EFFECTS OF PELLETING PEARL MILLET-BASED DIETS ON THE PERFORMANCE OF BROILER CHICKENS

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ABSTRACT

This study evaluated the effects of pelleting and replacing maize with pearl millet (PM) cultivar (Okashana 2) on the production performance and cost efficiency of broilers. The experimental design used in this study was a Completely Randomized Design with a 2 x 3 factorial arrangement of treatments (i.e. two processing methods (grinding and pelleting) and three replacement levels (50%, 75% and 100%). A commercial finisher pelleted diet was used as a positive control. The first experiment investigated the effects of pelleting on nutritional composition of broiler diets when maize was replaced with PM at 50%, 75%, and 100% levels. The second experiment examined the influence of pelleting on the growth performance of broiler chickens. In this study, the effects of pelleting and replacing maize with PM on the carcass characteristics, gizzard and proventriculus as well as the cost efficiency of broiler production were determined. Results from this study revealed that PM grains had higher ($P<0.05$) CP, fat and essential amino acids content compared to maize grains. Pelleted diets had higher ($P<0.05$) CP contents compared to their respective mash diets. Pelleting reduced ($P<0.05$) crude fibre, calcium and fat contents of broiler diets at all replacement levels. A combined effect of grinding and pelleting indicated that pearl millet based broiler diets contains high CP, fat and calcium contents compared to maize based diets. Pelleting had no significant effects ($P>0.05$) on the feed intake, live weights, weight gain, feed conversion ratio (FCR) and mortality rate of broiler chickens. Pelleting increased carcass weight significantly when maize is replaced with PM at 50%. Replacing maize with PM had no significant influence ($P>0.05$) on the feed intake, live weights, weight gain and FCR of broiler chickens. Replacing maize with PM grains had no significant effect ($P>0.05$) on the carcass characteristics of broiler chickens. Replacing maize with PM had no significant effect ($P>0.05$) on the development of the gizzard and proventriculus. Replacing maize with PM had no significant ($P>0.05$) effect on feed production costs of broiler diets. Pelleting had no significant effects ($P>0.05$) on the cost of feeds required per 1 kg of weight gain. Due to similar gross margins observed for mash and pelleted diets, when feeding broilers, producers may choose to use either of them based on their own preferences. This study revealed that PM based diets can successfully be pelleted and replace maize up to 100 % without any adverse effects on growth performance, carcass characteristics and feeding costs. The optimal replacement level in this study was found to be 50 % PM, which yielded high weight gain, carcass weight and better FCR.

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LIST OF ABBREVIATIONS

ADF	Acid Detergent Fiber
ANOVA	Analysis of Variance
Ca	Calcium
CF	Crude Fiber
CP	Crude Protein
CV	Coefficient of Variation
DCPP	Dry Land Crop Production Program
DM	Dry Matter
EE	Ether Extract
FCR	Feed Conversion Ratio
LSD	Least Significant Difference Test
MAWF	Ministry of Agriculture Water and Forestry
NAB	Namibia Agronomic Board
NCRs	North Central Regions
NDF	Neutral Detergent Fiber
NRC	National Research Council
P	Phosphorus
PM	Pearl Millet
PM1	Pearl Millet Okashana 1
PM2	Pearl Millet Okashana 2
PMK	Pearl Millet Kangara
PMT	Pearl Millet Traditional

UREC	University of Namibia's Research Ethics Committee

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DECLARATIONS

I, Sesilia Hafeni-Shihepo, hereby declare that this study is my own work and is a true reflection of my research, and that this work, or any part thereof, has not been submitted for a degree at any other institution.

I, Sesilia Hafeni - Shihepo, grant The University of Namibia the right to reproduce this dissertation in whole or in part, in any manner or format, which The University of Namibia may deem fit.

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Name of Student Signature Date

CHAPTER 1: GENERAL INTRODUCTION

1.1. Background

Cereal grains supply poultry with a major part of their energy requirements here in Namibia and many other parts of the world. Modern commercial broiler chickens are genetically selected for improved growth rate and low feed conversion ratio (i.e. high feed conversion efficiency). Studies have shown that today's fast-growing broiler chickens can attain 2 kg of their body weight within 5 weeks, with feed intake of 3 kg (Choct, 2009). According to Klasing (2007), the rapid growth in modern broilers is due to increased feed intake rather than high nutrient digestibility. Therefore, high feed intake is said to be the most important factor which determines the feed efficiency for broiler chickens (Bao and Choct, 2010). A number of factors such as physical feed modification, feed quality, and diet nutrient density tend to influence the amount of feed intake by the broilers (Jafarnejad et al., 2010). However, physical modification and handling of the feed seem to have greater effect on the growth performance of broiler chickens (Jafarnejad et al., 2010). This makes processing of broiler chicken feeds to be important.

Although maize is a major ingredient in chicken diets (Panda et al., 2010), it is scarce in semi-arid countries such as Namibia, and hence costly to import (Medugu et al., 2010). On the other hand the cereal pearl millet (PM) is a staple food in Namibia, yet it is not used as the main source of energy in commercial broiler feeds. Most farmers in the northern part of the country are subsistence farmers, producing rain-fed PM grains for a living. Pearl millet is found to have high protein (12-14 %) and lysine (0.38-0.41 %) contents as compared to maize and sorghum (Garcia and Dale, 2006).

Pearl millet is known for its ability to grow under arid to semi-arid environments and frequently referred to as a drought resistant cereal crop by some researchers (Mehri et al., 2010). Since Namibia's environmental conditions favors PM production, a bit of work on rain water harvesting for supplemental irrigation would put Namibian economy at another level with increased pearl millet production.

Developed countries have recently recognized the value of PM as a cereal crop and foremost of greater value as a replacement of maize in poultry diets. For example, research by Singh et al. (2009) identified PM as a suitable alternative, efficient and cost effective feed source for the Australian meat chicken industry. Maize which has been used in poultry diets is becoming much more expensive due to its increased variable usage developments such as bio-diesel production, brewery and starch industry (Tornekar, et al., 2009) as well as the fact that maize production requires a lot of water and the amount of water in the whole world is reducing considerably as a result of global warming. Namibia and the rest of African countries with the ability to grow PM, with less harvested rain water used for supplemental irrigation, may grab the opportunity to grow more PM not just to feed the local people but for exportations as well.

The Namibian government has invested a considerable amount of efforts through its Dry Land Crop Production Program (DCPP) assisting farmers with subsidized farm inputs (fertilizers and improved seeds i.e. pearl millet Okashana 2 cultivar) and agricultural services (ploughing and weeding services i.e. tractors) (MAWF, 2014). In the cropping season 2014/2015 alone, the Namibian government managed to distribute a total 130 000 (one hundred and thirty thousand) tonnes of PM and sorghum seeds to communal farmers through its subsidy program (MAWF, 2014). In addition to the Pearl millet Championship program put in place by the government of Namibia; more need to be done with some assistance from education-institutions of high learning to empower farmers more on the importance of producing PM.

Gazetted in May 2008, as a controlled crop under the Agronomic Industry, Act 20 of 1992, Pearl millet was accorded the similar status as maize and wheat in Namibia (NAB, 2011). In Namibia, PM prices can be determined separately based on its production inputs unlike in the past when its prices were based on that of maize. Therefore, there is a potential for the recent agricultural graduates to venture into PM production as poultry feed to cater for both the local and international markets. The use of PM in poultry feeds reduces the amount of protein source required Baurhoo et al. (2011b). This means that, instead of Namibian poultry feed producing companies importing very expensive plant protein sources, may utilize any much lower plant protein source produced locally.

