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Particles Size as Feed Quality Parameter in Ghana - A Case Study of Dormaa Municipality

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Abstract

There is a general agreement between researchers that particle size of poultry feed should be between the size ranges of 600-900 µm. This study investigated the particle size of poultry feed produced in the Dormaa Municipality of Ghana. A survey was conducted on various feed mills which were made up of nine on-farm mills and five community-based commercial mills. Feed samples were collected from each mill and analyzed using the sieving method for the particle size. The results showed that 42% of mills produced feed coarser than the accepted particle size ranges of 600-900 µm. The geometric mean diameter (GMD) of the samples ranged from 608-1791 µm. A comparison of the on-farm and commercial feed mills showed that there was no significant difference (P = 0.669) between GMDs of the feed produced by the commercial and on-farm mills. This study confirmed that particle size analysis should be carried out routinely at the feed mills, in order to control the quality of the feed being produced.

Introduction

The poultry industry is one of the vibrant sectors within the global meat industry in recent years. The demand for poultry products is expected to increase due to population growth and therefore a corresponding increase in meat production will be required. Though Ghana produces about 14,000 tons of meat and 200 million eggs annually, available data from FAO indicates that poultry production is far below the demand for the product. Poultry imports in Ghana have increased by five percent from 157,000 tons in 2012 to 165,000 tons in 2013, with imports more than quadrupling since 2002 to augment production (FAO, 2014).

In commercial poultry production, the economic importance of feed cannot be over emphasized. This is because feed is mainly accountable for the bird's growth response. It accounts for the highest cost in the production of poultry (Avila *et al.*, 1992; Neves *et al.*, 2014). About 70% of the total feed produced in Ghana is consumed by the poultry industry (Rondon and Ashitey, 2011). In the preparation of maize and sorghum diet for broilers, there seems to be generally an agreement between researchers that in order to obtain an optimum benefit from the feed by the birds, the feed particle size should be between 600-900 µm (Amerah *et al.*, 2007).

Feed ingredients such as cereals and legumes undergo some form of particle size reduction before mixing with protein meals to prepare poultry feed. Reece *et al.* (1985) reported that in broiler feed production, particle size reduction is the second largest consumer of energy after that of pelleting, and in cases where no pelleting of feed is done, it is the largest cost in feed

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manufacturing. Energy cost accounts for 25-30% of the manufacture of broiler feed (Dozier, 2002). When preparing formulated feed, particle size is important in the handling and mixing of feed ingredients and it is vital in achieving optimum utilization of the feed by the birds (Koch, 1996). Particle size reduction involves the crushing of seed coat and then the exposure of the endosperm. Continuous reduction of feed ingredients results in an increment in both the number of particles and the surface per unit volume and this permits an increased access to digestive enzymes. Particle size reduction changes the physical characteristics feed and results in an improvement in mixing, feed handling, pelleting, transport and probably in an improved animal performance. Knowledge of the particle size of feed farmers give to their birds will give an idea on whether farmers are receiving the maximum benefits from the feed they give to their birds.

There is a limitation to the extent of size reduction, since very coarse or very fine particles may have a negative impact on the birds' ability to consume the feed. However, the feed's particle size from the mill may vary and might not be within ranges for optimum utilization by the poultry (Amerah *et al*., 2007).

Nutritionists and consultants recommend frequent particle size analysis to ameliorate feeding programs. The geometric mean diameter (GMD) is used to describe particle size. However, a proper description of particles size must include the geometric standard deviation (GSD), which is a measure of data variability and range of variation, with a bigger GSD representing lower uniformity.

Nir *et al.* (1994) reported that when birds were fed maize-soy diet with lower GSD, they produced better weight gain and feed utilization. Broiler performance also increased when maize particle size reduced from 1289 µm to 987 µm (Reece *et al*., 1986). Lott *et al.* (1992) reported similar results; whereby birds showed high feed efficiency when feed particle size decreased from 1175 µm to 710 µm. Despite this importance, works on the effect of particle size uniformity in poultry feed have been very limited. For instance, in Ghana only two articles on particle size in relation to poultry has been published by Addo *et al*. (2012) and Oppong-Sekyere *et al*. (2012). Oppong-Sekyere *et al*. (2012) reported that birds consumed lower quantity of feed and achieved better feed to weight gain ratio, when fed on maize diet of particle size 713 µm as compared to those fed on much coarser particle size of 1462 µm and 1506 µm, respectively.

