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Effect of Processing on Feed Quality and Bio-Economic Performances of Broiler Chickens in Benin

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ABSTRACT

The purpose of this study was to compare the quality of feeds and the performances of broilers fed with diets processed by six processing methods. Unsexed 450 day-old chickens (Red Bro) were fed up to 49 days of age with a pelleted and five mashed feeds. The feeds were processed in factories using hammer grinders or cereal mill and different types of mixer (small *versus* big, vertical *versus* oblique, manual). Dry sieving and chemical analyses of feeds were done using samples from three bathes (top, middle and bottom) defined during the collection of the feed from the mixers. The physical and chemical uniformity of the feeds did not vary with the batches (P>0.05). The contents of ash, crude protein, gross and metabolizable energy were similar between feeds. However, crude fibre content was significantly higher (P = 0.03) in feeds processed in a company supplying mainly feeds for rabbits. About 91% of particles in pelleted feed had more than 4.75 mm, whereas 45 to 54% of particles in mashed feeds had less than 1 mm. The proportion of particles having 2.36–4.75 mm was significantly lower in the feed from cereal mill, while that of particles having 1–2.36 mm increased significantly with the capacity of the mixer. However, the geometric mean diameter (GMD), were similar between mashed feeds (1.12 – 1.21 mm) and significantly higher in pelleted feed (6.01 mm). In spite of the variations in particles size, the daily feed intake, the daily weight gain (WG), the feed conversion ratio and the economic feed efficiency were similar between diets indicating an adaptation of chickens to the particles size of the feeds to fulfill their requirements. However, at three week of age (d21), broilers fed with diets from the cereal mill and bigger mixers had significantly higher final body weight (FBW). At d49, the broilers fed grower pelleted feeds (HP) diet had a significantly higher FBW compared to those fed mashed diets (1812 g vs 1534 to 1607 g). Unfortunately, up to d21 the feeding cost was significantly higher in HP than mashed diets (0.794 vs 0.610 to 0.659 €/kg WG). On the whole, the pelleted feed was cost effective due to a high pelleting cost. The quality of pelleted feeds processed in Benin was more profitable for grower than starter chickens. The bio-economic performances were similar between mashed feeds; but the bigger mixers appeared more suitable than the smaller for the processing of starter feeds of broilers.

Key words: Broiler; mashed feed; mixer; pelleted feed; tropical region

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INTRODUCTION

The quality of feed is the most important factor that affects poultry performance. It is therefore necessary to use adequate ingredients and processing method to supply suitable balanced diet that would contribute to an optimum broilers' performance. According to Amerah *et al.* (2007), although it has been postulated that finer grinding increases substrate availability for enzymatic digestion, there is evidence that coarser grinding to a more uniform particles size improves the performance of birds maintained on mashed diets. Svihus and Hetland (2001) reported a decrease of the digestibility of starch in pelleted diet compared to mash feeding. However, Svihus *et al.* (2004) stated that, although there were large differences in feed intake of broilers between diets fed as mash and as pellets, no difference in starch digestibility was detected. They formulated two hypotheses to explain that result: (i) the much lower concentration of starch (341 g/kg) in the wheat-based diets, (ii) the processing and the effect of feed intake of broilers influence the starch digestibility of pelleted diets in different directions, and thus no overall effect is seen.

The grinding method, the type of grain and its cultivar can affect the particle sizes of the feed (Amerah *et al*., 2007), while the diet uniformity affects broilers chick performance up to 42 days-old (McCoy *et al*., 1994). After the grinding the processing factors that could cause the non-uniformity of balanced feed could be the insufficient mixing time, the filling of the mixer beyond its capacity, the poor mixer design, the improper mixer adjustment (Wilcox and Balding, 1986), the incompatibility of physical characteristics of the ingredients being mixed and the residual ingredient buildup in the mixer (Wicker and Pool, 1991). Pelleted diet is reported to improve diet uniformity (McCoy *et al*., 1994) and broilers' performance (Plattner and Rokey, 2006; Greenwood *et al*., 2005; Jensen, 2000; Nir *et al*., 1995). Furthermore, the effect of grinding was reported to be additive to that of pelleting on the development of the gastrointestinal tract and on the growth of broilers (Nir *et al*., 1995).

On the other hand, the cost of feed depends on the cost of ingredients (most part), the processing cost and the delivery cost. Fairfield (2003) reported that although the benefits of pelleted feed on performance are significant, pelleting must be cost-effective. Thus, for commercial feed manufacturers, the additional margin for pelleted feed must exceed the operation's costs, while for integrated manufacturers improved feed conversion must pay for the pelleting cost Fairfield (2003).

In Benin, hammer grinding mills were commonly used in commercial feed factories; but the mixers are different in form, direction and capacity. Some feeds were also ground in cereal grinders/mills and mixed manually, while a very few part of poultry feeds were pelleted (the use of pelleted feeds being seldom in developing countries). The quality of the feeds could therefore depend on the processing method adopted. The objective of this paper was to evaluate the effect of six commercial processing technologies/methods on the physical and chemical qualities of balanced feeds, the performance of broiler chickens and the economics of their feeding.

