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DETERMINATION OF FEED MIXTURE UNIFORMITY USING DRY MATTER, ASH, AND PARTICLE SIZE DISTRIBUTION ANALYSES AS RAPID ASSAYS

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Abstract

Four experiments were conducted to test the homogeneity of chicken diets using dry matter (DM), ash, and particle size distribution (PSD) analyses as rapid assays. In both on-farm and on-station experiments, 100 and 200-kg chicken diets were mixed. In each experiment, the diets were manually mixed at different intensities (2–7 times) on a cemented floor. After each intensity of mixing, 5 samples of 300 g were fetched from the cardinal coordinates and the top of the heap for the analysis of DM (%), ash (%), and PSD and calculation of their coefficient of variations (CV). The results indicated that in all 4 experiments, there were no differences ($P > 0.05$) in the DM and ash content across all mixing intensities. Mixing 5 and 6 times on-farm (100 kg) reduced the quantity of ($P < 0.05$) < 75 μm particles. Also, mixing 7 times on-farm (200 kg) reduced ($P = 0.88$) < 75 μm particles. The CV of the 100-kg diet (on-station) was lower for particle size > 1000, > 500, and > 250 μm. For the 200-kg diet (on-station), the CV was lower for particle sizes > 250, > 75, and < 75 μm. For the 100-kg diet (on-farm), the CV was lower for DM, ash, and particle size of > 500 and < 75 μm. A lower CV was observed for the ash and particle sizes > 500 and < 75 μm for the 200-kg diet (on-farm). In conclusion, the hypothesis that DM, ash, and PSD analysis can be used as a reliable, rapid assays for determining feed uniformity was not fully supported in this study and warrants further studies.

Keywords
Feed uniformity, feed analysis, poultry diet, rapid assay

Introduction

Feed cost contributes about 60 to 80% of the total cost of commercial poultry production. Therefore, to ensure that there is efficient utilisation of the diet for growth and health, proper mixing of the diet is crucial. Diets are mixed such that all nutrients are randomly distributed in the mix to provide the birds with an adequate nutrient supply for growth, production, and health as intended (Pope et al., 2023). Also, the goal of the feed mixing is not only to create a uniform feed but also to do so in a minimum amount of time. In chicks, a proper feed mix is even more essential as their nutrient requirement is higher, yet they have relatively low daily feed intake (Wang et al., 2017). With the increased use of feed additives in feed formulation in the poultry industry in recent times, efficient mixing of feed has become even more critical, as a wide variation within a mixture of feed may lead to toxicity or deficiency of minerals and vitamins (Hashem et al., 2021). Additionally, poor mixing of feed can reduce the uniformity of body weight of the same batch of birds, which is necessary in mechanised meat processing plants (Barbut and Leishman, 2022). Therefore, the uniformity of the live birds becomes a prerequisite for the achievement of the optimum operational and economic performance of the plant. For example, the automatic transfer of uniform birds to the evisceration lines is easier with a uniform flock and reduces carcass rehanging, and saves labour required.

Several factors affect the uniformity of the feed. These include mixer design, variation in the particle size of the ingredients, and mixing time (Adusei et al., 2021; Dirk, 1995; Traylor et al., 1994). In most small-scale poultry farms in developing countries, feed mixing is done manually. This method is not only labour-intensive but also less efficient. Mostly, the homogeneity of the mix is not tested due to the cost involved. Elsewhere, various methods such as the use of synthetic amino acids, sodium, vitamins, chloride, chromium, zinc, manganese, copper, coloured iron particles, and micro tracer, have been used as indicators in assessing mixing uniformity (Clark et al., 2007; Rocha et al., 2015). While these approaches are expensive, they are also time-consuming. Therefore, a search for a less expensive and quicker alternative to testing the homogeneity of feed for small-holder poultry producers is important. Some possible alternatives and quicker methods of testing the uniformity of feed are the dry matter (DM), ash, and particle size distribution (PSD). Though these methods are used widely in the analysis of samples across various fields of study, little is known about whether they could be useful in assessing the homogeneity of poultry feed.