In Ghana, maize is the major source of energy requirements of poultry. However, most feed producers do not consider particle size as a quality index in feed formulation and may be producing feed particles outside the ranges that have been recommended which are 600-900 µm (Addo *et al*., 2012).

Feed accounts for about 65-75 % poultry activities, thus, ameliorating the efficiency of feed usage will have an enormous effect on the cost of production (Goodband *et al*., 2002). In the feed industry, next to pelleting, whole grain milling consumes the second largest quantity of electricity (Reece *et al*., 1985). Particle size reduction of feed ingredients into finer sizes utilizes a greater amount of energy. However, even small melioration in the efficiency of feed utilization will often justify any extra cost (Ensminger *et al*., 1990). Therefore information on the particle size of feed produced in the study area will help understand if the particle size is within range for optimum utilization by birds which might reduce production cost through efficient feed utilization. The study sort to investigate if the particle size of feed ingredients produced in the Dormaa Municipality were within recommended values for optimum feed utilization by the birds.

Materials and Methods

Study area

The Dormaa municipality is located in the western part of the Brong Ahafo Region of Ghana. Agricultural activities dominate the micro economic environment of the area especially in the area of livestock; poultry production is most prominent in the municipality. Data gathered from the Dormaa Poultry Farmers Association (DPFA) indicates that there are almost 150 poultry farmers in the municipality. These farmers have bird capacity ranging from as low as 500 birds to as high as 150,000 birds. Most of the farmers in the municipality produce their own feed. They obtain grains mainly maize from crop farmers within and around the municipality. These grains are taken to commercial feed mills within the community where the grains are ground and mixed with either fish meal or soya bran etc. which they obtained pre-ground from suppliers. There are 11 on-farm feed mills and also 5 community-based commercial feed mills in the municipality.

Methodology

Samples and data were collected by purposive sampling of farms with on-farm feed mills and also community based commercial feed mills. A total of 9 on-farm feed mills and 5 community-based commercial mills participated in the study. The fourteen mills were designated as Mill I, II, III, IV, V, VI, VII, VII, VIII, IX, X, XI, XII, XIII and XIV, respectively. Random samples of 1.5 kg feed were collected from the grinder-mixers during discharge into packaging sacks as recommended by Herrman (2001). A total of 10 replicate samples were collected from each hammer mill.

Sample Preparation

The initial moisture content on wet basis was determined for each sample by oven drying method. Each sample was dried at 40 °C until a constant weight was achieved and recorded accordingly. The moisture content of the sample was then calculated using equation 1.

$$W = \frac{w_i - w_f}{wi} \times 100\% \quad \text{[Eq. 1]}$$

Where: $W = moisture\ content$ (%)
$w_i = initial\ weight\ of\ sample\ (g)$
$w_f = final\ weight\ of\ sample\ (g)$

One kg each of the main samples was taken and then partitioned into 5 uniform sub-samples using a SCP Science sample riffle to attain a weight of 200 g. Each 200 g sub-sample was further dried at 40 °C for 6hr to attain equal moisture content at 13%. The 200 g sub-sample was then further sub-divided into two to obtain a 100 g working sample.

Particle size analysis

The particle size was determined by the sieving method. One-hundred g working sample was used in the determination of particle size and making inferences using a full stack of sieve. The impact sieve shaker SV001 was used in this study. Ten replicates of each feed sample were filtered through sieves using the shaker for 15 minutes. The sieves were selected so that they follow a geometric progression according to American Society of Agricultural Engineers (ASAE, 2008) Standard S 319. The size of screen opening employed in this study were 2360, 1700, 1180, 710, 425, 250, and 100 µm. The weight of the ingredient particles that did not filter through each sieve was determined and noted using the procedure described by the American Society of Agricultural Engineers (ASAE, 2008). The particles that filtered through the screen were also collected in a pan and weighed using an electronic balance. The sieves were then cleaned for the next batch of samples.