MATERIALS AND METHODS

Processing methods and diets

Six different technologies/methods were used to process each time 100 kg of starter and 300 kg of grower balanced feeds. In the first five methods, ingredients were ground by hammer mills, while in the sixth they were ground in a cereal grinder/mill (CG) often used for human foods. Then, the mashed ingredients were mixed during 3 to 5 minutes in vertical (V) or oblique (O) mixers of different capacities (small, 1; big, 2) or manually (by hands, M) (Table 1).

The pelleting occurred after the mixing without addition of binder. The same die was used in the single factory available to pellet all categories of feeds. Hence, the diameter of the starter and grower pelleted feeds (HP) was the same as defined by the hole in the die. However, the order of ingredients in the grinder and the time of mixing adopted in the companies could affect the feeds. Diets were formulated to meet the requirements of National Research Council (1994) by using the chemical compositions of feedstuffs reported by Institut National de la Recherche Agronomique (1989). The solver of Microsoft Excel (Thomson and Nolan, 2001) was used in that purpose. The characteristics of diets are shown in Table 2.

Animals and housing

Total 450 broilers chickens (Red Bro) were used in the experiment. They were unsexed day-old chickens purchased from a hatchery in Benin. They were divided in 18 replications of 25 chickens each as soon as they arrived. The design of experiment is summarized in Table 3. Chickens were kept on deep litter.

During the first 3 weeks, chickens were in a starter room provided with heating and lighting. The heating was stopped at the end of week 2. In the room, the temperatures measured during the starter phase were between 29 and 36°C, while the relative humidity varied from 60 to 79%.

At 22 days of age (d 22), chickens were moved from the starter room to pens under natural light for the grower phase. During 4 weeks, chickens were kept in 18 pens until d 49. In pens, the temperature was between 26 and 34°C, while the relative humidity varied from 66 to 87%. The densities of chickens on litter were 15 and 7 birds/m^2 at starter and grower phases respectively. The chickens were weighted weekly.

Feeding

From the first day (d 1), the same diet was delivered to chickens in 3 random replications. Starter and grower diets were used to feed broilers, respectively, from d 1 to 21 and d 22 to 49. At the beginning of grower phase, the starter diet was progressively substituted by the grower diet at the respective daily rate of 33, 67 and 100%. Birds had *ad libitum* access to feed and water. Daily, the delivered feed and the residues were recorded per pen.

Sampling of feeds and laboratory analyses

At the end of processing, the feeds were removed from the mixer in three successive bags named batches A, B and C in equal quantity. Then a sample (500 g) was taken from each batch for laboratory analyses in order to evaluate the influence of the processing method and the batch (withdrawal order) on the composition of the feeds.

Physical analysis of the feeds was performed by dry sieving to compare the particles size, while chemical analyses were done for the contents of dry matter, total ash, crude fiber, crude protein, gross energy. Only the grower feeds were analyzed.

Table 1: Characteristics of the processing methods and prices of feeds

Methods	Grinder	Hammer	Hammer		Hammer		Cereals grinder
	Mixer	Pellet	Vertical[a]		Oblique[a]		Manual[b]
	Feeds	HP[c]	HV1[c]	HV2	HO1	HO2	CGM
Form of diets		Pelleted	mashed	mashed	mashed	mashed	mashed
Mixer capacity (ton)		2	2	3	0.5	1	-
Prices of feed	Starter	425	357	357	357	357	357
(€ / ton)[d]	Grower	419	351	351	351	351	351

[a] Vertical or Oblique are the direction of the mixer used after the grinding; [b] Mixing of diet was done manually after the grinding; [c]Diets ground and mixed in the same mill before the pelleting of HP feed; [d]Prices including ingredients and processing costs

Table 2: Ingredients, Costs and chemical composition of diets as formulated

Ingredients / Nutrients	Starter diet	Grower diet
Ingredients (% of diet)		
Maize	60	63
Soybean meal	27	25
Fish meal	7	6
Wheat bran	3	3
Oyster shell	1.75	1.65
Salt (NaCl)	0.30	0.20
Lysine	0.10	0.10
Methionine	0.30	0.30
Bi-calcium phosphate	0.30	0.50
Premix[1]	0.25	0.25
Cost of ingredients (€/ton diet)[2]	349	343
Chemical compositions (g/kg dry matter)		
Crude Protein	209	199
Crude fat	36.3	35.8
Crude fibre	35.7	34.7
Lysine	13.1	12.6
Methionine	6.3	6.1
Methionine + Cystine	8.1	7.8
Calcium	12.1	11.6
Total Phosphorus	6.6	6.6
Phosphorus available	3.2	3.3
ME (MJ/kg dry matter)[3]	12.1	12.2