According to Behnke and Beyer (2002), a significant portion of the 70 to 80 percent attributed to feed costs in livestock production is associated with feed processing which influences the performance of broilers. Feed processing techniques include grinding, proportioning, dry and wet heat treatment, blending, pelleting, flaking, removal of anti-nutrients and extrusion. Processing techniques to be used usually depend on facilities available, cost, as well as the purpose of production (Abdollahi, 2011). Physical form of broiler chicken diets can be crumbs, pellets, or mash. Mash is coarsely ground/milled feed while pellets are in form of feed compressed or compacted biomass (FAO and IFIF, 2010). Crumbs are pellets broken down or crumbed into small pieces for the young chicks in the starter age to be able to swallow the feed. There is limited scientific evidence that can be used as a guide by less privileged poultry farmers in developing countries, on feed form selection given the poor housing infrastructures and environmental conditions available to them.

Currently, farmers in the poultry industry are faced with many challenges as a result of high costs of feed ingredients, which necessitated a closer look at both feed formulation and manufacturing processes. Therefore, farmers worldwide are looking up to animal nutritionists and feed manufacturers to: determine least cost diets which yield the highest profit margins; evaluate the effects of particle size on nutrient utilization; determine the value of reducing the amount of percentage fine particles in the feed (Stark, 2012). These may be achieved through research on the utilization of local feed ingredients supplemented by efficient feed processing methods to ensure good feed quality, high nutrient density and improved palatability among other factors.

A study conducted by the Ministry of Agriculture, Water and Forestry (MAWF) (2008) revealed that there is an increasing demand of about 60, 000 kg per month of chicken meat in the northern regions of Namibia alone. Until recently when the Namibia Poultry

Industry opened its doors in 2012, Namibia has been considered as a net importer of both eggs and chicken mainly from South Africa. Currently chicken in Namibia is regarded as a luxury. A 2 kg packet of chicken which used to cost about N$40 (when imported from South Africa) now costs over N$90 (when produced locally) (Personal observation). More research is required to identify possible ways to address this shortage because chicken is a very good source of protein which is required by all Namibians.

Chicken production in Namibia especially in rural areas is very low with most households owning less than 15 chickens (Petrus, 2011). This is mainly due to both the scarcity and high costs of the ingredients used in manufacturing high quality chicken feeds. Chicken feeds which are available at the major feed company in Namibia, i.e. the Feed Master Ltd, are produced using imported feed ingredients which make the feed unaffordable to Namibian rural farmers. A significant reduction in feed costs has been reported elsewhere when broilers are fed PM based diets compared to maize based diets (Elangovan et al., 2003). Pearl millet grains can easily be cultivated in arid to semi-arid areas by farmers with limited resources at minimal costs as compared to other cereal crops such as maize and sorghum (Hanafi et al., 2014). Clearly, there is a potential in utilizing PM in broiler chicken diets as a means to reduce feed costs.

A reasonable amount of research has been carried to provide evidence that PM can be utilized as a main source of energy in broilers diets (Burton, et al., 1972; Smith et al., 1989; Hildalgo et al., 2004; Jacob, 2013). However, limited research evidence is available on feed processing and handling parameters of PM grains when used in broiler diets. Pearl millet in its natural form is difficult to handle due to its small sized grains (Hafeni, 2013). A study by Dozier et al. (2005) has shown that PM grains require less energy hence processing costs compared to maize grains. There is limited information on the effects of processing PM based broiler diets (especially pelleting) on its feeding value as well as the performance of broiler chickens. Therefore, there is need to research on how processing of PM based broiler diets through pelleting can improve broilers productivity.

It has become a common practice in the poultry industry worldwide, to feed layers with mash diets while broilers are fed pellets. In developing countries like Namibia, feed production companies tend to have no choice but to adopt the technologies of pelleting as a necessity for broiler feed production, although at an extra cost due to the use of high energy consuming pelleting machines. The high costs of processing equipment seems to have discouraged the setting up of poultry feed start-up companies, resulting in a limited supply of local chicken and low contribution of poultry production to the Gross Domestic Product of 0.71 % (Matthys, 2018). Scientific research is required to investigate the effects of feeding pelleted diets compared to mash diets on the productivity of broilers in arid to semi-arid regions given their harsh environmental conditions, poor poultry housing infrastructures in addition to the limited power supply, especially in the rural areas. The main objective of this study was to determine the effects of pelleting on the feeding value of PM based diets as well as production performance and economics of broiler chickens fed graded levels of PM as a replacement of maize.

1.2 Problem statement

Cereal grains are well known to be the primary energy source in broiler diets. The past few years have seen a considerable increase in many uses of maize grains resulting in high prices of poultry feeds in the world. As a response to the ever increasing world population and effects of global warming there is a need to identify alternative feed resources with low cost of production such as PM grains to replace maize. The high demand of poultry products in Namibia has been satisfied by imports mainly from South Africa. Until now, there are no commercial poultry breeders hatcheries in Namibia to supply day old chicks to local farmers, therefore many local farmers are forced to import day old chicks mainly from South Africa.

The main source of poultry production challenges in Namibia is lack of poultry affordable feed. Currently, there is only one commercial broiler feed producing company in Namibia. The problem with this current situation is that, the feed company has to meet the feed demands for its own poultry before it can sell the excess to the rest of poultry farmers. The high prices of imported maize and soya bean meal may have been caused by absence of research on the local alternatives to poultry feed ingredients. Very limited financial resources have been directed on research to identify local alternative feed resources for poultry feeding purposes in Namibia. Therefore, PM which is an ideal alternative for maize in poultry feed is still produced by subsistence farmers in Namibia. Pearl millet is well known for its high protein (12-14 %) and lysine (0.38-0.41 %) contents as compared to maize, corn and sorghum (Garcia and Dale, 2006). Since PM is a great source of protein and amino acids which are the most limited and expensive nutrients in poultry nutrition, its use in poultry diets may reduce the amount of protein sources, such as soybean meal, required for feed formulation. Furthermore, PM is considered to be difficult to handle nutritionally by birds, therefore, it is necessary to identity appropriate processing techniques that promotes optimum feed utilization efficiency. Although whole PM grains can successfully be incorporated in chicken feeds grinding the grains may be necessary to compliment the fast growth genetic traits of broiler chickens.

Particle size reduction is necessary to increase the surface area of the feed, thus allowing for greater interaction with digestive enzymes. Feed processing methods such as grinding and pelleting may have different effects on both the feed value and performance of broilers. Research on the utilization of local ingredients and exploring the optimum levels of PM as an energy source to ensure feed quality, lower bulk density and high palatability, is crucial as attempts to reduce feed costs and promote optimum feed utilization efficiency. Livestock nutrition, especially value addition of local feed ingredients; need to be given a special consideration. There is limited scientific knowledge on how poor housing infrastructures and environmental conditions mostly faced by less privileged poultry farmers in developing countries, such as Namibia may influence the choice of poultry feed form (pellets or mash) to be utilized.

1.3 Objectives

1.3.1 General Objective

The main objective of this dissertation was to investigate the effects of pelleting PM based broiler diets on the nutritional composition as well as the production performance and feed cost efficiency of broiler chickens.

