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Production performance of broiler chickens fed mash and pelleted pearl millet-based diets

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Abstract

This study investigated the production performance of broiler chickens (Cobb-500) fed on mash and pelleted pearl millet-based diets. A completely randomised experimental design with a 2 × 3 factorial arrangement of treatments was used. Two feed processing methods (grinding and pelleting) and three replacement levels (50%, 75%, and 100%) were evaluated. A commercial diet (0% pearl millet) was used as a control diet. The pearl millet-based finisher diets were formulated to be iso-nitrogenous (17% crude protein) and iso-caloric (11.5 MJ ME/kg); however, the 75% and 100% pearl millet-based diets had higher crude protein (16% and 16.7%, respectively) and crude fat (6.76% and 8.1%, respectively) concentrations than the maize-based diet (15% crude protein and 4.48% fat). Pelleting substantially increased the crude protein content when maize was replaced with pearl millet at 50% (from 140 g/kg to 164 g/kg) and at 75% (from 160 g/kg to 169 g/kg). Pelleting had no marked effects on the crude protein content of the total replacement (100%) diet. Pelleting negatively influenced the calcium and fat contents of the broiler diets. Replacement of maize with pearl millet grains did not substantially affect the live body weights, weight gains, or feed conversion ratios of the broilers. Pelleting also had no marked impact on the performance of the broiler chickens. Based on the findings of this study, pearl millet can replace maize up to 100% in broiler diets. Pearl millet-based diets can successfully be pelleted, without adverse effects on the feeding value and growth performance of broilers.

Keywords: COBB-500, feed, formulation, intake, maize, replacement, weight
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Introduction

The integration of pearl millet (PM) grains into poultry diets has emerged as a viable strategy for enhancing broiler growth and egg production, capitalising on the genetic advancements and improvements in nutritional management that have contributed to poultry performance. Pearl millet (*Pennisetum glaucum*; also known as *P. americanum* and *P. typhoides*), is recognized for its drought resistance and adaptability to arid and semi-arid climates, such as those found in Namibia and other parts of Africa. This makes PM an excellent crop choice in regions with limited rainfall, where it still manages to produce adequate yields under varying moisture conditions (Bezancon *et al*., 1997; Mallet & du Plessis, 2001).

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There is a growing interest in poultry farming in Namibia, but this is challenged by the high prices of poultry feeds from commercial retailers. Poultry production is one of the sectors providing quality meat protein to people living in both urban and rural areas. Therefore, the possibility of using locally-available feed ingredients needs to receive all the necessary attention.

Nutritionally, PM stands out for its high energy and protein content, surpassing that of traditional cereals like maize, which is beneficial for laying hens (Mehri *et al*., 2010). The rich carbohydrate, lipid, and essential amino acid profile, including higher contents of lysine, methionine, and threonine, enhances its value for use in poultry feeds (Rahman *et al*., 2019; Labetoulle, 2000). The presence of B-complex vitamins and minerals, such as phosphorus and potassium, further support its nutritional superiority (Rahman *et al*., 2019). Research has demonstrated that PM can effectively replace maize in broiler and layer diets without compromising performance, as evidenced by equivalent or improved growth rates, feed conversion ratios, and egg quality (Kumar *et al*., 1991; Amato & Forrester, 1995; Hafeni, 2013). The higher oil content of PM, which is particularly rich in omega-3 fatty acids, contributes to the production of eggs with a favourable fatty acid profile and may enhance feed palatability and growth (Amini & Ruiz-Feria, 2007; Jacob, 2013). The ability of PM to substitute for maize and soybean meal in poultry diets not only addresses nutritional requirements but also presents an opportunity for cost reduction and improved sustainability in poultry production. This is supported by findings indicating that PM-based diets require less soybean meal due to its high protein content and can be processed efficiently with reduced energy usage (Dozier *et al*., 2005; Baurhoo *et al*., 2011; Hanafi *et al*., 2014).

Pearl millet offers a promising alternative to conventional cereals in poultry nutrition, contributing to the resilience and sustainability of poultry production systems, particularly in environments challenged by climate variability and resource scarcity. Its widespread adoption could play an important role in alleviating poverty and enhancing food security in Africa and globally, leveraging the genetic and nutritional advancements achieved in poultry science. Limited information is available on the effects of pelleting PM-based broiler diets on their feeding value as well as the effects of pelleting on the performance of broilers.