[1]Premix contained per kg: Vitamins: A 4000000 UI; D3 800000 UI; E 2000 mg; K 800 mg; B1 600 mg; B2 2000 mg; niacin 3600 mg; B6 1200 mg; Minerals: Cu 8000 mg; Mn 64000 mg; Zn 40 000 mg; Fe 32000 mg; Se 160 mg. B12 4 mg; choline chloride 80000 mg; [2]Processing cost per ton was € 76.2 for pelleted diet and € 7.62 for the others 5 diets; [3] Metabolisable energy

Table 3: Experimental design

Processing methods or Feeds		HP	HV1	HV2	HO1	HO2	CGM
Chicks per diet		75	75	75	75	75	75
Replications per diet		3	3	3	3	3	3
Body weight at start (g/chick)	Means	37.6	37.3	37.3	37.7	37.5	36.9
	SEM	0.20					

All the analyses were done at the Faculty of Life Sciences, University of Copenhagen in Denmark. Dry Sieving technique was done with a Retsch AS 200 (Retsch GmbH & Co., Haan, Germany). A stack of three sieves of different fractions were used: T (4.75 mm), O (2.36 mm) and M (1 mm). The bottom bowl (B) was constituted by particles having less than 1 mm. 100 g of feed was sieved. For each fraction 3 mm of sieving at the amplitude of 1.5 mm/g was done. After each sieving the top sieve was removed and the remaining was shaken again with the same setting. B fractions were collected at the end.

Concerning chemical analyses, dry matter (DM) was determined by evaporation of water at 105ºC. Ash was obtained after burning the material at 525ºC. Nitrogen (N) content was estimated by the technique of Kjeldahl. Then, the percentage of crude protein (CP) was calculated as N x 6.25. Gross energy (GE) was measured in an adiabatic bomb calorimeter (IKA® calorimeter system, IKA® GmbH & Co. KG, Staufen, Germany). Crude fibre (CF) was determined using the Fibertec FiberCap 2021/2023 system (FOSS Tecator AB, SE-263 21 Hoganas Sweden).

Calculations

Using the data from laboratory analyses, the content of metabolisable energy in balanced feeds was estimated by the equation of Carré et al. (1989) in Larbier and Leclercq (1994) as following:

AMEn (kcal/kg DM) = 0.913GE – 18.5CP – 109.5CF

Where AMEn is the apparent metabolisable energy corrected to zero nitrogen retention; GE is the gross energy in kcal/kg; CP and CF are, respectively, the content of crude protein and crude fiber in percentage.

The geometric mean diameter (GMD) was determined as the estimation of the average particles size in the feed (Baker and Herrman, 2002; Amerah et al., 2007):

$GMD = \log^{-1}[\sum(W_i \log d_i)/\sum W_i]$, (Baker and Herrman, 2002)

Where:

$d_i = (d_u * d_o)^{0.5}$

d_i = diameter of i^{th} sieve in the stack

d_u = diameter opening through which particles will pass (sieve preceding i^{th})

d_o = diameter opening through which particles will not pass (i^{th} sieve).

Using the mass of particles or the content of chemical components, the coefficient of variation was expressed as following:

CV (%) = (Standard deviation/Mean)*100.

For each growth phase the economic feed efficiency (EFE) was calculated as following:

EFE (€ WG/€ feed) = Revenue WG/Feed cost

Where, WG is the body weight gain during the phase, and feed cost is the amount invested in feeding.

Statistical analyses

The proportions of particles calculated with data from dry sieving analysis were compared using the mixed procedure in SAS (2004). The effect of the processing method was analyzed considering the batch as random factor, while the diet was used as random factor to check the batch effect.

The general linear model (GLM procedure) was used to analyze data from the growth experiment. The effect of pen (replication) and the interaction between diet and pen were not significant (P>0.05). Hence, mixed and GLM procedures were performed according to the following models, respectively, to compare the effects of the processing methods (M) and of the batch (B):

$Y_i = \mu + M_i + \varepsilon_i$

$Y_i = \mu + B_i + \varepsilon_i$

Where, Y_i is the observation for dependent variables, μ is the general mean, M_i is the fixed effect of the processing method, B_i is the fixed effect of the batch and ε_i is the residual error.

Mean values from both statistic analyses are presented in tables with their pooled standard error of the mean (SEM). The significant effect of the processing method or of the batch was stated when P-value < 0.05.

