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The Influence of Regrinding Coarse Particles from Milled Corn on Mash Properties, Growth Performance and Blood Chemistry in Broilers Chickens

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ABSTRACT

Particle size distribution rather than the average particle size is a more accurate method of specifying feed for animal growth and feed processing. In the feed industry, hammer mill is extensively more used since it is easier to operate and maintain although it produces a broad range of particle sizes and excess of unwanted fines. Thus, an alternative approach to fine milling by hammer mill is needed to avoid the production of unwanted dust-like particles when poultry diet is offered in mash form. This study was conducted to evaluate the effect of grinding coarse particles, after segregation by sieving on: milled corn particle size properties, growth performance, and blood chemistry in broilers during the growing stage. Fifty six Hubbard broilers (3 weeks of age) were randomly allocated into two-dietary treatment groups with seven replicates per treatment and four broilers per replicate. The grower diets were isonitrogenous and isocaloric, but they differed in the level of corn particle size. Corn grains were ground and then sieved to segregate the coarse fraction from the fine fraction. Coarse fraction was then milled again and then mixed with the fine fraction. The two-processing treatments were coded for the influence of corn particle size on diet particle size: Ground Diet (GD) and Reground Diet (RD). The effect of re-milling of the segregated coarse particles and recombining with the fine fraction reduced both the geometric mean diameter (from 1.75 to 0.85mm) and the geometric standard deviation (from 2.14 to 2.01). The effect of re-milling also increased both the particle surface area (from 23.12 to 52.14cm^2/gram) and the number of particles per unit mass (from 3350.55 to 16942.60 particles/gram). When compared with GD, RD did not influence the cumulative feed intake, the average daily gain, or the feed conversion ratio. The results showed that the total cholesterol, High Density Lipoprotein (HDL), Low Density Lipoprotein (LDL), and glucose concentrations were not ($p>0.05$) affected by the dietary particle size. However, both triglyceride and the Very Low Density Lipoprotein (VLDL) concentrations increased ($p<0.05$) in birds fed RD. It can be concluded from this study that re-milling coarse fraction of corn particle size did not affect broiler growth performance but did not produce excess of fines when diet was offered in mash form.

Keywords: Corn, Particle size, milling, growth performance, blood chemistry, broiler.

INTRODUCTION

Corn grains are considered the main diet component that delivers energy to most of farm animals, especially monogastric animals. Based on grain structure, the presence of corneous endosperm and the presence of protein matrix that surround starch granules with grain endosperm make the grain resistant to water penetration for digestion, and thus reduce nutrient release for animal utilization (Rooney and Pflugfelder, 1986). To maximize energy delivery to animals, grains should be further processed, such as milling, to enhance enzymatic digestion by animals and to facilitate complete diet manufacturing.

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From a feed processing point of view, it has been reported that the distribution of particle size, rather than the average particle size, is a more accurate method of specifying feed for animal growth and for feed processing (Al-Rabadi, 2011; Wolf *et al.*, 2010). Consequently, this may provide a superior nutrient synchrony between amino acids and glucose by harmonizing digestion rates of starch and protein (Al-Rabadi *et al*., 2009; Weurding *et al.*, 2003). In the feed industry, hammer mill is more extensively used since it is easier to operate (Amerah *et al.*, 2007) even though it was reported to produce a broad range of particle sizes (Douglas *et al.*, 1990). Although fine milling of grains increases digestibility, it was reported to cause processing problems, such as reduced feed mill production output (Al-Rabadi, 2013a,b), increased electricity power consumption (Wondra *et al.*, 1995), and handling problem represented in bridging formation (Al-Rabadi, 2011). A few number of studies adapted a methodology to achieve the benefit of removing large particles of barley (Al-Omari *et al.*, 2014, Al-Rabadi *et al.*, 2017) and sorghum grains (Al-Rabadi *et al.*, 2017) after hammer milling without producing too much fines by separating large particles and then regrinding them to reduce their size. These studies positively enhanced overall animal growth performance and reduced particle size without generating excess fines. However, no study has been conducted to study the influence of this milling approach on the corn particle size distribution, blood chemistry, and the growth performance of broilers fed by such treated diets.

MATERIALS AND METHOD

The protocol for this experiment was reviewed and approved by the Department of Animal Production, Faculty of Agriculture, Mutah University, Jordan. A qualified veterinary monitored the birds' health and welfare.