Materials and Methods

Ethical clearance for this research was granted by the University of Namibia Research Ethics Committee (UREC) in accordance with the University of Namibia's Research Ethics Policy and Guidelines (Ethical clearance number FANR/25/2015).

This study was conducted at the Neudamm Campus of the University of Namibia, situated between 22°30.105′ S and 017°20.824′ E in the Khomas Region, which is located about 34 km east of Windhoek, the capital city of Namibia. Experimental diets used in this study were formulated to be iso-nitrogenous (17% CP) and iso-caloric (11.5 MJ ME/kg), as per poultry requirements listed by the NRC (1994). Soybean meal, which was used as a source of protein, was purchased from a feed production company in Namibia (FeedMaster). A completely randomized experimental design with a 2 × 3 factorial arrangement of treatments was used: two processing methods (grinding and pelleting), and three replacement levels (50%, 75%, and 100%). A commercial finisher pelleted diet was used as a control.

The main ingredients (maize, PM, and soybean meal) and all experimental diets were analysed for dry matter (DM), crude protein (CP), crude fibre (CF), ether extract (EE), calcium, and phosphorus, according to the official Methods of Analysis (AOAC, 2000) (Table 1). The different replacement levels of maize with PM in the broiler experimental diets are indicated in Table 2. Amino acid profiling was performed using an ultra-performance liquid chromatography technique (Table 3).

A Megazyme Total Starch HK Assay Kit was used to determine the total starch concentration. The total starch essay procedure used was the "determination of total starch content of samples containing resistant starch (RTS-NaOH Procedure - Recommended)" as described in the manual.

The metabolizable energy (ME) content was determined using the following equations:

1. Firstly, the following equation was used to calculate the nitrogen free extract (NFE):

$$NFE = 100\ - (Moisture + CP + EE + CF + Ash) \tag{1}$$

2. Secondly, the digestible energy (DE) was determined in MJ/kg using the equation described by Noblet & Perez (1993):

$$DE = 00.479\, CP\,\% \,+\, 0.472\, EE\,\% \,+\, 0.375\, NFE\,\% \,-\, 21.2 \tag{2}$$

3. The ME in MJ/kg was then calculated using the equation described by May & Bell (1971):

$$ME \,=\, DE \,\times\, (1.012 \,-\, (0.0019CP\,\%)) \tag{3}$$

Since the results obtained from the laboratory analyses were on a DM basis, the following equation was used to convert these results to an ‘as is’ basis for final mixing:

$$Ingredient\ nutrient\ content\ (as\ is) = \frac{DM\ basis}{100} \times (100 - Moisture) \tag{4}$$

Table 1 Nutritional composition of the main ingredients used to formulate the experimental diets

Chemical component (g/kg DM)	Pearl millet	Maize	Soybean meal
CP	110	60	490
CF	29	26	42
Ash	15	18	70
EE	52	43	10
ADF	69	48	94
NDF	28	18	21
Ca	0.2	0.2	0.3
P	3	3	7
Starch (g/100 g)	37.805	39.051	

DM: dry matter; CP: crude protein; CF: crude fibre; EE: ether extract; ADF: acid detergent fibre; NDF: neutral detergent fibre, Ca: calcium; P: phosphorus

Table 2 Different replacement levels of maize with pearl millet in broiler experimental diets

Ingredients	Commercial diet	Inclusion levels of pearl millet		
		50%	75%	100%
Maize	100	37.4	19	0
Pearl millet	0	37.4	58	79.2
Soybean meal	-	25.2	23	20.8
Vitamin-mineral premix	-	0.3	0.3	0.3
Sodium chloride	-	0.3	0.3	0.3
Vegetable oil	-	0.3	0.3	0.3
Sodium bicarbonate	-	0.1	0.1	0.1
Limestone	-	0.25	0.25	0.25

Table 3 Amino acid profiles of pearl millet and maize grains used to formulate the experimental diets

Amino acids (g/100g)	Pearl millet	Maize
Arginine	5.30	3.40
Serine	4.00	3.00
Aspartic acid	6.70	4.00
Glutamic acid	16.3	11.1
Glycine	2.90	2.40
Threonine	3.40	2.40
Alanine	6.40	4.40
Tyrosine	3.70	2.80
Proline	4.70	5.10
HO-proline	0.20	0.20
Methionine	1.20	0.80
Valine	4.50	0.28
Phenylalanine	4.00	2.80
Isoleucine	3.60	2.10
Leucine	8.20	6.60
Histidine	3.20	2.20
Lysine	3.50	2.00