Statistical analysis

Microsoft Excel 2013 was used in the analysis and drawing of the distribution graphs. The weight values of particles collected on each sieve were recorded and entered into the appropriate columns in a spread sheet and the determination of the particle size, GMD, GSD, surface area, and the number of particles was done using Equations 2 to 6, respectively (ASAE, 2008).

SPSS Statistics 20 software was used to compare feed samples from both the on-farm feed mills and community-based commercial mills. An independent t-*test* was used in the analysis.

Pfost and Headley (1976) suggested that the average particle size of the material retained on a sieve can be calculated as the geometric mean of the diameter openings in two adjacent sieves in a stack as shown in Equation 2.

$$d_i = (d_u\ x\ d_o)^{0.5} \quad \text{[Eq. 2]}$$

The average particle size of the samples was calculated on weight basis. This was done using ***Equation 3.***

$$D_{gw} = log^{-1}\left[\frac{\Sigma(W_i\ log\ d_i}{\Sigma W_i}\right] \quad \text{[Eq. 3]}$$

The standard deviation of the particles which gives an indication of the uniformity of particle size distribution was calculated using ***Equation 4.***

$$S_{gw} = \log^{-1}\left[\frac{\Sigma W_i(\log d_i - \log D_{gw})^2}{\Sigma W_i}\right] \quad \text{[Eq. 4]}$$

where,
d_i= diameter opening of i^{th} sieve in the stack (μm)
d_u= nominal sieve aperture size in the next, larger than i^{th} sieve (just above the set), (μm)
d_o= diameter opening through which particles will not pass (i^{th} sieve), (μm)
D_{gw}= geometric mean diameter or median size of particles by size, (μm)
S_{gw}= geometric standard deviation of particle diameter by mass (μm)
W_i= mass on i^{th} sieve (g)

Results and Discussion

Particle size distribution

Figure 1 shows the average particle size (Geometric Mean Diameter GMD) of milled feeds collected from the various mills. The GMD ranged from 603.44 µm to 1791.43 µm. The average GMD for all the fourteen mills was calculated to be 951.2 µm and the coefficient of variance (CV) and the standard deviation (SD) were found to be 28.18% and 268.00, respectively. This showed that there was a high degree of variation amongst the feed particle sizes farmers fed to their birds.

Mill V had the highest GMD followed by mills X, VII, VIII, XII, and IX with GMD of 1791.43, 1127.78, 1112.66, 969.81, 947.12, and 907.144 µm, respectively. These mills were producing feed coarser than the recommended particle size range of 600-900µm. Mills II, I, XII, III, XI, XIV, II, and VI produced feed GMDs of 895.08, 892.02, 883.42, 843.07, 836.3, 803.71, and 603.44 µm, respectively. The particle size of these mills was producing feed within the accepted range of particle size.

The typical particle size distribution for the different feed samples is as indicated in figures 2-15. Each feed sample exhibited a different type of distribution. The data shows that the highest proportion of feed particles lied within the 710 to 2360 µm screen sizes. Mill I had more than 66% of particles within the range of 710-2360 µm with a GMD of 892.02 µm and a GSD of 2.41 whilst Mill II had a total of about 50.83% of the particles within 710-2360 µm and a GMD of 703.82 µm and a GSD of 2.41. Sample from mill III also had more than 59% of the particles within the sieve opening ranges of 710-2360 µm with GMD of 703.82 µm and a GSD of 2.44. More than 62% of the sample from mill IV was within the particle size range of 710-2360 µm and the GMD was 895.08 µm and a GSD of 2.28. Sample V produced the greatest GMD of 1791.43 µm with a GSD of 1.64. More than 95% of the particles were within the size ranges of 710-2360 µm. In contrast, feed mill VI had the lowest GMD of 603.44 µm with a GSD of 2.68. Less than 46% of the particles were within the sieve sizes of 710-2360 µm.