Presently, there is no standard for measuring feed uniformity. Exploring alternative and cost-effective methods for measuring mix uniformity would enhance feed quality control at the feed mill. The DM and ash analysis are by far the easiest, cheapest, fundamental, yet critical analyses in the determination of nutrient concentration and mineral quality. They have been used for routine monitoring even in resource-limited small-scale settings. Their procedures require minimal technical expertise compared to complex nutrient analyses like amino acid profiling and other tracers stated above. Therefore, this study was designed with the hypothesis that testing the homogeneity of chicken feed mixed at different intensities could be done using the DM, ash, and particle size distribution, or their coefficient of variation.

Materials and Methods

Location of the Study

Four experiments (two each on-station and on-farm) were conducted to test the homogeneity of chicken diets. The on-station studies were conducted at the poultry section of the Department of Animal Science of the University of Skills Training and Entrepreneurial Development, Asante Mampong campus. The on-farm studies were conducted at a small-scale poultry farm (KD Farms) in Asante Mampong.

Feed composition and mixing of diets

The feed composition and the calculated nutrient analysis are shown in Table 1. Two diets (100 and 200 kg) each were formulated and mixed in both study areas. In each case, there were 2, 3, 4, 5, 6, or 7 intensities of mixing. The mixing was done on a concrete floor using a shovel by pushing the material to one side, representing an intensity and then back to another side as a new intensity, as is the practice in small-scale poultry farms. After each intensity of mixing, an equal quantity of 300 g of the feed was fetched from the cardinal coordinates and the top of the mix. The 5 samples collected for each intensity of mixing were the replicates. The samples were bagged, labelled, and kept until used for the DM, ash, and PSD analysis. Hand mixing of poultry feed is a common practice in most small-scale poultry farms without industrial mixers. The choice of the various mixing intensities was arrived at based on decades of practical observations of feed mixing in small-scale poultry farms.

Variables measured

Dry matter (%) and ash (%) determinations

The DM and ash content of each replicate sample, both on-farm and on-station, was determined following the guidelines of AOAC (2010). Briefly, 2 g of the feed sample was weighed out into a porcelain crucible. The crucible + feed sample was placed in an oven at a temperature of 105 °C overnight until a constant weight was achieved. The samples were cooled in a desiccator and reweighed. Then, the DM (%) was calculated as follows:

$$\text{Dry matter (\%)} = \frac{\text{Mass of dry sample}}{\text{Mass of fresh sample}} \times 100 \qquad (1)$$

After the determination of the DM, the sample + crucibles were placed in a muffle furnace at a temperature of 550 °C overnight until only the ash remained. The crucibles were removed, cooled in a desiccator, and reweighed. The masses of the crucibles and their contents were calculated by subtraction. The ash (%) was calculated as follows:

$$\text{Ash (\%)} = \frac{\text{Mass of ash}}{\text{Mass of dry sample}} \times 100 \qquad (2)$$

Particle size distribution analysis

Each replicate sample was passed through five sieve sizes (1000, 500, 250, 125, and 75 μm). The sieve stack (Endecott, London, UK) was shaken vigorously for 5 minutes. The amount of sample retained on each sieve was weighed and recorded. To determine uniformity of the DM, ash, and PSD, the CV, indicating a homogeneity indicator, was calculated in Minitab (20.0) as 100 × standard deviation/mean (Clark et al., 2007). The CV has been used as the standard metric for assessing feed uniformity in the poultry industry, with lower values below 10% widely accepted as the standard for good mixer efficiency (Choi et al., 2026; Clark et al., 2007).