1.3.2 Specific Objectives

Specific objectives of the study were to:

i. Determine the effects of pelleting and replacing maize with PM (at 50; 75 and 100%) on nutritional composition of broiler diets.

ii. Determine the effects of pelleting and replacing maize with PM (at 50; 75 and 100%) on the growth performance of broiler chickens.

iii. Determine the effects of pelleting and replacing maize with PM (at 50; 75 and 100%) in diets on carcass characteristics, gizzard and proventriculus weights of broiler chickens.

iv. Determine the effects of pelleting and replacing maize with PM (at 50; 75 and 100%) on the feed cost efficiency of broiler production.

1.4 Hypotheses

i. Ho_1: Pelleting and replacing maize with PM (at 50; 75 and 100%) had no effect on the nutritional composition of PM based diets.

ii. Ho_2: Pelleting and replacing maize with PM (at 50; 75 and 100%) had no effect on the growth performance of broiler chickens fed on PM based diets

iii. Ho_3: Pelleting and replacing maize with PM (at 50; 75 and 100%) had no effect on carcass characteristics, gizzard and proventriculus weights of broiler chickens fed PM based diets

iv. Ho_4: Pelleting and replacing maize with PM (at 50; 75 and 100%) had no effect on the feed cost efficiency of broiler production when maize is replaced with PM

1.5 Significance

This study was carried out in order to investigate the efficacy of pelleting PM based broiler diets when maize is substituted with PM locally grown in Namibia. The study therefore, provided an understanding on the influence of pelleting PM based diets on broiler performance as well as the economics of broiler production. The study aimed at increasing growth performance of broilers, which would eventually promote broiler meat production in Namibia through pelleting PM based diets. Local poultry feed manufacturers stand to benefit from the results of this study as they are likely to start using PM as an alternative energy source to the imported maize either as pellets or mash. Increased efficacy in broiler production has a potential to increase the contribution of chickens to the livestock Gross Domestic Product of Namibia and possibly lower the consumer price.

1.6 Limitations

This study involved brooding of chicks and rearing of chickens, therefore, threats of cold winter to chickens and diseases were a major limitation to the study. Although, a normal flock health program was put in place as an effective delimitation strategy, the poor poultry housing infrastructures at Neudamm campus made it hard to control the extreme temperature changes inside the experimental house. However, by employing temperature control measures such as lighting charcoal heated drums just before the sunset in addition to infrared bulbs fitted in the house as well as a fan to optimize air circulation, the experiment was a success. Due to a lack of feed processing happening as a result of limited broiler chicken feed production in Namibia, sourcing of the pelleting machine as well as its technical and operational skills was a huge challenge. However, these were acquired after protracted negotiations which delayed the start of certain stages of research project. Furthermore, with financial support from the University of Namibia's Staff Development Funds (SDF), Department of Animal Science and family, data collection was done judiciously.

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CHAPTER 2: LITERATURE REVIEW

2.1. Background

The poultry production industry has long been identified as an integral part of economic growth of any nation. This is due to the fact that the poultry industry has a huge potential to generate employment. Furthermore, poultry production is capable of supplying regular protein for human consumption, thus addressing supply gaps of animal protein (Anang et al., 2013). Chicken meat and eggs industries have been growing remarkably worldwide, with North and South America and Asia still continuing to supply the bulk of the world's demand (Leeson, 2008), including significant supplies to Africa. Developing countries including Namibia are yet to discover and utilize the full potential of chicken farming to improve household food and nutrition security as well as farm incomes including contributing to Gross Domestic Product. Farmers in arid to semi-arid countries like Namibia are mostly affected by low rainfalls, high environmental temperatures as well as poor soil fertility. Chicken production in developing countries is also challenged by low supply of day old chicks, short falls in supply of veterinary drugs but more importantly very high costs of feeds. The later point is significant in that up to 80% of poultry production costs are basically feed costs.

2.2. Challenges of chicken production in Namibia

Poultry nutrition researchers, in Namibia and Africa at large, are faced with a challenge of pinpointing local barriers to effective chicken production. Lack of knowledge on feed formulation and processing as means to enhance feed quality in addition to high prices of commercial feeds are some of the major challenges faced by farmers in Africa.

Nutritionists in this regard are expected to base their research studies on improving quality of locally available feed ingredients and possibilities of further processing these feeds. Furthermore, poultry nutritionists are also expected to research into improving digestion in chickens as a mean of improving feed utilization (Ravindran, 2012) to reduce the nutrients excreted. The same author also suggested that improving feed utilization is very important because in the past chicken feed formulation was mostly based on increasing the production efficiency to meet the progress achieved in the genetic potential of broilers and layers. As a result, excessive nutrients were being added into diets in order to meet the chicken's nutritional requirements as per recommendations. Approximately, broilers lose almost 25-30% of ingested dry matter, 20-25% of gross energy, 30-50% of nitrogen and 45-55% of phosphorus intake in the excreta (Ravindran, 2012). The excess nutrients when excreted become potential pollutants which threatens the wellbeing of the environment and its habitants.

Although poultry nutrition is researched very well in other countries, Namibia is still to realize and value the potential of research in poultry nutrition. Research enabled other nations worldwide to succeed in genetic selection which resulted in fast growing broiler chickens and high egg producing layers (Ravindran, 2012). Genetic selection is responsible for up-to 90% improvements in broiler growth and advances in nutritional management have provided 10-15% of the changes (Havenstein et al., 2003). Currently, male broilers weigh about 3 kg at 42 days of age as a result of consuming just less than 5 kg of feed and female broilers weight 1.7 kg at 30 days of age (Leeson, 2007; 2008). The white egg layers seen to-date are capable of producing in excess of 330 eggs in 52 weeks of lay (Leeson, 2008). Furthermore, research enabled other nations to avail vaccines, antibiotics and disseminate the awareness of proper hygiene as well as the importance of biosecurity on chicken farms (Leeson, 2007). Research for sure, may deliver Namibians in particular and Africans at large, from poverty. Research aimed at identifying and studying the potential of local feed ingredients may make a major contribution in alleviating poverty in Africa.

2.3. Status of pearl millet production in Namibia

Pearl millet (PM) which is locally known as Mahangu is a cereal crop comparable to maize, sorghum, wheat and barley. The taxonomic name for PM is *Pennisetum glaucum*, but it is also known as *P. americanum* and *P. typhoides*. Pearl millet is known for its ability to grow under arid to semi-arid environments and frequently referred to as a drought resistant cereal crop (Mehri et al., 2010). Pearl millet is a common traditional staple food cereal crop in most arid and semi-arid tropical zones of Africa and other parts of the world. Pearl millet is grown mostly in areas that receive approximately 150 mm to 800 mm of rain fall per annum (Bezancon et al., 1997). It is resistance to moisture stress, adaptable to high temperatures but generally commands low yields of 0. 6 t/ha under rain fed dry conditions and over 0.8 t/ha under wetter conditions (Mallet and du Plessis, 2001).

Some years back, high quality PM due to its superior crude protein content compared to other cereal and its shortage of supply in Namibia prompted the Government of Namibia to venture into searching for ways to increase its supply to the local people. The

Government of Namibia through the Namibia Agronomic Board (NAB) looked into the possibility of importing PM from other parts of Africa. Unfortunately, it was an expensive exercise to import enough PM to meet the country's demand. The Government of Namibia further pursed the possibility of breeding PM cultivars which yields higher outputs in a given short period of time, complementing the Namibia short rainy seasons. Sadly, the adoption of new cultivars by the local farmers has been slow over the years. However, in recent years, farmers are left with almost no choice since the rainy seasons are even shorter making it impossible for the survival of the traditional PM variety which takes very long to mature.