Table 4: Proportion of particles size (PPS), geometric mean diameter (GMD) in grower feeds of broiler chickens

	Particles size (mm)	Sieves	Processing methods						SEM	P-value
			HP	HV1	HV2	HO1	HO2	CGM		
PPS (%)	> 4.75	T	90.6^{a}	1.59^{b}	0.98^{b}	0.62^{b}	0.47^{b}	0.23^{b}	0.53	< 0.0001
	2.36 - 4.75	O	7.86^{a}	16.9^{b}	16.7^{b}	13.3^{c}	13.1^{c}	4.54^{d}	0.94	< 0.0001
	1 - 2.36	M	0.44^{a}	27.4^{b}	32.6^{c}	32.9^{c}	38.7^{d}	49.7^{e}	1.50	< 0.0001
	< 1	B	1.11^{a}	54.0^{b}	49.7^{bc}	53.2^{b}	47.7^{bc}	45.5^{c}	2.11	< 0.0001
	GMD (mm)		6.01^{a}	1.18^{b}	1.21^{b}	1.14^{b}	1.18^{b}	1.12^{b}	0.04	< 0.0001

$^{a\ b}$ Means with unlike superscripts in the same row differ significantly (P < 0.05)

Table 5: Proportion of particles size (%) in grower feeds according to the bathes

Batches		Particles size (mm)			
		> 4.75	2.36 - 4.75	1 - 2.36	< 1
First	A	15.8	11.9	30.1	42.2
Second	B	15.2	12.1	30.2	42.5
Third	C	16.2	12.2	30.6	41.0
SEM		0.48	2.10	6.80	8.36
P-value		0.15	0.97	0.96	0.78

Table 6: Chemical composition of the grower feeds according to the methods and the batches

Processing methods	Component* (g/kg dry matter)				
	DM (%)	TA	CF	CP	MEm (kJ/kg DM)
HP	88.6	73.7	37.1^{a}	213	13695
HV1	87.2	77.7	35.8^{a}	218	13019
HV2	86.5	82.4	33.5^{b}	215	13344
HO1	86.2	71.3	32.4^{b}	216	13319
HO2	87.0	74.1	33.6^{b}	222	13486
CGM	86.5	79.6	31.2^{b}	218	13603
P-value	0.158	0.30	0.03	0.97	0.40
SEM	0.60	3.5	01.1	6.9	228

* DM is dry matter; TA is total ash; CF is crude fiber; CP is crude protein; GE is gross energy and ME is metabolizable energy; $^{a\ b}$ Means with unlike superscripts in the same column differ significantly (P < 0.05)

RESULTS

Quality of feeds

The Tables 4, 5 and 6 present the characteristics of the feeds. As expected, particles in pelleted feed were significantly larger than those in mashed feeds (Table 4). Thus, about 91% of particles had more than 4.75 mm in HP feed, while the mashed feeds had 76 to 86% of particles having less than 2.36 mm and 46 to 54% less than 1 mm. The direction of mixer (vertical or oblique) had significant effect on the proportion of particles having between 2.36 and 4.75 mm (Table 4). Furthermore, the proportion of particle having 1-2.36 mm increased with the increase of the mixer's capacity. The cereal mill reduced significantly the proportion of particles having 2.36-4.75 mm and produced similar amount of fine particles having less than 1 mm as the bigger mills. As a consequence of these variations of particles size, the geometric mean diameter (GMD) was significantly higher in pelleted feed than mashed feeds.

Regarding the proportion of particles according to the batch, no significant difference was found when the means of the particle fractions were compared with the processing method as random factor. Thus, there was a uniformity of particles in all batches (Table 5). However, the pattern of coefficient of variation (CV) in Figure 1 showed that between batches of feed, the physical variation depended to the particles fractions. Very large CV (more than 40%) was found in mashed feeds for particles having more than 4.75 mm, while in pelleted feed the largest CV (67%) occurred in particles having 1–2.36 mm. In mashed feeds, CV decreased with the size of the particles and increased in the bottom bowl, whereas it was the opposite in the pelleted feed.

The chemical composition showed a similarity between feeds in total ash, crude protein and both gross and metabolizable energy; but, the crude fiber was significantly high in HP and HV1 than other feeds (Table 6). Furthermore, no significant difference in chemical composition was found between the batches (P>0.05).

However, the pattern of CV in Figure 2 showed some small variations between batches of feed according to the chemical component. Thus, the largest CV was found in total ash (15.1%) followed, respectively by, crude fiber (10.6%), crude protein (7.6%), metabolisable energy (5.3%) and gross energy (4.8%). CV in dry matter were very low (0.13 – 2.5%).

Feed intake and feed efficiency

The Table 7 presents the daily feed intake (DFI) and the feed conversion ratio (FCR). No significant effect of diets was found on both variables (P>0.05). However, at the grower phase DFI was about 10% higher in pelleted feed than in mashed feeds.

The pattern of feed intake in Figure 3 showed more evident difference between dietary treatments at grower phase than at starter phase even though the differences were not statistically significant.

Growth and mortality

The processing method did not affect significantly (P>0.05) the daily body weight gain at both phases (Table 8). However, at d 49 the final body weight (FBW) of broilers fed pelleted feed (HP) was significantly higher than that of broilers fed mashed feeds, whereas FBW in HP feed was the lowest at starter phase.

The live weight of broilers fed HP became higher than that of other broilers from the sixth week of age (Figure 4). At d 49 the lowest FBW (1534 g in HO2) represented about 86% of the highest FBW (1812 g in HP). Overall mortality rates of broilers up to 7 weeks of age varied from 3.5 to 4.1% and were similar (P>0.05) between diets.