Samples from mills VII, VIII, and IX produced GMDs of 1112.66, 969, and 907.14 µm and a GSD of 2.40, 2.21, and 2.39, respectively. The proportion of accumulation of particles on sieve ranges of sizes 710—2360 µm was 72.92, 65.22, and 61.34%, respectively. Likewise mills X, XI, XII, XIII, and XIV produced feed with high percentage of samples retained on sieves 2360, 1700, 1180 and 710 µm giving percentages of 74.18, 58.53, 64.19, 62.14, and 57.55%, respectively. The GMD was determined to be 1127.78, 836.30, 947.28, 883.42, and 803.71 µm in that order. The GSD was also estimated to be 2.27, 2.49, 2.21, 2.19, and 2.41 correspondingly.

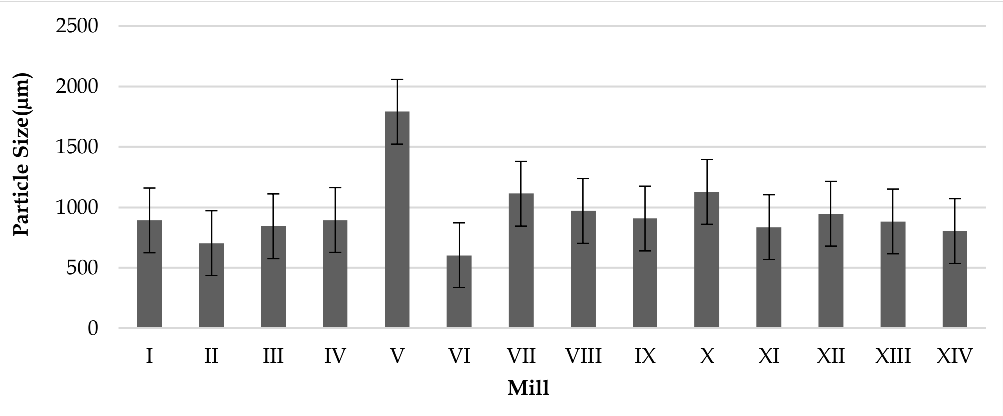

Figure 1. Geometric mean diameter variation of feed samples from the various mills.

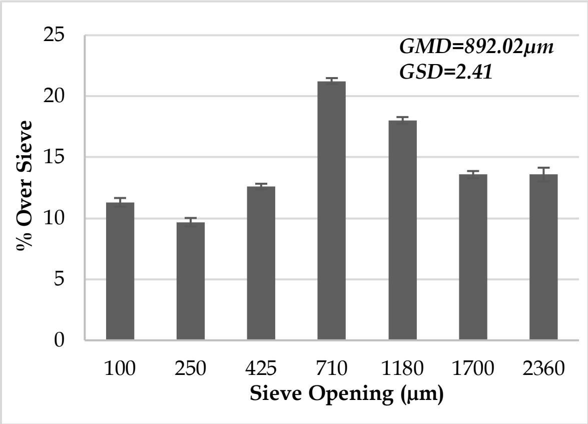

Figure 2. Particle size distribution for mill I.

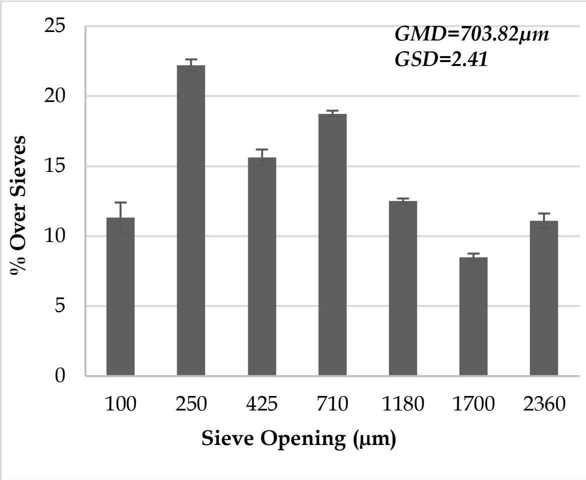

Figure 3. Particle size distribution for mill II.