Since poultry production is one of the sectors providing quality meat protein to people living in both urban and rural areas among others, the possibility of using the Namibian PM cultivars in poultry diets is a "billion dollar research idea". Research is necessary to study the effects of using PM in processed poultry feeds as a mean to accelerate growth of the poultry industry in Namibia. In recent years, a fast growing interest in poultry production has been observed in Namibia with the local people frequently attempting to feed whole PM grains to improved chicken breeds. This observation demonstrates that people are willing to venture into poultry farming but poultry feed is limited and when available, it is very expensive. More often small poultry operations and new poultry business ideas are fading because of limited feed supply in Namibia.

2.4. Nutritional values of pearl millet cultivars found in Namibia

The nutritive value of PM is said to be either superior or comparable to that of other cereals such as maize, sorghum and rice. Pear millet is digested more slowly, thus delaying hunger pangs; it has higher contents of protein and lipids as well as a better balanced amino acid profile (Labetoulle, 2000). According to Mehri et al., (2010) PM is a good source of energy (13.30 MJ/kg) and protein (114 g/kg) for laying hens whereas maize has crude protein value of 80-90g/kg).

2.5. Processing of poultry feeds

2.5.1. Overview of poultry feed processing

Feed processing technology was developed as a means of accelerating livestock production in response to high food demand due to increased global population. Decades ago, monogastric animals such as chickens and pigs were left to scavenge for their feed and supplemented with any available household left overs. In order to address the problem of food scarcity as a result of high population growth, it became a common practice worldwide, as of the 19th century, to cultivate and use agricultural products as animal feeds with the support of increased usage of mechanized agricultural implements (Dordevic and Dinic, 2011).

Due to genetic selection which resulted in 90% improvements in broiler growth as revealed by Havenstein et al. (2003), necessitated the development of feed processing technologies to cater for the increased demand of high quality feed to meet their nutritional requirements. It is well known that for improved breeds with very high productivity to express their genetic potential fully, proper diet formulation and management is required (Labetoulle, 2000). Feed processing allows the compilation of different feed ingredients forming a nutrient rich feed mixture as per specific animal's nutrient requirement.

Particle reduction

The process of feed processing usually begins with grinding as a mean to reduce the particle sizes of the main ingredient. Particle sizes of different cereals which are mostly used as main energy source in poultry diets differ greatly. For instance, the sizes of maize grains are larger and almost impossible to be pelleted without grinding. Other ingredients such as pearl millet grains have small grains and may possibly be pelleted as whole. However, if the same sieve size is used, grinding tends to produce much more uniform particle sizes which may ease the blending of ingredients. If milled ingredients are mixed and packaged for sale and subsequently used, the poultry feed is in the form known as mash.

Homogenization

As part of feed processing, homogenization through mixing is a crucial stage of feed manufacturing necessary to ensure nutrient uniformity of a complete diet (Beumer, 1991). Several tests such as the use of certain markers and an indigenous nutrient i.e. chloride or sodium ion have been developed to determine the nutrient uniformity of a given diet (Eisenberg, 1992). The marker is basically mixed with one of the ingredients and its uniformity in distribution evaluated to determine the degree of mixing adequacy.

This is mostly done by random sampling, collecting samples throughout the whole batch of feed for CV (coefficient of variation) determination (Behnke and Beyer, 2002). There is limited information on exactly how inadequate mixing of feed may influence broiler chickens growth performance.

Broiler feed mixing can also successfully be done by hand in small operations, where feed mixers are not available. After mixing, the feed produced may be offered in a mash form, without any further processing. Otherwise feed may be pelleted to further enhance its palatability, increase bird performance, ease handling, and reduce bacterial loud etc (Labetoulle, 2000). It is of great importance to mention that costs of any feed processing method to be utilized shall be carefully weighed against the anticipated increased bird performance (Behnke, 1996).

Pelleting

Pelletizing refers to a method of particle size enlargement, whereby compound feed fine particles are processed into pellets. Pelleting involves “the agglomeration of smaller particles into larger particles by means of a mechanical process in combination with moisture, heat and pressure” (Falk, 1985).

Crumbling

Crumbling refers to a method of reducing large pellets particle sizes into smaller pellets particle sizes. This may be achieved by running whole pellets through a sieve less grinder to get crumbles. Crumbles are fed to young birds since whole pellets might be too big for the younger birds to swallow.

2.5.2. Effect of feed processing on the chemical composition of feeds

The main objectives of feed processing is to (i) improve nutritional value of animal feeds, (ii) improve ease of handling and (iii) enable homogeneous mixing of feed ingredients by means of particle size reduction and agglomeration of feed particles into pellets. A thermal treatment known as pelleting is further applied to animal mash feeds in order to enhance animal feed quality.

Feed processing by means of pelleting, involves the use of high temperature, moisture and pressure which may influence the chemical composition of feed ingredients. Due to the uniqueness of raw feed ingredients, feed processing may affect the chemical composition of each feed differently (Medel et al., 2004). The nutrients found in animal feed ingredients are classified into water, ash, protein, fiber, starch, sugar and fat (Thomas et al., 1998). Both the physical (e.g. reduced particles) and chemical (e.g. molecular structures of feed components) changes resulting from feed processing may either reduce or increase the nutritional quality of feeds (Medel et al., 2004).

Proteins and starch feed components which are characterized by larger molecules of three-dimensional structure with covalent bonds, are known to be affected by feed processing more than other nutrients (Rakic, 2012). The breakage of tri-dimensional structures of protein (denaturation) and starch (gelatinization) during feed processing is said to increase nutrient availability if done optimally. In the presence of water during feed processing, application of heat results in the gelatinization of starch (Milanovic, 2017). According to Svihus and Gullord (2002), starch gelatinization can be referred to as the bonding performance of gelatinized starch properties resulting in structural changes on starch molecules. The source of starch is said to influence the extent of gelatinization during feed processing. For example, it is easier to gelatinize starch that is sourced from oats as compared to starch from wheat, maize and barley (Hoover et al., 2003). Furthermore, the extent of gelatinization may also vary within the cereal source (Rakic, 2012). Starch gelatinization is generally known to improve the pellet quality, although there is no complete clarity on the mechanism in which starch contributes to the binding characteristics during pelleting (Milanovic, 2017). Starch is known to be sensitive to hydrolysis from enzymatic attacks, due to increased surface area as a result of particle size reduction (Rakic, 2012).

In addition to starch gelatinization, pellet quality is said to also be improved by protein denaturation caused by the application of moist heat (steam) and friction resulting in hardness of pellets (Wood, 1987; Thomas et al., 1997). Heating affects both proteins and carbohydrate, with partial denaturation of proteins (Sunde, 1972). The same author also indicated that, heating the raw feed ingredients (cereals or main protein sources such as soybean meal) may result in better availability of nutrients. The interruption of the orderly protein structure improved the digestion in young monogastric animals (Sunde, 1972). Improvements in carbohydrates and proteins digestibility in pig diets as a result of feed particle size reduction has been reported (Wondra et al., 1995). Hydrothermal pressures and shearing forces of feed processing are reported to disrupts cell walls and structures of high fibre components of feeds (Saunders et al., 1969), influencing the degradability as well as the solubility of fibre components of feeds (Bjorck et al., 1984). Clearly, significant amounts of research have been carried out to understand how feed processing affects proteins and starch molecular structures of feed. Furthermore, sufficient information is also available on how processing affects the production performance of poultry as indicated section 2.5.3 below. However, limited information is available on how feed processing affects the chemical composition of poultry feeds.