Table 1. Feed composition and calculated analysis of experimental diets (%), as-is basis

Ingredients	On-station diet	On-farm diet
Maize	64.0	65.0
Soybean meal (48% CP)	10.95	8.0
Wheat bran	8.55	6.8
Maize bran	–	5.0
Fishmeal (52% CP)	14.0	13.0
Dicalcium Phosphate	1.0	–
Salt	0.5	0.5
Oyster shell	0.5	0.2
Vitamin/mineral premix	0.5	0.5
Lysine	–	0.4
Methionine	–	0.4
Toxin binder	–	0.2
Total	**100**	**100**
Calculated Nutrients, %		
Crude Protein	21.0	19.65
Calcium	1.05	0.92
Available Phosphorus	0.48	0.30
ME (kcal/g)	2910	2748
Methionine, total	0.42	0.81
Lysine, total	1.18	1.00
Sodium	0.32	0.51
Chloride	0.30	0.31

Note: Vitamin A, 8,000,000 IU; Vitamin B_1, 1300 mg; Vitamin B_2, 2500 mg; Vitamin D_3, 3000 IU; Vitamin E, 10,000 IU; Vitamin K_3, 1,500 mg; Vitamin B_6, 1,000 mg; Vitamin B_{12}, 6 mg; Nicotinic Acid, 5,000 mg; Pantothenic Acid, 4000 mg; Choline Chloride, 8000 mg; Copper, 2,500 mg; Cobalt, 700 mg; Iron, 4,500 mg; Zinc, 55,000 mg; Methionine, 50,000 mg; Lysine, 200,000 mg; Selenium (1%), 1,300 mg; Iodine, 2,000 mg; Manganese, 60,000 mg; Antioxidant, 625 mg.

Statistical Analysis

The data on DM, ash, and particle sizes were subjected to the analysis of variance (ANOVA) using the General Linear Model procedure of Minitab (20.0). The mean values of the treatments were compared within the confidence interval adjusted by the Tukey test. All significant differences were determined at $P < 0.05$. The CV of DM, ash, and particle size was calculated using the basic descriptive statistics of the statistical software.

Results and Discussion

Generally, the results revealed that mixing intensities did not influence ($p > 0.05$) DM, ash, or PSD (Tables 2 and 3), irre-

Table 2. Effects of different times of mixing of chicken feed on its DM (%), ash (%), and particle size distribution (g), on-station

Mixing intensity	100 kg							200 kg						
	DM, %	Ash, %	>1000	>500	>250	>75	<75	DM, %	Ash, %	>1000	>500	>250	>75	<75
2	89.84	15.06	108.25	42.24	33.78	ND	ND	86.67	9.124	197.21	42.92	31.60	19.47	20.47
3	86.97	12.32	113.93	43.36	31.49	ND	ND	86.55	9.088	187.86	49.00	31.77	21.40	22.40
4	89.13	14.54	110.94	44.52	30.96	ND	ND	86.55	9.889	184.50	53.31	35.89	17.20	18.20
5	89.07	13.11	114.83	43.96	34.43	ND	ND	86.56	10.431	174.53	48.55	34.39	19.72	20.72
6	89.33	12.32	119.72	46.96	36.11	ND	ND	86.31	8.593	174.54	42.44	29.46	16.46	17.46
7	89.58	14.30	114.27	46.02	32.15	ND	ND	86.40	8.789	182.85	52.11	31.38	20.35	21.35
SEM	0.320	0.522	1.93	0.817	0.711	–	–	0.05	0.287	3.24	1.62	1.27	0.871	0.871
P value	0.111	0.539	0.678	0.618	0.276	–	–	0.117	0.444	0.333	0.260	0.769	0.590	0.590

Note: ND = not determined; SEM = standard error of the mean. Particle size columns (>1000, >500, >250, >75, <75) are in μm.