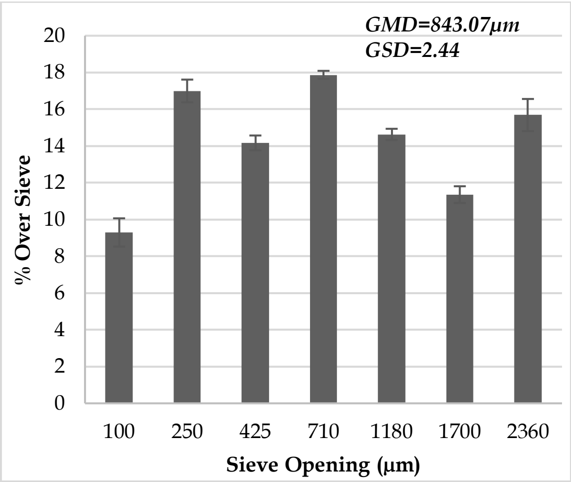

Figure 4. Particle size distribution for mill III.

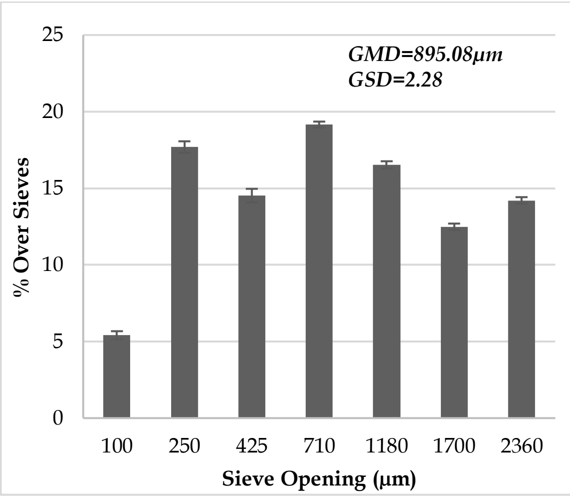

Figure 5. Particle size distribution for mill IV.

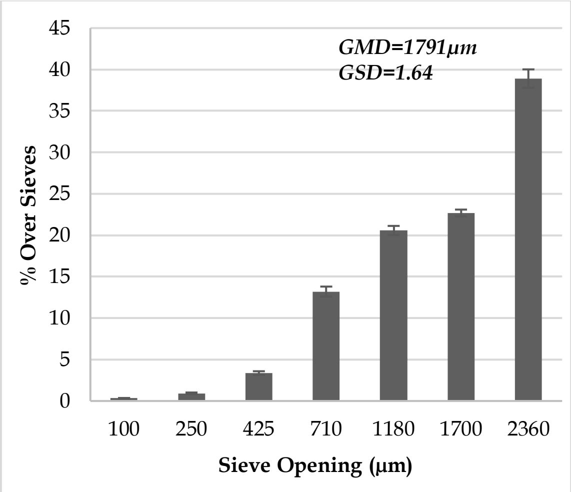

Figure 6. Particle size distribution for mill V.

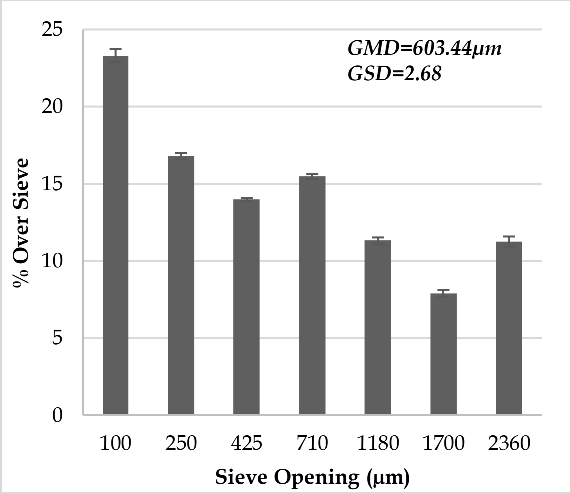

Figure 7. Particle size distribution of mill VI.

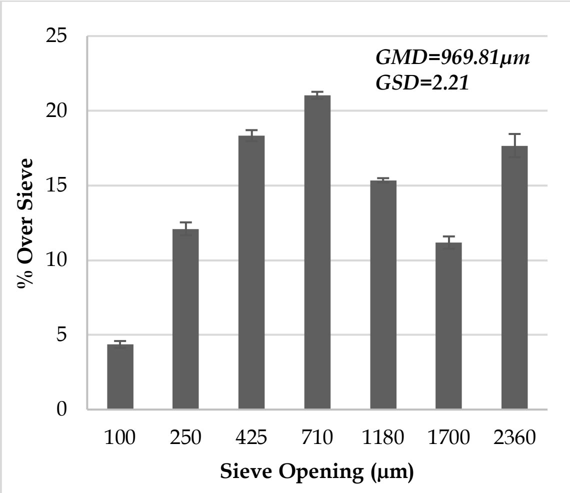

Figure 8. Particle size distribution for mill VII.