2.5.3. Effect of feed processing on feed intake and utilization by birds

Ideally, all feed ingredients to be used in feed manufacturing are subjected to some type of particle size reduction. A survey on particle size analysis of feed samples indicated that the majority of producers are possibly losing 3 to 8 percent of their feed utilization costs because of coarsely ground feed (Goodband, et al., 2002). Particle size reduction is necessary to increase the surface area of the feed, thus allowing for greater interaction with digestive enzymes.

In poultry diets, the effects of diet particle size appear to be confounded with complexity of the diet as well as further processing such as pelleting or crumbling. A study by Cabrera (1994) found no effect of diet particle size reduction (1,000 to 400 microns) on growth performance of broiler chicks fed a complex (added tallow, meat and bone meal, and feather meal) diet fed in a crumbled form. The same author found that, feed efficiency improved 3 percent by reducing particle size from 1,000 to 500 microns in simple diets fed as a meal form but not in crumbled diets. Therefore, from this trial the response to reduced particle (600 to 500 microns) size in broiler chicks appears to be greatest when fed simple (grain-soybean meal) diets in a mash form (Cabrera, 1994). Feeding a complex diet in a crumbled form appears to be beneficial in starter diets. Other studies with laying hens suggest no advantages in reducing particle size below 800 microns (Goodband et al., 2002).

Feed processing disrupts the structure of starch resulting in the union between protein and starch in the grain endosperm which improves digestibility (Abdelgadir and Morrill, 1995). Studies have shown that, feeding pellets to broiler chickens does not only increase feed intake (Nir et al., 1995; Chewning, 2010), but it also improves the growth performance (Behnke, 1994) and feed conversion ratio (FCR) (Goodband et al., 2002; Amerah et al., 2008) as compared to the mash form. According to Behnke (1998), improved growth rate of broiler chickens fed pellets may be attributable to improved palatability, reduced apprehension, reduced feed wastage, decreased segregation of ingredients and increased digestibility.

Broiler performance is highly influenced by the physical form of feed (Zang et al., 2009). This is so because according to (Jahan et al., 2006), a mash which is a coarsely ground and mixed diet, is said to unify broiler growth and more economical, but it is considered to be of poor quality and less palatable. Moreover, pelleting is generally accepted since it improves the growth rate as compared to mash (Nir et al., 1995). This could be associated with the reduction of ingredients segregation, high digestibility, less energy used for consumption, destruction of pathogenic organisms, thermal modification of starch and protein, as well as higher palatability and higher nutrient density.

2.5.4. Effects of feed processing on slaughter characteristics

Due to the increased price of cereal grains, plant protein sources, and other feed ingredients used in poultry feeds, scientists are exploring alternative ingredients and processing methods which may be used to improve feed efficiency while reducing production costs. Feed particle size is known to have effects on many aspects of poultry production, including nutrient utilization, growth performance, digestive tract development, and feed passage rate (Gabriel et al. 2003; Amerah et al. 2008).

The muscular organ known as a gizzard, in birds, is responsible for the reduction of feed particle sizes and mixes them with digestive enzymes (Duke, 1986). Feed particle reduction by means of feed processing results in the underdevelopment of the gut. The underdeveloped gizzard due to feeding broilers with processed feeds results in an enlarged proventriculus (Taylor and Jones, 2004), because the gizzard tends to work as a transit rather than a grinding organ (Cummings, 1994).

When the gizzard is large and well developed, the motility of the digestive tract is improved (Ferket, 2000). According to Svihus et al. (2004b), when the gizzard is well developed, the rate at which the cholecystokinin is released increases. The increased level of cholecystokinin stimulates the secretion of pancreatic enzymes and the gastro-duodenal refluxes (Duke, 1992). The slow passage of feed through the gizzard maximizes the exposure of nutrients to digestive enzymes improving the nutrient digestibility and energy utilization (Nir et al., 1994; Carre, 2000). Feeding birds with pelleted diets has been reported to decrease the weights of both gizzard and small intestine weights as compared to feeding mash diets (Nir et al., 1995).

According to a study by Amerah et al. (2008), coarse grinding lowered feed per gain compared to fine feed particle size grinding regardless of the grain type. Lower feed per gain compounded to improved feed efficiency in birds fed coarsely ground feeds resulting in greater relative gizzard weights (Amerah et al., 2008). The same authors reported similar particle size distribution in the duodenal digesta of the birds fed fine and coarse particles which were attributed to the gizzard which evened out dietary particle size differences. Furthermore, Amerah et al. (2008) revealed that birds fed corn-based diets had a relatively heavier gizzard than those fed wheat based diets. However, the duodenal morphometry was not influenced by either grain type or particle size. Pellets made from fine particle sizes were more durable than those made from coarse ground grains (Amerah et al., 2008).

A study by Hassan and El-Seihk (2010) reported a reduction in gizzard percentage and digestive tract weight for ducks fed pelleted diets as compared to those fed mash diets. Attia et al. (2014) reported that pelleting decreased the weight of the gizzard and caecum length. They further indicated that feeding 3.5 mm (larger particle sizes) pellet diets increased abdominal fat compared to that of broilers fed mash diets. Research by Amerah et al. (2007) reported improved bird performance and increased relative gizzards weights in broilers fed coarsely ground feed and compared to those fed on diets with fine particles.

Grain particle size is more critical when fed in a form of mash diets but less important when fed in a form of pellets (Nir et al., 1995; Svihus et al., 2004). However, the fact that pellets dissolve when they get into the crop after consumption (Nir and Ptichi, 2001) may suggest possible effects of particle size on broiler performance after pelleting. Furthermore, the particle size spectra of milling outcomes are said to be influenced by grain type, resulting in different particle size distribution even when passing through the same screen size opening in a hammer mill (Amerah et al., 2007). Studies by Peron et al. (2005) and Lentle et al. (2006) observed positive effects on performance and gizzard development providing more evidence that particle size distribution in wheat-based diets remained even after pelleting.

According to Agunbiade (2000) and Adeyemi et al. (2008) pelleting of broiler diets results in higher percentage of the most expensive commercial chicken cuts namely; dressing, breast meat, drumstick and thigh weights.

2.5.5. Economics of processing poultry feeds

Although feed processing eases handling and mixing properties of feed ingredients to avoid feed particle sedimentation during storage and transportation, grinding and modification may increase the energy costs of feed production. It is of great importance to pay attention on analysis of energy consumption and scientific forecasts of feed processing technologies given the high rate of human population growth and global warming threats. Grinding and pelleting are said to take up to 80 % of energy usage of feed production (Milanovic, 2017). It is important to ensure that the increased costs of processing should be offset by improved feed conversion which can only be achieved through the correct mix of processing technologies.

2.6. Pearl millet grains as chicken feed

Worldwide, PM has been successfully utilized in poultry rations as a replacement of common cereals such as maize, sorghum and wheat. Studies using iso-caloric and iso-nitrogeneous broiler diets using PM as a replacement for maize recorded broiler performance equivalent to those of maize based diets (Amato and Forrester, 1995; Hafeni, 2013). Increased egg size and better feed conversion indicated in a study by Kumar et al. (1991) were attributed to the higher contents of methionine and energy in PM grains. Nutrition wise PM is known and praised for its high protein contents and better balanced amino acids profile. It is said to be 8 % - 60 % higher in protein, 40 % richer in lysine and methionine and 30 % more threonine compared to maize (Burton et al., 1972).