Corn grinding and particle size analysis

Approximately, 200kg of corn grains were ground using hammer mill (Modle number M. K. 11 R180, Kteingesellschaft, Germany) fitted with 4mm-screen size. Half of the quantity of the milled corn was sieved using a rectangular 2mm sieve (500 x 600 mm) to segregate the coarse fraction from the fine fraction. The Coarse fraction was then milled using the same hammer mill utilized previously (fitted with 4mm screen size) and then mixed with the fine fraction. The two processing treatments were coded for the influence of the particle size on the diet particle size: Ground Diet (GD) and Reground Diet (RD). To estimate the effect of the milling treatment on particle size properties, a 100-gram sample from each milling treatment was sieved according to the procedure described by ASAE (2003).

Measured particles size properties (average particle size (d_{gw}), geometric standard deviation (S_{gw}), surface area /gram (A_{st}), and number of particles per gram (N_t)) were calculated according to the assumption that ground corn particles are spherical and have 1.4 g/cm^3 average particle density, using the following equations as previously described by ASAE (2003):

$$d_{gw}=\log^{-1}[\sum(W_i \log d_i)/(\sum W_i)]$$

$$S_{gw}= 1/2\ d_{gw}[(\log^{-1}S_{\log} - (\log^{-1}S_{\log})^{-1}]$$

$$A_{st}= (((\ \beta s Wt/\beta v\ P) \exp (4.5\sigma \ln^2 - \ln d_{gw}))/W_t)$$

$$N_t = ((Wt/\ \beta v\ P) \exp (4.5\sigma \ln^2 - 3\ln d_{gw})/W_t))$$

Where:

Wi is the mass on ith sieve, g.

W_t is the charge weight.

d_i is the nominal sieve aperture size of the ith sieve, mm.

d_{gw} is the geometric mean diameter (mm) particles by mass.

$S_{\log}$ is the geometric standard deviation of log-normal distribution by mass in ten-based logarithm (dimensionless).

S_{gw} is the geometric standard deviation of particle diameter (mm) by mass.

A_{st} the estimated total surface area per gram.

βs is the shape factor for calculating surface area of particles. Bs = π .

βv is the shape factor for calculating volume of particles. βv = π/6.

P is the particle density of the material, g/cm$^{3.}$

σ_{ln} is the log-normal geometric standard deviation of parent population by mass in natural logarithm.

N_t *is* the number of particles per gram.

Birds and diet formulation

Fifty six Hubbard broilers (3 weeks old) were raised during the experimental period for three weeks. The broilers were divided into two groups and were offered corn–soya bean based diet which differed in the levels of corn particle size (GD and RD). Both diets were formulated to be isocaloric and isonitrogenous and offered *ad libitum*. The composition of diet ingredients and chemical compositions are shown in Table 1. The broilers were exposed to continuous light, raised in floor cages, and equipped with trough drinkers and feeders in an open-housing system.

Data measurement

The broiler body weight and cumulative feed intake were recorded at weekly and daily intervals, respectively, throughout the experiment period (from week 4 to week 6) to study the growth response. The feed conversion ratio (mass of feed consumed/mass of body weight gain) was calculated based on the data of cumulative feed intake and body weight. At the end of week 6, a blood sample was taken from each bird directly from jugular vein into plain vacutainer tubes (without anticoagulant). Blood samples were centrifuged for 10min at 4226rpm. Then, serum was separated and stored at −20°C until further analysis. Serum lipoproteins (total cholesterol, Light Density Lipoprotein (LDL), High Density Lipoprotein (HDL), Very Light Density Lipoprotein (VLDL), and triglyceride (TG)) were assayed according to the manufacturer's recommendations (Linear Chemicals S.L., Montgat, Barcelona, Spain) using direct enzymatic colorimetric method. The experimental procedures were approved by the Department of Animal Production at Mutah University.

Data analysis

The student *t*-test at a significant level of 5% was used to compare estimated means between the two treatments (each treatment had seven replications, assigned randomly, of four broilers, each in a separate pen). For parameters measured at different weeks, repeated measurement analysis (PROC GLM) was carried out. All measured data were presented as means (± standard error (SE)). Statistical analysis was performed using Statistic Analysis Software (version 9.0, SAS Institute, Cary, NC).