The data were analysed by two-way analysis of variance (ANOVA) using the general linear models procedure of the IBM SPSS Statistics 25 (2017) package, with methods of feed processing and replacement levels as factors. When the interaction was not found to be significant, the effects of the individual factors were considered. When interactions were significant, separate analyses were conducted within each main effect. Differences were considered to be significant at P <0.05 and the significant differences between the means were determined using Duncan's multiple range test.

The data were analysed as a 2 × 3 factorial arrangement of treatments, evaluating the effects of two processing methods (mashing and pelleting) and three replacement levels (50%, 75%, and 100%), and their interactions. The model used was (Equation 5):

$$Yijk = \mu + Ai + Bj + (AB)ij + \varepsilon ijk \quad (5)$$

where: $Yijk$ = observation k in level i of methods of feed processing (factor A) and level j of the replacement levels (factor B); μ = the overall mean; Ai = the effect of level i of the two feed processing methods (i = 1,…,a); Bj = the effect of level j of the three replacement levels (j = 1,…,b); and εijk is the random error term (k = 1,…,n).

Results and Discussion

Based on the results of this study, pelleting substantially affected some of the nutrient contents of the PM-based broiler diets, but did not affect the productive performance of the Cobb-500 broilers. Although the experimental diets were formulated to be iso-caloric (11.5 MJ ME/kg) and iso-nitrogenous (17% CP) using the Pearson square feed formulation equation and a trial-and-error feed formulation software, the proximate analysis results yielded different concentrations for CP. The CP concentrations calculated by the feed formulation software when maize was replaced with pearl millet at 50%, 75%, and 100% were 18%, 6%, and 0.6% higher than those obtained from proximate analysis. Based on these results, the prediction accuracy of the feed formulation software seems to have increased with the increasing replacement of PM. Limited information is available on how different types of cereals may influence the proximate analysis of broiler diets formulated using a trial-and-error method of feed formulation. In this study, the CP concentration determined using proximate analysis of the total replacement (100% PM) diet was much more similar to the CP concentration obtained from the trial-and-error feed formulation method than was found for the 50% and 75% PM replacement diets. More research is required to determine the effects of cereal feed ingredients on the chemical composition of broiler diets when trial-and-error is used as a feed formulation method.

Table 3 The nutritional composition of broiler finisher diets when maize is replaced with pearl millet grains at 50%, 75%, and 100%, and the diet is produced as a mash or pelleted

Nutrients (g/kg)	Mash diets			Pelleted diets					
	50%	75%	100%	Commercial	50%	75%	100%	*P*-value	±SEM
DM	920^{abcd}	940^{abc}	950^{abc}	920^{abcd}	910^{ad}	920^{abcde}	920^{abcd}		0.655
CP	140^{a}	160^{c}	167^{d}	150^{b}	164^{cd}	169^{d}	165^{cd}	0.000	0.149
CF	31.4^{a}	42.8^{a}	37.6^{a}	45.9^{b}	22.3^{a}	24.7^{a}	16.7^{a}	0.003	0.328
EE	55.9^{a}	67.6^{b}	81.2^{c}	44.8^{d}	50^{e}	56.9^{a}	64.9^{f}	0.000	0.043
Ca	4.2^{a}	4.9^{b}	5.0^{bc}	6.1^{d}	3.2^{e}	3.1^{ef}	2.9^{f}	0.000	0.006
P	5	6	7	6	5	6	6	0.507	0.057
Ash	50^{abcd}	60^{ab}	50^{abcd}	50^{abcd}	40^{acd}	40^{abcd}	40^{acd}	0.243	0.354
Starch (g/100 g)	31.927	33.199	33.090	32.279	30.398	38.353	35.514		
ME (MJ/kg)	9.35	12.27	12.58	11.40	12.59	12.77	13.22		

DM: dry matter; CP: crude protein; CF: crude fibre; EE: ether extract; Ca: calcium; P: phosphorus, ME: metabolisable energy

[Abcd] Means in a row not sharing a common superscript are different (P <0.05)

The pelleted PM-based diets (75% and 100%) exhibited higher CP (16% and 16.7%, respectively) and EE (6.76% and 8.1%, respectively) concentrations than the maize-based diet (commercial/control diet), which contained 15% CP and 4.48% EE.