Pearl millet has higher oil content than maize, averaging 5 % (Amini and Ruiz-Feria, 2007). Linolenic acid makes up 4 % of the total fatty acids in the oil, making PM a good source of omega-3 fatty acids (Jacob, 2013). According to Collins et al. (1995), feeding hens with PM resulted in eggs with higher contents of mono-unsaturated and omega-3 fatty acids and lower omega-6 fatty acids as compared to other cereal. Amini and Ruiz-

Feria (2007) also observed that the eggs from hens fed the PM based diets were higher in omega-3 and lower in omega-6 fatty acids than those from hens fed a corn-based diet.

Although PM contains anti-nutrients like phytic acid, polyphenols and tannins among others (Boncompagni et al., 2018), limited information is available on how the anti-nutrients in PM affects the poultry production performance. The anti-nutrients present in PM are known to reduce palatability and inhibit the digestion of proteins in birds (Andrews et al., 1996). Therefore, scientific information on how different processing methods may enhance PM attributes is necessary. Furthermore, PM may contain an amount of up to 200 ppm levels of saponin anti-metabolites (Sodipo and Arinze, 1985) which are known to cause some damage to membranes in the digestive tract (Andrews et al., 1996). Traditionally, roasting, germination and fermentation, cooking and soaking among others are processing technologies utilized to enhance PM attributes (Boncompagni et al., 2018).

2.6.1. Replacement of maize with PM in broiler diets

According to research, when PM is used in chicken diets as a replacement of maize similar weight gains and feed efficiency are observed (Smith et al., 1989; Sullivan et al., 1990; Satyanarayana et al., 1991). Several researchers recorded heavier weights in birds fed PM based diet compared to those fed maize based diets (Sinha et al., 1980; Asha et al., 1986). However, birds fed PM based diets tended to consume more feed compared to those fed maize based diets (Asha et al., 1986; Satyanarayana et al., 1991). The increased feed consumption by broilers fed on PM based diets may be due to the higher oil contents of PM compared to maize/corn (Amini and Ruiz-Feria, 2007). According to Fuller (1981) and Moran (1986), the oil may enhance growth by improving the palatability of feed.

Sharma et al. (1979) recorded best FCR (feed conversion ratio) in a group of birds fed 50 % PM as compared to those fed maize, sorghum or wheat. A similar trend was observed when Sinha et al. (1980) recorded better feed efficiency (2.09) in a group of broilers fed PM based diets as compared to those fed maize (2.35), rice polish (2.56), sorghum (3.05) or wheat (3.29). The same trend manifested again when more researchers reported improved feed efficiency numerically, without any statistical difference, when broilers were fed PM based diets as compared to maize based broiler diets (Asha et al., 1986; Satyanarayana et al., 1989; Thakur and Prasad, 1992; Rama Rao et al., 2002; Hidalgo et al., 2004; Rama Rao et al., 2004).

Rama Rao et al. (2004) concluded that PM can replace maize in broiler diets without any effects on birds' growth performance, feed efficiency, carcass trait or their immunity. These conclusions are in agreement with those of previous researchers who also concluded that PM can completely replace maize in broiler diets without any adverse effects on the performance (Abate and Gomez, 1984; Asha et al., 1986; Satyanarayana et al., 1991). More recent studies concluded that replacing maize with PM completely in broiler diets had no effects on birds' growth performance (Jha and Kumar, 2008; Bulus et al., 2014), feed per gain as well as nutrient retention (Bulus et al. (2014).

2.6.2. The economics of using PM grains in broiler rations

Baurhoo et al. (2011b) as cited by Jacob (2013) indicated that in comparison to broilers fed corn-based diets, those fed on PM based diets required less soybean meal. This is due to the fact that PM is high in protein content as supported by Hanafi et al. (2014) who concluded that replacing maize with PM in broiler diets results in substantial partial substitution of the protein source.

Pearl millet is said to have a more balanced amino acid profile as compared to other cereals. Pearl millet is said to be higher in methionine than corn, alleviating some of the need for synthetic methionine supplementation in organic poultry diets (Andrews et al., 1996). Amato and Forrester (1995) concluded that it may not make economic sense to supplement PM based broiler diets with lysine and sulfur amino acids because PM has more of these. Eggs from hens fed the PM based diets which are higher in omega-3 and lower in omega-6 fatty acids than those from hens fed a corn-based diet can be sold at a higher price in the United States than that of conventional eggs (Jacob, 2013).

Rama Rao et al. (2002) observed lower costs of feed required per one (1) kg of live weight gain in broilers fed PM grains compared to those fed maize based diets. Another research by Elangovan et al. (2003) reported significantly less costs when broilers were fed PM based diets compared to maize based diets. Considering the fact that pearl millet grains can easily be cultivated by farmers with limited resources in dry land areas at minimal costs as compared to other cereal crops such as maize and sorghum (Hanafi et al., 2014), it warrants the conclusion that using PM in poultry diets may reduce feed costs.

A study by Hidalgo et al. (2004) reported that PM whole grains can be readily broken down by young broilers. Limited information is available on the optimum inclusion of whole PM gains in broiler diets. Hidalgo et al. (2004) recorded a significant increase in gizzard sizes for broiler chickens fed on whole grain PM grains. The significant increase in gizzard sizes for birds fed on PM whole grains was related to muscular adaptation to increased grinding activity.

Given the small size and heavy weight of PM grains, many times it becomes really hard to handle as compared to maize (Hafeni, 2013). Limited scientific information is available on how further processing of PM grains may influence the handling parameters of PM based diets as well as the production performance of broilers fed on PM diets.

2.6.3. Processing PM based poultry diets

Limited research evidence is available on feed processing and handling parameters of PM grains when used in broiler diets as a replacement for maize. A study by Dozier et al. (2005) has shown that PM grains are capable for grinding and pelleting with reduced energy usage compared to maize. In addition, reducing PM grain particle sizes by grinding improved pellet durability index and percentage fines. The authors therefore, concluded by acknowledging the grinding and pelleting performance acceptability for PM based diets compared to the typical maize based diets. Limited information is available on the effects of pelleting PM based broiler diets on their feeding value as well as their effects on the performance of broilers.

2.7. Determination of broiler feed utilization

Growth performance and carcass characteristics are the common measures used by scientific researchers to determine broilers feed utilization.

2.7.1. Growth performance

The growth performance of broilers is measured by means of live body weight and weight gains in addition to feed conversion ratio and feed intake parameters. Although growth rate and feed conversion ratio are the most common parameters used to measure the feeding potential of feedstuff (Leeson, 2000), mortality rate and days required to reach table weight are also important. Defined as the constructive synthesis of ingested nutrients, growth is a result of meat, fat and bone accumulation in the body as a positive difference between catabolic and anabolic processes in the body (Brody, 1945), in addition to improved weight gains, length or skeletal size (Pond et al., 1995). Nutritional imbalance, excess feed intake as well as optimal maturity lean mass are some of the factors which may result in fattening (Whittemore, 1988). The ratio of lean meat to bone tissue is used as a parameter of measuring the carcass quality while feed conversion efficiency is determined by means of absolute growth rate (Wakibia, 2015).