Economics of feeding

The feed price depended on the processing method used. The pelleting cost (€ 76.2/ton) was 10 times more expensive than the processing cost of mashed feeds (€ 7.62/ton). Hence, at starter phase the feeding cost (FC)

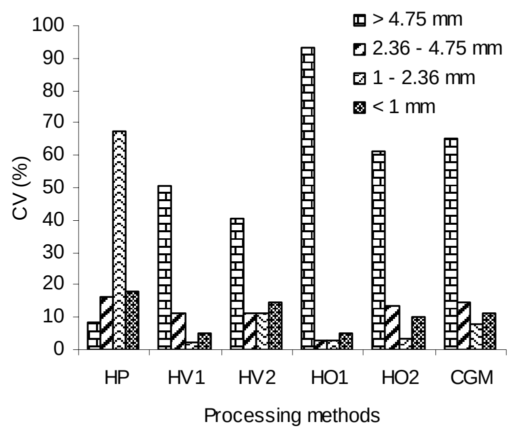

Fig. 1: Coefficient of variation (CV) of particles in broiler chickens' feeds.

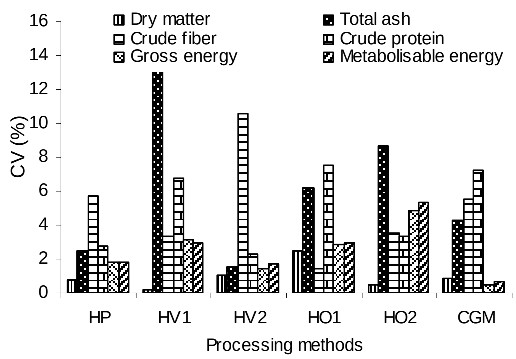

Fig. 2: Coefficient of variation (CV) of chemical components in broiler chickens' feeds.

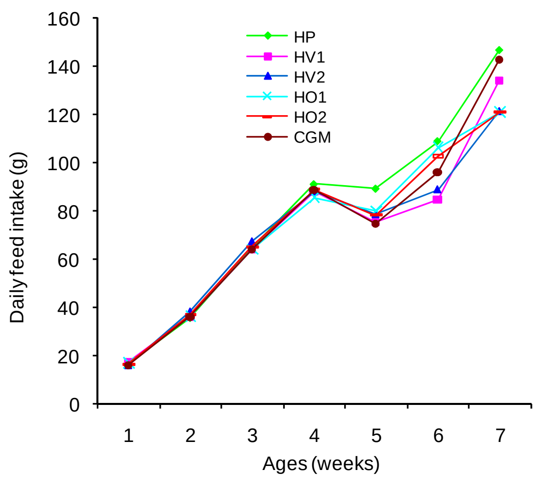

Fig. 3: Daily feed intake of broiler chickens fed with diets processed by six methods.

was significantly higher in pelleted than mashed feeds (Table 9).

The lowest feeding cost (0.610 €/g WG in HO1 diet) represented about 77% of FC in pelleted diet at starter phase. However, the economic feed efficiency (EFE) was not significantly affected by the processing method at both phases ($P > 0.05$).

Irrespective of the feed, FC and EFE were better during the starter phase than the grower phase. Thus, economically the broiler chickens gave better productivity at starter than at grower phases.

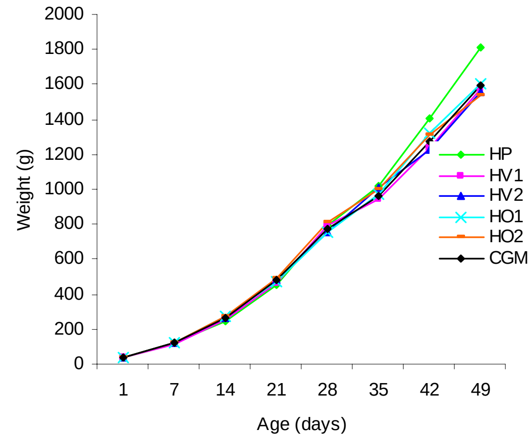

Fig. 4: Growth curves of broiler chickens fed with diets processed by six methods.

DISCUSSION

Quality of feeds

The differences in proportion of particles size linked to the directions or the capacities of the mixers were unexpected because theoretically the mixer does not ground the ingredients, but mixes them. The design of the grinding system in the big mills might be therefore different from that in smaller mills. Martin (1985) reported that the efficiency of the hammer mill is influenced by a number of factors, including grain type, grain moisture content, screen size, screen area, peripheral speed, hammer width and design, number of hammers, hammer tip to screen clearance, feed rate, power of the motor and speed of air flow through the mill. The results of this study suggested that the mixers in oblique direction and those associated with mills of big capacity might grind partially during the mixing the coarse particles of the most important and hard ingredients (mainly maize grains and soybean meal).