RESULTS AND DISCUSSION

The effect of the milling process on corn grains particle properties (d_{gw}, S_{gw}, particle surface area and number particles per unit mass), after milling using 4mm screen size and after re-milling the coarse fraction, are shown in Table 2. The effect of re-milling on the segregated coarse particles and recombining with the fine fraction reduced both the geometric mean diameter (from 1.75 to 0.85mm) and the geometric standard deviation (from 2.14 to 2.01). It also increased both the particle surface area (from 23.12 to 52.14cm^2/gram) and the number of particles per unit mass (from 3350.55 to 16942.60particles/gram). In this study, re-milling the coarse fraction increased the level of particles that were <0.5mm by 16.27% (from 7.84% to 24.11%). Particles less than 0.5mm are considered as the critical size that affects the handling processing in feed mills (Al-Rabadi, 2011), and which may cause health problems in monogastric animals (Wondra *et al.*, 1995). From a processing perspective, re-milling the coarse fraction may enhance binding properties of particles during the pelleting process through increasing the surface area and the number of particles per unit mass (Muramatsu *et al.*, 2015). Higher surface area of smaller particle sizes enhances hydrothermal transference to the mash inside the conditioner (Lowe and Judging, 2005). The pellet durability index has been reported to increase from 78.8% to 86.4% when particle size reduced from 1mm to 0.4mm

(Wondra *et al.*, 2015). The pelleting process must be conducted to examine the influence of current re-milling approach on pellet durability.

The re-milling process of separated coarse fraction did not influence (p>0.05) the cumulative feed intake, the average daily gain, or the feed conversion ratio (Table 3). Different levels of corn particle size, when milled above the recommended level of particle size, have been reported not to influence broiler growth performance during growing stage when diet offered in mash form (Al-Rabadi, 2013b). In this study, re-milling coarse fraction of corn maintained some particles size within the upper recommended particle size limit in broiler diets, i.e. 0.9mm (Amerah *et al.*, 2007). The inclusion of corn coarse fraction (25 and 50%) in broiler diet has been reported to produce similar growth performance at different growth stages (Xu *et al.*, 2015). However, it seems that the effect of particle size on broiler performance seems to be grain- and age- dependent (Abdollahi *et al.*, 2018). Re-milling course fraction of barley grains has been reported to reduce the feed intake and to improve feed conversion in broilers during growing stage (Al-Omari *et al.*, 2014). In the relevant literature, the effect of optimum particle size on poultry growth performance is confusing due to many factors that are related to ingredients compositions of diet, diet physical form, type of grain, diet form, and particle size distribution (Amerah *et al.*, 2007; Abdollahi *et al.*, 2018). Different mechanisms have been suggested to reduce the influence of feeding coarse particles on broiler diets. Existence of coarse corn particles in broiler diet has been reported to improve gizzard function and greater digesta retention time (Xu *et al.*, 2015). A more developed gizzard has been reported to be correlated with higher grinding activity (Amerah *et al.*, 2007). Amerah *et al.* (2008) reported that most of coarse grains particles that go through the duodenum are less than 0.1mm, suggesting that no added nutritional value can be obtained from fine milling. Parsons *et al.* (2006) reported that the presence of coarse particles in corn-based diet can enhance protein and lysine retention in broiler. Furthermore, energy requirements by birds consuming coarse particles have been reported to be reduced as the number of pecks per specific amount of feed is reduced (Jensen *et al.*, 1962; Amerah *et al.*, 2007). In this experiment, high feed conversion (feed: gain) is noticed during week 5 (compared to week 6), and this may have been attributed to an unexpected heat wave which affected the performance of birds during week 5. Heat stress has been reported to reduce feed intake and negatively affect feed efficiency in broiler (Oskan *et al.*, 2003).

The outcomes of blood chemistry parameters are shown in Table 4. The results showed that total cholesterol, HDL, LDL, and glucose concentrations were not affected (p>0.05) by dietary particle size. However, both triglyceride and VLDL concentrations increased (p <0.05) in birds fed re-milled coarse corn grain diet. Very low density lipoprotein has been reported to be the main carriers of triglyceride (Aliakbarpour *et al.*, 2013) and have been reported to be positively correlated with triglyceride (Musa *et al.*, 2006; Hermier *et al.*, 1989) and high rates of adipose deposition (Whitehead, 1984). Rezaeipour and Gazani (2014) reported a similar influence of diet form (pellet vs mash) on blood chemistry; pelleted diet significantly increased both triglyceride and VLDL concentrations, while other blood chemistry components remained similar. It seems that in their experiment, the secondary grinding effect (when the mash feed passed through the pellet die) may resulted in further reduction in average particle size and particle size distribution (Wolf *et al.*, 2010) as is the case in our study. VLDL has been reported to be positively correlated with fat deposition (Whitehead, 1984; Navidshad *et al.*, 2010). The higher concentration of VLDL in broilers fed re-milled corn grains diet may be attributed to the rate of starch digestion. Higher digestion rate of starch in reduced grain particle size (Al-Rabadi *et al.*, 2009) may result in more glucose synthesized into fat in the absence of nutrient synchrony, i.e. absence of protein (Weurding *et al.*, 2003; van den Borne *et al.*, 2007).