Feed conversion ratio (FCR) as a ratio of feed intake to weight gain is used to determine effectiveness of birds to convert a given feed into live weight and it estimates nutrient adequacy of feedstuff (Pond et al., 1995). Lowest FCR is most preferred because it means high conversion of a feed to live weight. High FCR could easily translate to some undesirable economic losses due to the fact that 70 % of total production costs in the poultry industry are attributed to feeds (Waller, 2007). Feeding a diet with an ability to promote higher rate of weight gain may result in better FCR because, a higher percentage of the total feed consumed is utilized for muscle deposition and only a smaller percentage on maintenance (Pond et al., 1995). In addition to feed, feed conversion ratio may also be influenced by diseases, age, environmental temperature as well human related factors (Wakibia, 2015).

2.7.2. Carcass quality

Breast, thigh and drumstick muscles are utilized in most scientific studies as parameters to measure carcass performance complemented by the sizes of organs such as the liver, pancreas and gizzard in an attempt to determine feed quality. The high quality broiler chicken has more breast meat and less abdominal fat content. The most valuable broiler cuts are the breast, thigh and drumstick muscles because they contribute the highest proportions of edible meat. According to Nasr and Kheiri (2011), the amount of dietary protein and lysine in feed may influence the proportion of the breast, thigh and drumstick muscles, although the breast muscle tends to develop faster. Energy is mostly diverted from fatty tissue growth into the lean tissue accumulation as a result of increased dietary protein, reducing the carcass fat content

Fatty tissue growth or fat deposition is said to be a balance between absorbed fat, fat catabolism by β-oxidation (lipolysis) and fat synthesis (lipogenesis) (Wakibia, 2015). Fast growing broiler breeds tend to have accelerated carcass fat deposition associated with risks of cardiovascular diseases leading to lower carcass value and customer preferences (Micha et al., 2010) if proper feeding measures are not well employed. High contents of abdominal fat can be associated with lower feed efficiency as well as some economic losses during evisceration, when the abdominal fat is removed especially when chickens are sold in cuts (Emmerson, 1997).

A significant reduction in the amount of abdominal fat relative to live weight of broilers resulting from a reduced amount of energy in the diet has been reported (Fan et al., 2008). According to Tanaka et al. (1983), reduced body fat deposition could possibly result from a decreased activity of some enzymes linked to liver lipogenesis, including fatty acid synthase (FAS), nicotinamide-6-phosphogluconate dehydrogenase and glucose-6-phosphate dehydrogenase (G-6-PDH). Yalçin et al. (2010) indicated that reduced dietary protein contents may lead to an increased content of abdominal fat. This happens because of the increased FAS mRNA expression in the liver for broilers (Choi et al., 2006). According to Back et al. (1986), FAS enzyme is vital in the de novo lipogenesis in the liver.

Increased amount of lysine and methionine in broiler diets have been reported to significantly reduce the abdominal fat composition (Andi, 2012). According to Takahashi and Akiba, (1995), increased amount of methionine in the broiler diet decreases the carcass fat content because of the reduced FAS activity involved in lipogenesis which increases the activity of hormone-sensitive lipase (HSL) that is involved in lipolysis. Furthermore, lysine reduces the carcass fat content by inhibiting lipogenesis (Grisoni et al., 1991). Moreover, carcass fat is also reportedly reduced by manganese supplementation which decreases the lipoprotein lipase activity and increases HSL activity in the abdominal fat (Lu et al., 2006).

A gizzard which is a thick muscular organ, grinds and mixes feed particles by means of rhythmic contractions (McDonald et al., 2002). Although there are enzymes produced in the gizzard, the hydrochloric acid and pepsin from the proventricus are used (Jurgens, 1969). The passage of feed particles is controlled by the narrow exit of the poultry pylorus (Wakibia, 2015). As a result, larger feed particles remain in the gizzard for a longer period of time which promotes the muscular development of the gizzard (Hetland and Svihus, 2007). According to Hetland and Svihus (2007), increased gizzard weight relative to live body weight may suggest high fiber content in the diet. As the largest gland in the body, the liver detoxifies anti-nutritive factors which could be harmful to the body (Ologhobo et al., 1993). The pancreas releases digestive enzymes such as amylases, proteases, nucleases and lipases (Slack, 1995) as well as hormones such as insulin, somatostatin, and pancreatic polypeptidase (Scanes et al., 2004). The weight of the pancreas is said to be affected by reduced protein digestion caused by trypsin inhibitors, through protease enzyme inhibition (Wakibia, 2015).

2.8. Broiler health management

Broiler health management is a very important component which should be understood by anyone undertaking any kind of broiler operation. When undertaking research involving broiler chicken feeding, the health management should be more on disease prevention oriented to ensure that no disease outbreak occurs throughout the experiment. There is however some health issues such as metabolic diseases like ascites syndrome which are sometimes hard to control. An ascites syndrome is a condition characterized by excessive accumulation of fluid in the abdominal cavity and causes high mortality at 4 to 6 weeks of age (Ranson, 2005). Ascites is more common in regions with high elevations above 1200 meters especially during winter. Mortality rates due to ascites are typically in a range of 8-12 %, although they might go up to 25% age (Ranson, 2005). High altitude regions are characterized by low atmospheric pressure which is associated with reduced oxygen levels in the air in addition to low temperature and humidity. The low temperatures are said to increase metabolic rates resulting in high demand for oxygen (which is already low at high altitudes), this results in reduced growth (Esmail, 2012). Ascites syndrome is known to be a result of little oxygen supplied to body tissues and increased metabolic demand (Ranson, 2005). As broilers today are bred to yield more meat, their metabolic demand for oxygen increased as well. Fast growing birds tend to suffer even more due to high oxygen and metabolic demands which are not being met (Ranson, 2005). Male birds are the most affected because of their fast growth rates. Rearing broilers under a completely environmentally controlled house and feeding mash or reduced feed intake may reduce incidences of ascites (Zohair et al., 2012).

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CHAPTER 3: GENERAL MATERIALS AND METHODS

3.1. Description of the study site

This study was conducted at 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.

3.2. Experimental design, diets and ingredients used

Experimental diets used in this study were formulated to be iso-nitrogenous (17% CP) and iso-caloric (11.5 MJ/kg ME) as per poultry requirements listed by the NRC (1994). Soya bean meal which was used as a source of protein was purchased from a feed production company in Namibia, FeedMaster. The experimental design used in this study was a Completely Randomized Design with a 2 x 3 factorial arrangement of treatments (i.e. two processing methods (grinding and pelleting) and three replacement levels (50 %, 75 % and 100 %). A commercial finisher pelleted diet was used as a control.

Other ingredients such as a Stress pack, limestone and bicarbonate of soda were obtained from companies in Windhoek. Pearl millet (okashana-2) used in experimental diets, was grown at the crop field section at Neudamm campus (Figure 3.1a - g). It was planted, harvested, air dried, threshed and cleaned. Five hundred kilograms of pearl millet was harvested and processed into chicken feeds for this study.

Figure 3.1. a) Pearl millet after weeding, b) Pearl millet ready for harvesting, c) Pearl millet air drying in the shade, d) Dry pearl millet and ready for threshing, e) A thresher was used to process (thresh) pearl millet, f) After threshing, the grains was cleaned by hands using a traditional pail, g) Cleaned grains that was used in the experimental diets, h) Different ingredients (pearl millet and maize grains, full-fat soybean meal, broiler finisher vitamin and mineral premix and limestone) used to formulate experimental diets.