Pelleting substantially increased the CP concentrations of the 50% and 75% PM diets, from 140 g/kg and 160 g/kg to 164 g/kg and 169 g/kg, respectively. Pelleting had no marked effect on the CP concentration in the total replacement (100% PM) broiler finisher diet (mash: 167 g CP/kg; pellets: 165 g CP/kg). Pelleting negatively influenced the calcium concentrations of all three PM-based diets (50%, 75%, and 100%), reducing it from 4.2 g/kg, 4.9 g/kg, and 5.0 g/kg, respectively, in the mash to 3.2 g/kg, 3.1 g/kg, and 2.9 g/kg, respectively, in the pelleted feeds. Therefore, the addition of a calcium supplement is required at diet formulation if PM diets are to be pelleted.

Feed processing is generally known to have the potential to affect the chemical composition, nutritive quality, and functionality of feed products. Pelleting substantially increased the CP concentration when maize was replaced with PM at 50% and 75%. However, pelleting had no effect on the CP concentration of the total replacement (100% PM) broiler diet. According to Medel *et al*. (2004), both the physical (e.g., reduction in particle size) and chemical (e.g., alteration of the molecular structures of the feed components) changes resulting from feed processing may reduce or increase the nutritional quality of feeds. The increased CP concentrations caused by pelleting observed in this study may be attributed to protein densification due to the pelleting process. According to a review by Sivhus (2017), the process of pelleting enhances the availability of protein through the destruction of enzyme inhibitors present in the native form of proteins. This may result in the exposure of nutritive components that were initially encapsulated in the endosperm, as well as enhancing enzyme activity through protein denaturation (Sivhus, 2017).

As highlighted above, the results of this study indicated that pelleting had no marked effect on the CP concentration of the total replacement (100% PM) broiler diet. This may suggest that the normal pelleting temperature used to pellet the experimental diets for this study (~80 °C) was only sufficient to induce structural changes, resulting in protein denaturation in the diets containing higher proportions of maize, and was not sufficient to do this in the 100% PM diet. In other words, these finding suggests that the source of protein may influence the extent of denaturation that takes place during pelleting at normal temperatures. This may mean that when pelleting at normal pelleting temperatures (60–90 °C) it is easier to denature protein sourced from maize than protein from PM. A study by Sunde (1972) indicated that, if done properly, heating raw feed ingredients during pelleting may result in better availability of nutrients. Protein denaturation, which entails a considerable change in the secondary, tertiary, and quaternary structures of a protein, is said to occur because of the application of high temperatures, moisture, and friction during pelleting (Wood, 1987; Thomas *et al*., 1997). There is limited information on the effects of pelleting on the CP contents of PM-based broiler feeds, and it was therefore not possible to compare our findings with those of previous studies.

This study also found that the mash diets contained more fat (EE) than the pelleted diets. Pelleting involves the application of heat and moisture, and this could be the reason for the reduced fat concentrations of the pelleted diets. Pelleting also negatively influenced the calcium concentrations of the experimental diets. Calcium is a mineral that may be negatively affected by the application of high temperatures during pelleting, and it is therefore always advisable to supplement diets using vitamin–mineral premixes. According to Abdollahi (2011), the very high conditioning and pelleting temperatures used by industrial machines during feed production aimed at producing high quality pellets tend to have a detrimental impact on the nutritive quality of the pellets. Proximate analysis of the experimental broiler diets used in this study revealed that pelleting had no effect on the ash, DM, and phosphorus concentrations of the diets.

The PM-based broiler diets had substantially higher CP concentrations than the maize-based diet. The high concentrations of CP in the PM-based broiler diets may be attributed to the higher CP and amino acid concentrations found in PM grains than in maize. Although the exact mechanism underlying the increased CP concentrations in the PM-based diets is not clear, given the absence of literature to support the findings of this study, it is clear that PM contains beneficial nutritional factors. The quality of the CP in feed ingredients is determined by the balance of the essential amino acid profile, rather than by the dietary CP concentration (Appleby, 2010). Because of the high CP concentration in PM, the PM was partially substituted for soybean meal in the diets while replacing maize, resulting in a reduced quantity of soybean meal being used in the PM-based diets.

