Accordingly, the intermittent feed intakes of commercial diet were significantly less than that of experimental diet. This indicated the much better performance of birds on experimental diet compare to commercial diet by change through intermittent feeding. The reason for this result might due to the high level of barley and oat (with hulls) present in

experimental diet because diluting the diet has been shown to increase the feed intake (Newcombe and Summers, 1985). The broiler chicken might consume more when the diet contain low nutrient concentration. It is likely that the increased voluntary food intake caused by a lower nutrient concentration. This is correlated to experimental diet which was lower in nutrient concentrate than commercial diet due to its high fibrous content.

This interaction between feeding system and diet structure may also explained by that the gizzard increased in volume may promote bird`s adaptability to intermittent feeding (Barash et al., 1993, Buyse et al., 1993). This result is a confirmation of several previous studies highlighting the stimulation effect of structural component on the size and holding capacity of gizzard (Preston et al., 2000, Hetland et al., 2002, Plavnik et al., 2002, Svihus et al., 2004, Ravindran et al., 2006, Biggs and Parsons, 2009b, Hetland et al., 2003) because the experimental diet contain significant amount of structural component. However, the contrary result had been reported by Svihus et al. (2010) and Sacranie et al. (2012) who found the increased gizzard volume has no effect on the ability of birds to adapt with intermittent feeding which demonstrated by lack of interaction between feeding regimes and diet structure.

Overpowering evidences showed that intermittent feeding improves feed efficiency compared with ad libitum (Buyse et al., 1996b). In consistent with this, feed/gain ratio was significantly improved by intermittent regime at the later period, although the significant difference has not shown in the former period in this experiment. The feed efficiency of birds might promoted by intermittent program through reduced activity during the darkness to save the energy consumption on maintenance which assigned to a concave pattern of growth rate (Buyse et al., 1996b, Sacranie et al., 2012). But since this concave pattern of growth rate had not shown in this experiment, so the result was more likely to the observation from Svihus et al. (2010). They found no appearance of enormous feed intake and lower feed efficiency in intermittent feeding. It also

supported by Mahmud et al. (2011) who found that the restrictive feeding, by use of intermittent light treatment program have beneficial effect on feed efficiency.

Contrary to expectations, this study did not find a significant difference between empty gizzard weights in either diet at day 29. However, from the experimental diet was much higher compare to the commercial diet shown at the end of experiment (day 34&35). Nevertheless, the group of birds from 29 days of age were fed intermittently whereas birds near the end of the study were fed ad lib, so the feeding regime could be a potential factor for this result. In accordance with previous research, litter material could be an alternative structural component (Svihus, 2011), and birds have been shown to consume considerable quantity of litter material (Santos et al., 2008). Similar gizzard weight at 29 days of age also might be due to the wood shaving as a litter material provided in the pens. When the diet lacks the structural components, birds might peck wood shavings to stimulate the gizzard as shown previously (Hetland et al., 2004, Hetland et al., 2005). This is especially true for intermittent feeding, when the access was restricted on diet but full on litter for bird (Sacranie et al., 2012). In addition, an individual bird has shown particularly high relative empty gizzard weight from commercial diet at day 29.

It's well established that the structural component in diet resulted in stimulation of gizzard development. The larger gizzard weight from wheat barley-oat-wheat based diet at finishing period of experiment was probably caused by increased grinding activity of the gizzard when whole grains (without de-hulling) were present (Hetland and Svihus, 2001). The gizzard size increased rapidly at 7 days of age and also the volume of gizzard increased substantially when structural component was added into the diet for broiler chicks, as observed by Biggs and Parsons (2009a) and Svihus (2011). More research showed that the hulls from whole oat stimulate the gizzard development

to increase gizzard volume. It thus prolong the retention time and further increase empty gizzard weight (Svihus, 2011).