The non significant effect of the batch and the similarity in most of the chemical components of feeds can be attributed to a mixing efficiency of the mashed ingredients, hence the chemical uniformity of the feeds from the different processing methods. In spite of the wide interval of coefficients of variation (CV) found for physical variables (2.5 to 93%), the CV of chemical components were lower (0.16 to 10.6%) apart from that in total ash (15%). In feed industry, a CV less than 10% was used as the level to be considered for a good mixing (Clark *et al*., 2007). Thus, the types of mills, the order of ingredients in the grinder and the mixing time adopted by mill managers were suitable for broiler chickens' feeds processing in Benin.

However, some improvements can be suggested regarding the grinding. In mashed feeds 46 to 54% of particles size were below 1 mm. Goodband *et al*. (1987)

Table 7: Daily feed intake (DFI) and feed conversion ratio (FCR) of broiler chickens

	Phases	Processing methods						SEM	P-value
		HP	HV1	HV2	HO1	HO2	CGM		
DFI (g)	Starter	38.9	39.0	40.5	38.9	39.4	38.7	7.0	0.99
	Grower	109	95.7	94.3	98.1	97.8	100	6.6	0.67
	Overall	79.1	71.4	71.2	72.7	72.8	73.9	8.2	0.97
FCR (g feed/g weight gain)	Starter	1.87	1.85	1.79	1.79	1.71	1.72	0.12	0.90
	Grower	2.39	2.55	2.48	2.45	2.77	2.45	0.19	0.77
	Overall	2.16	2.25	2.18	2.17	2.32	2.14	0.15	0.96

Table 8: Daily body weight gain (WG) and final body weight (FBW) of broiler chickens

	Phases	Processing methods						SEM	P-value
		HP	HV1	HV2	HO1	HO2	CGM		
WG (g)	Starter	19.8	20.1	21.3	20.5	21.7	21.2	2.7	0.99
	Grower	48.5	39.9	38.3	40.7	37.2	39.7	3.0	0.14
	Overall	36.2	31.4	31.0	32.0	30.5	31.8	3.0	0.80
FBW (g)	Starter	454^a	459^a	484^b	467^a	494^b	482^b	7.8	0.02
	Grower	1812^a	1576^b	1556^b	1607^b	1534^b	1592^b	62.8	0.04

$^{a\,b}$ Means with unlike superscripts in the same row differ significantly (P < 0.05)

Table 9: Feeding cost (FC) and economic feed efficiency (EFE) of broiler chickens

	Phases	Processing methods						SEM	P-value
		HP	HV1	HV2	HO1	HO2	CGM		
FC (€/kg WG[1])	Starter	0.794^a	0.659^b	0.637^b	0.610^b	0.637^b	0.614^b	0.050	0.04
	Grower	1.00	0.893	0.869	0.973	0.861	0.861	0.070	0.57
	Overall	0.913	0.793	0.770	0.817	0.765	0.755	0.052	0.28
EFE (€ WG/€ feed)	Starter	2.21	2.61	2.76	2.87	2.76	2.81	0.19	0.20
	Grower	1.78	2.02	1.97	1.86	2.01	1.96	0.13	0.76
	Overall	1.97	2.28	2.31	2.29	2.33	2.33	0.14	0.41

$^{a\,b}$ Means with unlike superscripts in the same row differ significantly (P < 0.05)

[1]Body weight gain

reported that feeding a balanced diet in a crumbled form did not appear to require particle size below 0.8 and 1 mm, respectively, in layers' and broilers' diets. Thus, the grinding for so high proportions of small particles size in the feed of grower broilers might not be necessary. It was reported that during feed processing, the production rate decreases while the energy consumption increases for particles having between 0.4 and 1 mm (Wondra *et al*., 1995). The companies could therefore save a part of the energy consumed to grind by using for example higher diameter of screen size. In that perspective, the mills made in Benin could be improved by increasing the screen size as suggested by Reece *et al.* (1986) who found an energy saving of 27% by increasing the screen size of hammer mill from 4.76 to 6.35 mm.

The particularly high content of crude fiber in the feeds HP and HV1 might be the consequence of the residue of previous feeds remaining in the mill because; these feeds were processed in the same company (cf. Table 1), which belongs to the network of rabbits' keepers who used feeds with very high crude fiber content. The values of GMD and the low proportion (9%) of particles having less than 4.75 mm, indicated that the pelleted feed was the most uniform. This result confirmed an increase of the feed uniformity by pelleting as reported Svihus *et al*. (2004) and McCoy *et al*. (1994). However, further research can be done in Benin on the quality of the pelleted feed and on the effect of the rate of mixer filling on the quality of mashed feeds.