Table 3. Effects of different times of mixing of chicken feed on its DM (%), ash (%), and particle size distribution (g), on-farm

Mixing intensity	100 kg							200 kg						
	DM, %	Ash, %	>1000	>500	>250	>75	<75	DM, %	Ash, %	>1000	>500	>250	>75	<75
2	89.43	12.34	194.17	51.15	27.09	15.60	7.650^{ab}	89.37	12.62	194.26	53.58	22.05	17.22	9.74
3	89.50	12.93	195.57	53.70	26.36	15.58	5.648^{bc}	89.31	12.29	187.22	59.89	22.48	18.05	9.651
4	89.31	11.59	197.24	49.32	25.36	19.17	6.542^{bc}	89.62	13.05	187.87	56.17	23.37	19.61	9.91
5	89.58	11.45	188.59	53.94	29.18	21.03	5.250^{c}	89.88	15.73	184.70	61.51	22.17	19.12	8.19
6	89.49	11.54	190.83	55.64	28.78	17.60	5.060^{c}	89.92	16.03	182.90	61.00	22.99	19.72	10.16
7	89.72	13.18	184.69	56.32	26.99	18.27	9.730^{a}	89.87	16.45	177.09	59.87	29.41	22.58	7.51
SEM	0.105	0.602	2.21	1.17	0.814	0.684	0.404	0.089	0.719	2.72	1.25	0.959	0.948	0.326
P value	0.936	0.946	0.615	0.536	0.787	0.149	0.001	0.155	0.336	0.629	0.414	0.202	0.713	0.088

Note: SEM = standard error of the mean. Particle size columns (>1000, >500, >250, >75, <75) are in μm. Values with different superscripts within the same column are significantly different at $p < 0.05$.

spective of the quantity of the feed mixed or the study area. However, particle size <75 μm was significantly affected ($p < 0.05$) by the intensity of mixing. This observation is contrary to the hypothesis of this study that the intensity of feed mixing would influence the DM and ash contents of feed. Poor mixing was expected to result in uneven distribution of ingredients, leading to erratic concentration of nutrients in the feed samples (Clark et al., 2007; Rocha et al., 2015). This suggests that even with minimal manual effort, a certain level of homogeneity is achieved. Though a search into the literature does not show any report of the effect of mixing intensity on either the DM or ash content of feed, it could be inferred from the present study that while there may be minor variations in DM, these are often not statistically significant and may be within an acceptable range.

The uniformity of the diets, as indicated by the CV of the DM, ash, and particle size, showed a few lower values (Tables 4 and 5), but this did not follow a consistent trend. For instance, a feed mix of a CV < 5% ensures that the bird receives its formulated dietary allowances 95% of the time. High-intensity mixing is intended to promote uniform mixing, leading to a distributional homogeneity, a correlation not wholly supported by the findings of the present study. In a similar study by Amornthewaphat et al. (1998) involving machine mixing, as the mixing time increased from 15 to 120 seconds, the CV for salt and blue particulate as markers decreased. In the same study, the variation was higher when large maize particles were used at a shorter mixing time, suggesting that larger particles may be more prone to segregation and require a higher intensity of mixing to achieve a uniform mixture, whereas smaller particles mix more uniformly. Though the particle size of the maize used in the present studies was not analysed, it is likely that a larger-than-normal particle size might have been used, as is the practice in most Ghanaian poultry farms.

The relevance of the present study to the performance of birds reared in small-holder farms fed manually mixed diets is worthy of note. A more uniform diet will reduce the time spent by the bird searching for larger particles, and the number of pecks the bird consumes is reduced with larger particle size (Iqbal et al., 2019). The consensus from previous studies seems to be that diets with lower variation give better weight gain and feed efficiency in broilers, increase feed consumption, decrease feed wastage, and improve feed efficiency (Nir et al., 1994a, 1990, 1994b; Yenice et al., 2025). Additionally, the effect of large particle size could be aggravated by the age of the bird, as it has been reported that feed intake decreased in young birds fed a very coarse particle size diet (Jacobs et al., 2010). Chicks are unable to utilise large particle size diets efficiently as the passage through the gizzard is narrower (Amerah et al., 2007, 2008). An undeveloped gizzard is physically unable to break down large grains. On the other hand, the digestive tract of birds fed the fine particle mash diet is likely to become impacted, causing highly viscous digesta from finely ground viscous grains.