Wood shaving as a litter have high moisture absorption thus possible to be an indication of fecal viscosity in the current experiment. The barley as a feedstuff could result in increased intestinal viscosity due to its high content of non-starch polysaccharides. The common solution regarding this issue was enzyme supplementation to reduce the intestinal viscosity and hence the dryer excreta and litter. The result of litter quality from the diet containing high proportion of barley, oat and wheat was similar with the wheat maize based diet at day 22 in this experiment which indicates the supplemented enzymes resulted in decreased fecal viscosity based on former findings (Wang et al., 1992). The assumption could be the worse litter quality due to more excreta from ad fed birds which had more activity and higher feed intake than intermittently fed birds. However, the result observed inversely, the litter quality were better under ad lib than under intermittent which is hard to explain. On the other aspect, the low litter quality has shown the effect on performance of broiler chickens (Ritz et al., 2009). For example, the increases of diseases incidence (such as breast blisters, skin burns, ammonia emissions etc.) could be caused by too wet litter.

Furthermore, at the end of experiment, although the ileal viscosity was higher from barley-oat-wheat based diet (experimental diet) but the number were still not enormous, indicating that the supplemented enzymes successfully functioned to control the ileal viscosity. The high proportion of barley and wheat in experimental diet resulted in higher ileal viscosity compared to commercial diet in this experiment. It is consistent with the former result shown that the high viscosity of small intestine from birds were due to ß-Glucans in the oat and barley (Wang et al., 1992, Fadel et al., 1987, White et al., 1983). Chicks fed barley diet had higher intestinal viscosities than fed corn diet (Wang et al., 1992), which is also supporting the result of this experiment that ileal

viscosities were higher in birds fed barley-oat-wheat based diet than maize-wheat based diet. Overwhelming outcomes had been found that the supplementation of enzymes to the barley-oat-wheat based diet resulted in a reduced viscosity of small intestinal content of broiler in general (Gracia et al., 2003, García et al., 2008). ß-glucanase supplementation in barley diet reduced the viscosity of jejunal contents in broiler chickens (Sieo et al., 2005). In addition, it has been well established that xylans from wheat diet are also another factor to contribute viscosity in digestive tract of broiler chickens and xylanase supplementation could be a solution for this issue (Steenfeldt et al., 1998b). The abundant research had been done regarding xylanase addition to diets contain wheat and resulted in decreased ileal viscosity of broiler chicken (Rexen, 1981, Chesson, 1987, Pettersson and Åman, 1989, Campbell and Bedford, 1992, Steenfeldt et al., 1998b, Steenfeldt et al., 1998a). This is also well correlated the result that found the ileal viscosity was not high in current experiment. In conclusion, the barley-oat wheat based diet had not given a high ileal viscosity to the broiler chickens in this study might due to the addition of enzymes.

Prolonged retention time in the crop under intermittent programme may decrease the crop pH (Bayer et al., 1978). The decreased pH due to the increased bacterial activity in the crop (Hagen et al., 2003) might give a sufficient time to facilitate the enzyme efficiency thus increase nutrient digestibility (Boling-Frankenbach et al., 2001). However, the lack of interaction between intermittent feeding and exogenous enzyme has found from Tanha (2012) and also from Svihus et al. (2013). Furthermore, the extended retention time in anterior digestive tract may also due to the structural component in the diet (Hetland et al., 2003). The increased efficiency of exogenous phytase from intermittently fed birds observed from Svihus et al. (2010). Based on above, there is a possibility of the improvement of enzyme efficiency completed by combination of structural component and intermittent feeding, which is in consistent

with result of current study. However, there needs to be more research conducted on this field.

5. Conclusion

The results from the current research indicated that birds fed intermittently with the diet containing structural component exhibited improved performance and adaptability to intermittent feeding due to advanced feed-storing capacity. The function of gizzard that stimulated by hulls from whole barley and oat, which also appears to have had beneficial effects on feed utilization. The enzymes supplementation showed successful effect on ileal viscosity of birds fed by barley-oat-wheat based diet which is also indicated by litter quality as a bedding in the pens. More research is needed to establish whether structural component in the diet improves the adaptability of bird to intermittent feeding.

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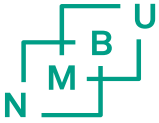

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