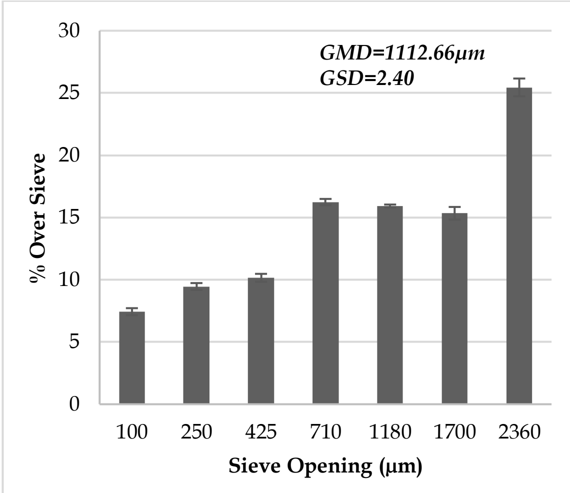

Figure 9. Particle size distribution for mill VIII.

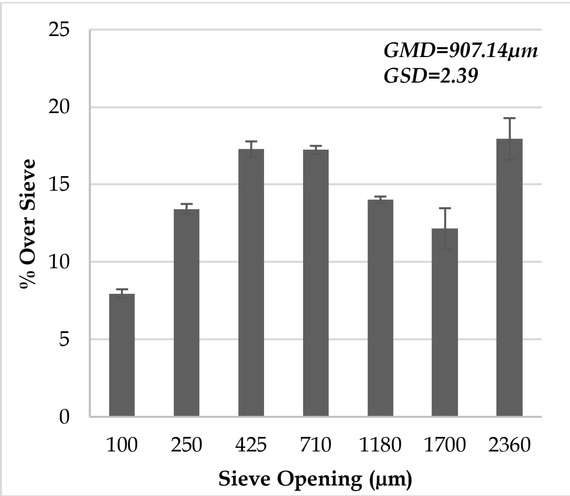

Figure 10. Particle size distribution for mill IX.

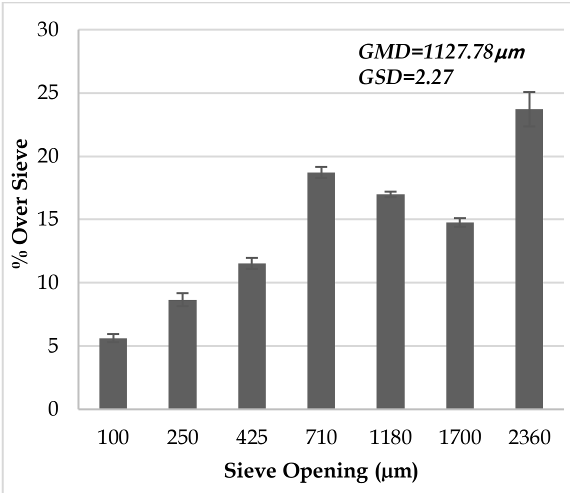

Figure 11. Particle size distribution for mill X.

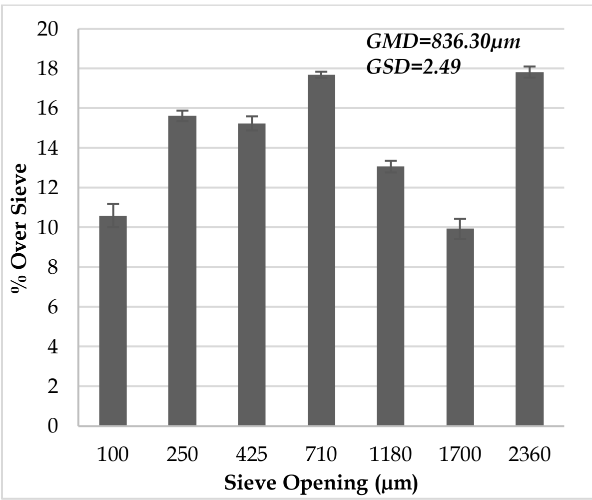

Figure 12. Particle size distribution for mill XI.