The results of this study indicated that increasing the proportion of PM as a replacement for maize in broiler diets increased the fat (EE) concentration. The high concentration of fat in the PM-based diets may be attributed to the high concentration of fat in the PM grains, as indicated by proximate analysis (Table 1). Amini & Ruiz-Feria (2007) indicated that PM has a higher oil content than maize, with an average fat concentration of 5%. Linolenic acid makes up 4% of the total fatty acids in this oil, making PM a better source of omega-3 fatty acids than maize (Jacob, 2013).

The calcium concentrations of the experimental diets increased markedly with the level of replacement of maize with PM. These findings could be the result of the high calcium concentration found in PM, relative to maize.

There were no statistical differences in daily feed intake between the broiler chickens fed the maize-based control diet and those fed the PM-based diets (Table 4). These results are in contrast with those of Ghazi *et al*. (2012), who reported higher feed consumption of pelleted than mash diets. This observation partly disagrees with the results of Choi *et al*. (1986), who found that broilers tended to eat more of a pelleted diet, improving the growth rate, since results of this study recorded heavier birds for pelleted diets, with less feed intake.

Based on the findings of the current study, the replacement of maize with PM did not affect live body weight, weight gain, or the feed conversion ratio (FCR). These findings agree with the findings reported by Kwari *et al*. (2014) who reported no marked effect on weight gain when maize was replaced with PM grains in broiler diets. However, they are in contrast with the findings of Ibe *et al*. (2014), who reported higher weight gains for broilers fed PM-based diets than those fed maize-based diets. These differences may be due to the different cultivars of PM used in the two studies, as well as the environmental conditions under which the PM grains were cultivated.

Table 4 Effects of experimental diets containing varying amounts of pearl millet (as a replacement for maize) on the growth performance of Cobb-500 broiler chickens

Processing method	Replacement level	Weight gain (kg)	Feed intake (kg)	FCR
Mash	**50%**	1.35 ± 0.25	1.92^{a} ± 0.12	1.49 ± 0.36
	75%	1.10 ± 0.01	2.03^{a} ± 0.17	1.85 ± 0.14
	100%	1.12 ± 0.10	2.54^{b} ± 0.0.05	2.29 ± 0.25
Pelleted	**50%**	1.30 ± 0.10	2.10^{a} ± 0.08	1.63 ± 0.18
	75%	1.10 ± 0.01	2.03^{a} ± 0.17	1.85 ± 0.14
	100%	1.15 ± 0.01	1.89^{a} ± 0.12	1.64 ± 0.09
Control	**0%**	1.24 ± 0.16	1.90^{a} ± 0.10	1.56 ± 0.28
***P*-value**		0.949	0.162	0.396

FCR: feed conversion ratio
^{ab} Means in a column not sharing a common superscript are different ($P < 0.05$)

No statistical interactions between processing methods and replacement levels were observed for the average feed intake, body weight, weight gain, or FCR. Furthermore, neither pelleting nor replacement levels substantially influenced the average feed intake, body weight, weight gain, or FCR of the COB-500 broiler chickens. These findings contradict the findings of Ghazi *et al*. (2012), who recorded the highest (1103.73 g) body weight in broilers fed on a pelleted diet and lowest (941.53 g) body weight in broilers fed on a mash diet from weeks 1–4 of the growing period. Munt *et al*. (1995) similarly reported that feeding mash diets substantially reduced the growth performance of broilers. A study by Kim & Chung (1996) indicated that broilers fed on a mash diet had the lowest live body weight at 41 d, relative to those fed on crumbled and pelleted diets.

Conclusion

Based on the results of this study, it can be concluded that PM grains can be used as a total replacement for maize in broiler diets, with no marked effects on the production performance of the chickens. Pelleting the PM-based broiler diets also had no marked effects on their feeding value or the performance of the broilers fed the diets.

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Author's contributions

HSS conceived, designed (with the assistance of Prof. I.D.T Mpofu, an experienced animal nutritionist) and conducted the experiments. HSS performed statistical analyses of the data in the experiments with the assistance of a biostatistician. HSS revised the manuscript. The author read and approved the finalised manuscript.

Conflict of interest declaration

The author declares no conflict of interest.

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