CONCLUSION

It can be concluded from this study that re-milling coarse fraction of corn particle size and then regrinding it did not affect broiler growth performance but did not produce excess of fines which is known to cause logistical problems in feed industry.

ABBREVIATIONS

GD: Ground Diet

RD: Reground Diet

W_i is mass on ith sieve, g

W_t is charge weight

d_i is nominal sieve aperture size of the ith sieve, mm

d_{gw} is geometric mean diameter (mm) particles by mass.

S_{log} is geometric standard deviation of log-normal distribution by mass in ten-based logarithm (dimensionless).

S_{gw} is geometric standard deviation of particle diameter (mm) by mass.

A_{st} estimated total surface area per gram

βs is shape factor for calculating surface area of particles. Bs = π,

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P is particle density of the material, g/cm^3

σ_{ln} is log-normal geometric standard deviation of parent population by mass in natural logarithm

N_t is number of particles per gram

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Table 1: Ingredient (%) and calculated chemical composition (%) of the experimental diet

Ingredients	(%)	Chemical composition [e]	(%)
Corn	58.49	ME(kcal/kg)	3200
Soybean meal	27.07	Crude protein	20.00
Degamed soybean oil	5.30	Crude fibre	3.41
Broncon concentrate[a]	4.88	Methionine	0.90
Salt (nacl)	0.31	Lysine	1.59
DCP[b]	1.0	Cysteine	0.21
Limestone	1.0	Ca	0.90
Vit+ min Premix[c]	0.2	Non phytate phosphorus	0.43
Mold inhibitor l[d]	0.1	Na	0.19
Threonine	0.5	Cl	0.22
Methionine	0.55		
Lysine	0.6		

[a]Brocon Concentrate® (Wafa, BV., Alblasserdam, Holland). [b]Dicalcium Phosphate
[c]Vitamin and mineral premix provided per kilogram of premix: Vitamin A, 700,000 IU; vitamin D3, 150,000 IU;vitamin E, 75mg; vitamin B1, 100 mg; vitamin K, 175 mg; vitamin B5, 600 mg; manganese oxide,4000 mg, ferrous sulphate, 9000 mg, zinc oxide, 6000 mg, magnisum oxide, 2500 mg, potassium iodide, 70 mg, sodium selenite, 125 mg, copper sulphate, 100 mg, cobalt sulphate, 50 mg, dicalcium phosphate, 7000 mg, sodium chloride, 10000 mg. [d] Mold inhibitor for animal feed (Kemin Industries, U.S.A) [e]Calculated based on analyzed values of feed ingredients (feed composition tables) from poultry NRC (1994).

Table 2: Means of particles size distribution and particle size parameters of both experimental diets (values are presented as means ±SE)

	Corn particle size	
	Control	Reground corn fraction
Sieve size (mm)	Fraction yield (%)	Fraction yield (%)
6	0.00±0.00	0.00±0.00
4	8.35[c]±0.86	1.11±0.41
2.8	24.4±1.67	3.35±0.21
2	22.16±0.5	6.55±0.02
1	26.14±0.27	30.97±0.49
0.5	11.03±0.6	33.87±1.18
0.25	5.68±1.03	21.73±0.63
0.125	2.166±0.06	2.38±0.65
0.045	0.00±0.00	0.00±0.00
Particle size parameters		
d_{gw}^{b} (mm)	1.78±0.04	0.85±0.01

	Corn particle size	
	Control	Reground corn fraction
Sieve size (mm)	Fraction yield (%)	Fraction yield (%)
S_{gw}[c]	2.14±0.04	2.02±0.01
surface area (cm^2/gram)	23.12±1.18	52.14±1.29
Number of particles / gram	3350.55±698.28	16942.6±819.18

[a] Average particle size. [b] Log normal geometric standard deviation (S_{gw}) [c] Each value was measured in duplicate analysis

Table 3: Effect of corn particle size on cumulative feed intake (gram), average daily gain (gram), feed conversion ratio, and final body weight (gram)during the experiment period (4-6 weeks old age) values are presented as means ±SD