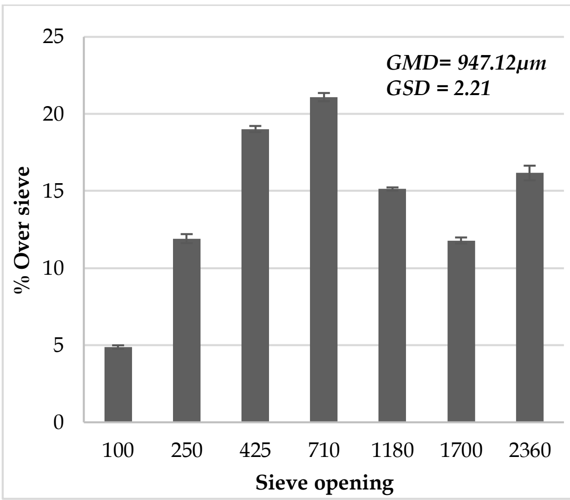

Figure 13. Particle size distribution for mill XII.

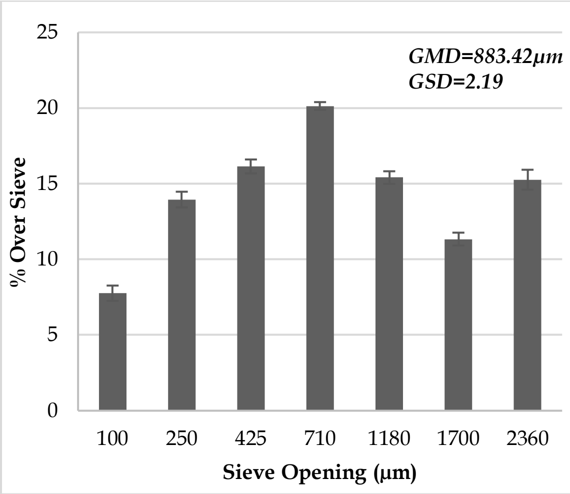

Figure 14. Particle size distribution for mill XIII.

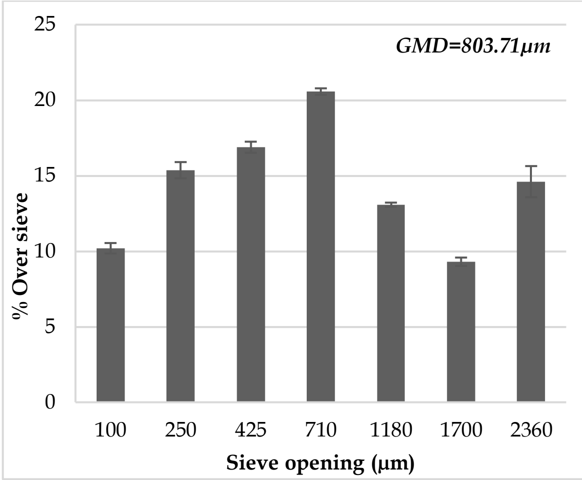

Figure 15. Particle size distribution for mill XIV.

The particle size analysis of the various mills indicates that a large percentage of feed mills produce feed larger than the recommended particle size ranges for broilers. For mash diet the recommended particle size should be between 600-900 µm (Nir *et al*., 1994; Dritz and Hancock, 1999). Only about 57% of the samples analyzed was within the size ranges of 600-900 µm, therefore more than 40% of the feed produced in the municipality was too coarse to allow optimum utilization by birds and so needs further grinding of maize. In contrast, Addo *et al*. (2012) reported only one mill was producing feed within the standard particle size range in the Kumasi Metropolis. This could imply that feed in the Dormaa Municipality were of a higher quality in relation to particle sizes than in the Kumasi Metro.