One of the limitations of this study is that the samples were collected at the periphery of the mix rather than by vertical stratification, in which case the samples would have been collected from different layers or depths (strata) of the mix. This is critical because feed ingredients, particularly in bulk, often segregate based on density, particle size, or moisture,

Table 4. Effects of different times of mixing of chicken feed on the coefficient of variation (uniformity) of DM (%), ash (%), and particle size distribution (g), on-station

Mixing intensity	100 kg							200 kg						
	DM, %	Ash, %	>1000	>500	>250	>75	<75	DM, %	Ash, %	>1000	>500	>250	>75	<75
2	0.60	25.96	10.56	13.48	12.21	ND	ND	0.26	12.96	9.52	14.22	25.81	23.22	22.18
3	4.35	12.70	10.32	6.90	7.58	ND	ND	0.22	21.39	7.84	3.63	22.50	16.92	16.16
4	1.01	30.39	9.22	14.07	14.65	ND	ND	0.30	9.80	9.26	15.65	17.18	29.99	28.35
5	0.51	13.66	10.46	7.28	10.07	ND	ND	0.28	16.88	10.03	24.66	24.98	34.78	33.10
6	0.20	15.45	8.47	4.68	13.39	ND	ND	0.26	12.22	11.94	20.12	29.42	34.81	32.81
7	0.24	17.72	8.52	12.05	8.28	ND	ND	0.30	24.34	8.13	20.67	12.20	7.52	7.17

Note: ND = not determined. Particle size columns (>1000, >500, >250, >75, <75) are in μm.

Table 5. Effects of different times of mixing of chicken feed on the coefficient of variation (uniformity) of DM (%), ash (%), and particle size distribution (g), on-farm

Mixing intensity	100 kg							200 kg						
	DM, %	Ash, %	>1000	>500	>250	>75	<75	DM, %	Ash, %	>1000	>500	>250	>75	<75
2	0.86	55.83	8.47	20.19	17.40	8.60	32.17	0.60	37.78	8.00	10.55	22.71	28.31	14.82
3	0.35	17.40	5.71	10.10	9.86	19.72	15.56	0.64	31.83	8.53	11.35	24.81	33.28	13.20
4	0.25	12.01	7.25	13.65	17.41	27.77	23.86	0.41	34.30	8.75	12.42	24.54	25.75	13.28
5	1.25	21.40	6.31	9.95	17.72	20.68	41.65	0.37	14.17	7.02	11.15	24.07	26.97	17.50
6	0.55	28.01	3.61	6.45	17.22	10.45	21.09	0.57	28.64	8.99	12.24	16.18	22.37	20.19
7	0.29	15.53	6.37	10.08	20.22	18.93	5.83	0.40	14.56	7.90	11.69	14.79	29.05	27.03

Note: Particle size columns (>1000, >500, >250, >75, <75) are in μm.

leading to nutrient variation between the top, middle, bottom, center, or periphery. It is also possible that the lack of a clear trend in CV relative to mixing intensity in this study implies that factors beyond just the number of turns, such as the physical properties of the ingredients or the technique of the operator, may play a dominant role in achieving uniformity. Thus, it is admitted that operator variability introduced by manual mixing might affect inconsistency, homogeneity and reproducibility of results, as manual mixing relies more on the operator's technique, and it is susceptible to variations in speed, pressure, motion, and time, leading to uneven mixtures and potential batch failures. However, for the smallholder producer, these findings are encouraging, as they suggest that exhaustive mixing may not be strictly necessary to reach an acceptable nutrient distribution.

Conclusion

In conclusion, since there were no differences observed in the DM, ash and PSD relative to mixing intensities, it suggests that these metrics may lack the sensitivity needed to serve as a quick assay for smallholder feed uniformity. For farmers mixing on cemented floors, the lack of a clear trend in CV means they might be over-exerting labour without a measurable return in feed consistency. A follow-up study comparing the results of this study to machine mixing might provide a benchmark to determine if the issue is in the mixing method or the diagnostic tools used.

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