Feed intake and feed efficiency

Despite the pattern of particles size of feeds differed significantly between processing methods, the daily feed intakes (DFI) were similar among diets at starter and grower phases. This result indicated an adaptation of broilers to the particles size of the feed. However, the eating time might be longer for broilers fed mashed diets resulting in a loss of energy comparatively to broilers fed HP diet (Amerah *et al*., 2007; Jensen, 2000). The non significant effect of the pelleting on DFI was in contrast with the results reported by Svihus *et al.* (2004), Jensen (2000) and Nir *et al*. (1995) according to which, pelleting increases significantly feed intake. The similar DFI of broilers might be related to the limitation of their growth performance in hot and humid climate comparatively to that in temperate climate. Furthermore, the diameter of pelleted starter feed could limit the feed intake in the first weeks because chicks were small, so the width of their beaks (birds' gape) might not allow a good intake of HP feed having about 6 mm as GMD.

The overall DFI in mashed feeds were in agreement with 69.3 g reported in Nigeria by Obun *et al*. (2008) with Cobb broiler chickens. Furthermore, the feed conversion ratio (FCR) in all dietary treatments (2.14 to 2.32 g feed/g weight gain) were very close to 2.29 (Obun *et al*., 2008) and 2.45 (Teguia and Fon Fru, 2007). A significantly lower FCR in pelleted diet compared to mashed diet was reported by Svihus *et al*. (2004). In the present study, the non significant effect of the processing method on FCR resulted from the similarity of DFI and of daily weight gain.

Growth and mortality

The DFI and in certain instance the chemical composition being similar, no significant effect of the processing methods was found on the daily body weight gain (WG) and the mortality. Hence, comparatively to mashed feeds the efficiency of HP feed was not significantly better. This result contrasted with the significantly higher WG found by Jensen (2000). It was also different in certain instance from the higher apparent digestibility of organic matter, especially starch (Zelenka, 2003) and of lysine (Greenwood *et al*., 2005) associated with broilers fed pelleted diet compared to mashed diet.

The similarity in growth performance between diets was more effective at starter than grower phases. This was confirmed by the significantly higher final body weight (FBW) of broilers fed HP diet at d 49, but not at d 21. Thus, the cumulative effect of the non significant difference of feed intake (Fig. 1) affected the live weight of broiler chickens from the sixth week of age (Fig. 2). Therefore, the pelleting effect on the growth performance of broilers increased with their age, maybe due to development of the gastrointestinal tract resulting from the maturity of the birds. The similarity of WG between broilers fed mashed feeds confirmed the results reported by McCoy *et al.* (1994), when they compared mashed diets mixed with different revolutions of the mixer.

However, the capacity of the mixer had a significant effect of the FBW, while its vertical or oblique direction did not. At the starter phase, broilers fed with the feeds from the big mixers (HV2 and HO2) and the manual mixing had significantly higher FBW comparatively to those fed with feeds from the smaller mixers (HV1 and HO1). The difference could be related to a better mixing by the bigger mixers of particularly the smaller ingredients (amino acids and minerals) incorporated in the feeds. It could also be (i) the effect of the particles having 1 - 2.36 mm which were in significantly higher proportion in diets from the manual mixing and both bigger mixers irrespective of their direction or (ii) that of particle having less than 1 mm which were in similar proportion in these three diets. FBW in mashed feeds were in the interval 1514 – 1715 g reported in Ivory Coast (Yo *et al*., 1998) with Hubbard broilers, while FBW in HP diet (1812 g) was lower than 1951 g recorded in Nigeria by Obun *et al*. (2008) with Cobb broilers feed mashed feed.

Economics of feeding

The significant difference found in feeding cost (FC) at starter phase could be explain by the similarity in feed intake and weight gain between diets, while the price of HP feed was higher due to the pelleting cost. The very high pelleting cost could be partially the consequence of the monopole situation in which was the pelleting factory in Benin. At the grower phase, the small but non significant increase of the weight gain of broilers fed HP diet tended to even out FC between dietary treatments. The overall FC in HP (0.913 €/kg WG) was close to 0.929 €/kg WG reported by Teguia and Fon Fru (2007) in Cameroon with Hubbard broilers fed mashed feed.

The similar economic feed efficiency (EFE) between diets at all phases demonstrated that the pelleting cost that affected highly the feed price can be balanced by the revenue from a better cumulative weight gain of broilers fed HP. The profit from the use of pelleted feed could be therefore improved if there was a significant decrease of the pelleting cost which represented about 18% of the HP feed price versus only 2% of the mashed feeds prices. This result confirmed that a better efficiency of a pelleted feed could pay for the pelleting cost (Fairfield, 2003) at least.

Conclusion

The results of this experiment showed that the pelleting of the feed increased significantly the feed cost at starter phase and the final body weight of broilers up to d 49, while the daily feed intake and the daily weight gain were statistically similar. The pelleted feeds produced in Benin can be suggested for grower broiler chickens especially. The balance in economic feed efficiency between diets showed that in Benin the profit in broilers production could be improved with lower pelleting costs.

The manual mixing of small amount of feed ground in cereal mill allowed similar bio-economic performances as the mechanic processes of mashed feeds. That manual processing method could be therefore adopted in small scale farms and in rural area lacking electricity; but a very careful mixing is necessary for a good uniformity of the feed.