	Diet		
	GD	RD	P value
Cumulative feed intake			
Week 4	955.66±21.09	989.35±17.25	0.26
Week 5	1016.80±17.23	1039.4±20.75	0.41
Week 6	1277.90±17.06	1275.6±22.86	0.64
Overall	3250.30±31.20	3304.3±31.54	0.82
Average daily gain			
Week 4	69.31±3.91	75.07±2.88	0.24
Week 5	64.05±3.15	59.80±3.9	0.42
Week 6	87.12±4.62	83.54±5.87	0.94
Overall	73.49±2.88	72.80±3.72	0.88
FCR			
Week 4	2.00±0.01	1.88±0.08	0.44
Week 5	2.30±0.14	2.77±0.20	0.33
Week 6	2.14±0.15	2.32±0.20	0.66
Overall	2.12±0.10	2.26±0.13	0.47
Initial body weight	841.29±15.63	840.71±6.08	0.97
Final body weight	2385.2±60.24	2371.5±81.48	0.90

Table 4: Effect of dietary treatment on blood chemistry parameters (mg/dl) for broilers at 42 day-old. Values are presented as means ±SD

	Diet		
Blood chemistry	GD	RD	P value
Total cholesterol	115.74±11.06	116.31±4.18	0.96
HDL	40.72±2.06	40.20±3.62	0.90
VLDL	14.93±1.56	21.86±3.09	0.005
LDL	60.07±10.45	54.24±4.02	0.66
Triglyceride	64.68±7.79	109.33±3.40	0.005
Glucose	241.14±4.89	246.07±5.99	0.56

أثر إزالة الحبيبات الخشنة بعد طحن حبوب الذرة على خواص الجريش، ونمو وكيمياء الدم في دجاج اللحم

غيد جميل الربضي*

ملخص

يعتبر مؤشر التباين في حجم الحبيبات العلفية اكثر اهمية من معدل حجم الحبيبات العلفية في تحديد جودة تصنيع الاعلاف واثرها على نمو الحيوان. تعتبر جاروشة المطرقة في صناعة الاعلاف اكثر استخداما واسهل تشغيلا من مثيلاتها من الجواريش على الرغم من انتاجها لحبيبات علفية متباينة في الحجم بالاضافة لوجود حبيبات علفية ناعمة غير مرغوبة. لهذا من الافضل ان يكون هناك طريقة معدلة لجرش العلف بواسطة استخدام جاروشة المطرقة دون انتاج حبيبات علفية ناعمة غير مرغوبة تؤثر سلبا على الدواجن عند تغذيتها باستخدام علف بشكل جريش (غير محبب). يهدف هذا البحث الى دراسة اثر عملية طحن حبيبات الذرة الخشنة بعد عزلها بواسطة التنخيل على خواص جريش الذرة، كيمياء الدم ونمو الدجاج اللحم. تم استخدام دجاج لحم (سلالة هابرد) على عمر 21 يوماً وتم توزيع الدواجن بشكل عشوائي في مجموعتين بواقع سبع مكرارات واربعة طيور لكل مكرر. كانت خلطتا الدواجن المستخدمة متساوية من حيث تركيز البروتين والطاقة ولكن تختلف في حجم حبيبات الذرة. تم جرش حبوب الذرة ومن ثم عزل الحبيبات الخشنة عن الحبيبات الناعمة بواسطة التنخيل. ومن ثم تم جرش الحبيبات الخشنة مرة اخرى وخلطها مع الجزء الناعم. تم تسمية المعاملتين في هذا البحث اعتمادا على حجم حبيبات الذرة: الاولى خلطة جريش الذرة العادي (ا) والثانية خلطة جريش الذرة بعد اعادة طحن الجزء الخشن منها ودمجها مع الجزء الناعم (ب). بينت الدراسة ان بعد اعادة طحن الجزء الخشن من الذرة ودمجه مع الجزء الناعم (خلطة ب) قد قلص معدل حجم الحبيبات من 1.75 ملم الى 0.85 ملم ومقدار التباين من 2.14 الى 2.01. بينما زادت كل من مساحة سطح الحبيبات العلفية لوحدة الوزن من 23.12 الى 52.14 سم^2/غرام وعدد الحبيبات العلفية لوحدة الوزن من 3350 الى 16942 حبيبة /غرام. عند مقارنة اثر حجم حبيبات الذرة في كل من المعاملة ا وب، لم يكن هناك اثر معنوي على كمية العلف المتناول او معدل الزيادة الوزنية او معدل التحويل الغذائي. كما بينت الدراسة انه لم يكن هناك اية فروقات معنوية في ليبوبروتينات الدم باستثناء لبوبرتينات الدم ذات الكثافة القليلة جدا والترايجليسرايد، حيث كانت اكثر في خلطة ب. يمكن الاستنتاج من هذه التجربة ان خلطة ب لم تؤثر على اداء الدواجن ولكن خفضت بشكل كبير كمية الحبيبات الناعمة.

الكلمات الدالة: الذرة، حجم الحبيبات، كيمياء الدم، دجاج اللحم.

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