In contrast, most farmers in the municipality have shifted from broiler production to farming layers, as it is with the case of most poultry farmers in Ghana (Rondon and Ashitey, 2011). Lohmann (2005) as well as Brown (2007) recommended that layer feed should have at least 75-80% of the feed particles' GMD within the sieve range of 500-3200 µm. However Goodband *et al*. (2002) stated that reducing particle size below 800 µm for layers showed no advantages. The results obtained indicates that only about 43% of feed mills met this criterion, with most of the feed having a substantial quantity of their particles remaining on the sieves with openings between 500-100µm. This shows that farmers may be overgrinding the maize they feed to their layers and therefore may be consuming more energy than necessary for size reduction. Unfortunately data on energy consumption used in the grinding process was not readily available. Therefore, energy consumption could not be quantified. Though certain mills produce feed within the recommended particle size ranges, the high variation and the absence of methods of checking the particle size of feed produced shows that the mills do not consider the particle size as important parameter. Addo *et al*. (2012) and Goodband *et al*. (2002) recommend a routine particle size monitoring program for checking either ground grains or complete diet at least twice in year for small operations and up to 60-90 days for large scale.

The geometric standard deviation (GSD) of the feed samples was averagely very high. The GSD describes the size distribution of the feed particle size within a sample. Feeds with high GSD of particle size have a strong tendency to separate and not stay well mixed (Midwest Laboratories, 2014), thus, the uniformity of the feed mix produced by these mills is questionable. Feed uniformity in diet is important to maximize nutrient utilization. Nir *et al*. (1994) reported of an improved performance for diets with lower GSD when diets of similar GMD were fed.

Commercial mills versus on-farm mills

The on-farm feed mills were associated with an average GMD *M=926.16* (SD =135.17). By comparison the commercial feed mills (N=5) were associated with a bigger GMD M=996.28 (SD= 459.24; Table 1). To test whether there was a difference in the GMD and GSD of the feed from community based commercial mills and on farm mills, an independent t-test with alpha equal to 0.05 as criterion of significance was adopted (Table 2).

Table 1. Results of statistical analysis in community based commercial mill verses on-farm feed mill

	Group	Mean	Std. Deviation	Std. Error Mean
GMD	On-farm	926.1576	135.169	45.056
	Community	996.2760	459.238	205.378
STD	On-farm	2.3099	0.0970	0.0323
	Community	2.3280	0.400	0.179

The commercial and on-farm feed distributions are sufficiently normal for the purpose of conducting a t-test [i.e. skew < 12.01 and kurtosis < 19.01 (Schmider *et al.*, 2010)]. The assumption of homogeneity of variance was tested and satisfied for the GMDs by using Levene's F test, F (12) = 4.643, P = 0.052. However, the test for homogeneity of variance was not satisfied for GSD, F (4.263) = 5.097 and P = 0.043. The *t-test* did not reveal any significant difference between the mean GMDs of the commercial mills and the on-farm feed mills. This showed that the on-farm feed mill and the community based commercial mills were producing feed of similar quality in terms of particle size.

Table 2. Independent samples T-test of community based commercial mills and on-farm feed mills

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
GMD	Equal variances assumed	4.643	0.052	-0.438	12	0.669	-70.118	160.189	-419.141	278.903
	Equal variances not assumed			-0.333	4.389	0.754	-70.118	210.262	-634.03920	493.80232
STD	Equal variances assumed	5.097	0.043	-0.133	12	0.896	-0.0181	0.136	-0.31480	.27854
	Equal variances not assumed			-0.100	4.263	0.925	-0.0181	0.182	-0.51074	0.47447

Conclusions

The results of this study showed a broad to narrow distributions of particle size amongst the feed mills with differences in proportions of large particle size. The study showed that farmers in the Dormaa Municipality are producing feed within the size ranges 608-1791µm with a GSD range of 1.64-2.68. More than 43% of farmers feed their birds with coarse feed materials; therefore farmers could be losing about 3-8% of their feed utilization cost due to coarse grinding of the feed in cases where farmers produce the feed for broilers. The research found out that the community-based commercial mills and the on-farm mills were producing feed of similar quality in terms of particle size. However, there was a high degree of variation in the GMDs of the feed coming from the various mills.

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