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REFERENCES

Amerah AM, V Ravindran, RG Lentle and DG Thomas, 2007. Feed particle size: implications on the digestion and performance of poultry. World's Poult Sci J, 63: 439-455.

Baker S and T Herrman, 2002. Evaluating particle size. Feed Manufact, MF-2051, 1–6.

Clark PM, KC Behnke and DR Poole, 2007. Effects of marker selection and mix time on the coefficient of variation (Mix Uniformity) of broiler feed. J Appl Poult Res, 16: 464-470.

Fairfield DA, 2003. Pelleting for Profit - Part 1. Feed and Feeding Digest, 54: 1-5.

Goodband RD and RH Hines, 1987. The effect of barley particle size on starter and finishing pig performance. J Anim Sci, 65 (Suppl. abstract 1): 317.

Greenwood MW, KR Cramer, RS Beyer, PM Clark and KC Behnke, 2005. Influence of feed form on estimated digestible lysine needs of male broilers from sixteen to thirty days of age. J Appl Poult Res, 14: 130-135.

Intitut National de la recherche Agronomique, 1989. Alimentation des animaux monogastriques: Porc, lapin, volailles (Feeding of non-rumimant animals : Pigs, Rabbit, Poultry) (in French). 2nd Edition, reviewed and corrected, INRA France.

Jensen LS, 2000. Influence of pelleting on the nutritional needs of poultry. Asian-Aust J Anim Sci, 13: 35-46.

Larbier M and B Leclercq, 1994. Nutrition and feeding of poultry. English translation ©, Nottingham University Press.

Martin S, 1985. Comparison of hammer mill and roller mill grinding and the effect of grain particle size on mixing and pelleting. Master Thesis, Departments of Food Animal Health and Management, Centre of Animal Sciences and Industry, Kansas State University, USA.

McCoy RA, KC Behnke, JD Hancock and RR McEllhiney, 1994. Effect of mixing uniformity on broiler chick performance. Poult Sci, 73: 443-451.

National Research Council, 1994. Nutrient requirements of poultry. 9th Revised Edition, Washington, D.C, National Academy Press, USA.

Nir I, R Hillel, I Ptichi and G Chefet, 1995. Effect of particle size on performance. 3. Grinding pelleting interactions. Poult Sci, 74: 771-783.

Obun CO, OA Olafadehan, BA Ayanwale and M Inuwa, 2008. Growth, carcass and organ weights of finisher broilers fed differently processed *Detarium microcarpum* (Guill and Sperr) seed meal. Livest Res Rur Dev 20(8), Article 126.

Plattner B and G Rokey, 2006. Better pellets with preconditioning. Feed Manag, 57: 24-28.

Reece FN, BD Lott and JW Deaton, 1986. The effects of hammer mill screen size on ground corn particles size, pellet durability, and broiler performance. Poult Sci, 65: 1257-1261.

SAS Institute Inc., 2004. Qualification Tools. User guide of statistic analysis system procedure, Version 9.1.2, SAS Institute Inc.Cary, NC, USA.

Svihus B and H Hetland, 2001. Ileal starch digestibility in growing broiler chickens fed on a wheat based diet is improved by mash feeding, dilution with cellulose or whole wheat inclusion. Br Poult Sci, 42: 633-637.

Svihus B, KH Kløvstad, V Perez, O Zimonja, S Sahlström, RB Schüller, WK Jeksrud and E Prestløkken, 2004. Physical and nutritional effects of pelleting of broiler chicken diets made from wheat ground to different coarsenesses by the use of roller mill and hammer mill. Anim Feed Sci Techno, 117: 281-293.

Teguia A and S Fon Fru, 2007. Growth performances of broiler chickens as affected by diets containing common bean (Phaseolus vulgaris) treated by different methods. Trop Anim Health Prod, 39: 405-410.

Thomson E and J Nolan, 2001. UNEForm: a powerfull feed formulation spreadsheet suitable for teaching or on-farm formulation. Anim Feed Sci Techno, 91: 233-240.

Wicker DL and DR Pool, 1991. How is your mixer performing? Feed Manag, 42: 40-44.

Wilcox RA and JL Balding, 1986. Feed manufacturing problems – Incomplete mixing and segregation. Bulletin C-555 revised, Kansas State University, Cooperative Extension Service, Manhattan.

Wondra KJ, JD Hancock, KC Behnke, RH Hines and CR Startk, 1995. Effect of particle size and pelleting on growth performance, nutrient digestibility, and stomach morphology in finishing pigs. J Anim Sci, 73: 757-763.

Yo T, PB Siegel, MJ Faure and M Picard, 1998. Self-selection of dietary protein and energy by broilers grown under a tropical climate: adaptation when exposed to choice feeding at different ages. Poult Sci, 77: 502-508.

Zelenka J, 2003. Effect of pelleting on digestibility and metabolisable energy values of poultry diet. Cz J Anim Sci, 48: 239-242.