Maize was obtained from Rundu in Kavango region in the north-eastern part of Namibia (Figure 3.1h.). One hundred and ninety six (196) Cobb-500 broiler chickens were sourced from Namib Poultry Industry (NPI). All chickens were kept in the same brooder house and fed on the same commercial starter diet for a period on three weeks. The birds were vaccinated for Newcastle and Guburo and kept in standard housing and fed ad libitum and clean portable water was provided. The numbers of replicates were two per treatment.

Table 3.1 Nutrition composition of the commercial starter diet used

Nutrients	**Contents**
Protein g/kg	178
Fat	25
Moisture	12
Fibre mg/kg	15
Phosphorus mg/kg	60
Calcium mg/kg	5

3.3. Data Analysis

The data were analyzed by two-way analysis of variance (ANOVA) using the General Linear Models procedure of IBM SPSS Statistics 25 (2017) package, with methods of feed processing and replacement levels as factors. When the interaction was not found significant, the effect of individual factors was 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 means were determined by means of Duncan's multiple range test.

CHAPTER 4: EFFECTS OF PELLETING ON THE NUTRITIONAL COMPOSITION OF PEARL MILLET BASED BROILER DIETS

4.1. Abstract

The effects of pelleting on nutritional composition of broiler diets when maize is replaced with pearl millet (PM) at different replacement levels was examined in this study. The experimental design was a Completely Randomized Design with a 2 x 3 factorial arrangement of treatments evaluating two feed processing methods (grinding and pelleting) and three replacement levels (50 %, 75 %, and 100 %). Broiler finisher diets were formulated to contain PM as a replacement of maize at 50 %, 75 %, and 100 % levels as mash and pellets. Diets were formulated to be iso-nitrogenous (17% CP) and iso-caloric (11.5 MJ/kg ME). The main ingredients (maize, PM and soybean meal) and all experimental diets were analyzed for dry matter, crude protein, crude fiber, ether extract, calcium and phosphorus according to official Methods of Analysis (AOAC, 2000). Amino acid profiling was done by ultra-performance liquid chromatography technique (UPLC). Pearl millet had higher ($P < 0.05$) crude protein (CP) and fat contents compared to maize. The contents of lysine, leucine, methionine, glycine, arginine, threonine and alanine contents found in PM were found to be 43 %, 20 %, 30 %, 17 %, 35 %, 29 % and 31 % higher ($P < 0.05$) than those found in maize, respectively. Pelleted diets had significantly ($P < 0.05$) higher CP contents as compared to mash diets. Pelleting significantly ($P < 0.05$) reduced the crude fibre (CF), calcium and fat contents of broiler diets but pelleting had no effects ($P > 0.05$) on ash, dry matter and phosphorus contents of broiler diets. Pearl millet based diet had significantly higher ($P < 0.05$) CP, fat and

calcium contents compared to maize based diets. It can be concluded from the results of this study that, PM based diets can successfully be pelleted without any detrimental effects on the nutritional composition. Although pelleting improved the CP content of broiler diets, other nutrients such as calcium and fat contents were affected negatively, therefore, supplementation of these nutrients is necessary if PM based diets are to be pelleted.

4.2. Introduction

Any form of treatment that poultry feed undergoes before it is actually consumed maybe referred to as feed processing (Maier and Bakker-Arkema, 1992). Animal feed processing operations such as grinding, batching, mixing, thermal treatment and packaging form part of the feed manufacturing process are widely utilized (Abdollahi, 2011). Feed processing which mostly involves manipulation of feed particle sizes is said to improve poultry performance. Research has proven that reducing particle sizes of main ingredients and diets results in improved performance of broiler chicken performance (Behnke and Beyer, 2002). The major poultry feed ingredients which are mostly cereal grains such as wheat, maize and PM are known to be coarse, therefore it is necessary to apply some degree of grinding before mixing into a diet. Apart from improving blending ability and homogeneity of the diets, grinding of coarse ingredients is performed in order to decrease segregation and ease pelleting. Thermal treatment like pelleting is another way of animal feed quality enhancement which involves “the agglomeration of smaller particles into larger particles by means of a mechanical process in combination with moisture, heat and pressure” (Falk, 1985).

Although feed pelleting improves broiler performance, negative effects may also be observed if care is not in place/taken. Improving quality of pellets using high conditioning and pelleting temperatures may reduce nutritive values of pelleted feeds (Abdollahi, 2011).

Feed processing, especially when heat, moisture and friction are applied, may damage some nutrients such as amino acids and vitamins. However, heat processing (Sunde, 1972) may make other nutrients such as carbohydrates more available. The same author further argued that digestibility of cellulose and protein are influenced by grinding. A considerable attention had been directed to studying the effects of processing broiler diets on growth performance of broilers as indicated in the literature review chapter of this study. However, there is limited information on the effects of processing methods on the chemical composition of PM based broiler finisher diets. Combined efforts of feed processing while utilizing locally available poultry feed ingredients may warrant a least-cost diet formulation which may increase poultry performance. This experiment was aimed at evaluating the effects pelleting PM based broiler diets when maize is replaced with pearl millet grains at 50 %, 75 %, and 100 % levels under Namibia conditions. The study aimed to determine whether there was a need to supplement broiler finisher diets when pearl millet based diets are to be pelleted.

4.3. Materials and Methods

4.3.1. Location of the study

Due to the lack of equipment only a few of the nutrients were analyzed in the Nutrition Laboratory of the Department of Animal Science at Neudamm Campus and these include; dry matter (DM), Ash and Ether Extract or fat (EE). While analysis for Crude Protein (CP), Crude Fibre (CF), Calcium (Ca), Phosphorus (P), Acid Detergent Fibre (ADF) and Neutral Detergent Fibre (NDF) were carried out at the Nutrition Laboratory of the Ministry of Agriculture Water and Forestry in Windhoek.

4.3.2. Experimental diet formulation

The experimental diets were formulated to fit the experimental design as described in chapter 3. Before diet formulation, the CP composition was determined as described in section 4.3.4. The CP content of the main ingredients was used to determine the amount/quantity of each ingredient required to formulate 100 kg of each of the experimental broiler diets. The information on the amount of each ingredient required to formulate iso-nitrogenous (17% CP) and iso-caloric (11.5MJ/kg ME) broiler diets from the software was utilized to determine the amount of each ingredient.

4.3.2.1 Grinding and mixing of ingredients

A Hammer mill was used to reduce particle sizes of maize and pearl millet grains to pass through a 2-mm sieve. Soybean meal was used as it is, without grinding. After weighing out the exact amounts (Table 4.1) of each ingredient to be used in each diet, the ingredients to be used were hand-mixed thoroughly. The hand-mixing was done beginning with major ingredients and further working on adding each one of the minor ingredients at a time. Hand-mixing was done because there was no feed mixer available. After adding an ingredient starting with the main ingredients, a pile was made by adding feeds on top of each feed addition. To ensure that a complete mixing is achieved, three new piles were made from the main pile of feeds as shown in Figure 4.1, this was repeated after each addition of new ingredient until all the ingredients has been added.

4.3.2.2 Pelleting

The feed was moisturized and conditioned for pelleting by adding 600 ml of boiled water to 400 ml of previously boiled cold water to make up a 1000 ml which was then sprinkled over the 20 kg of feed to be pelleted. When thoroughly hand-mixed the mixture was fed into the pelleting machine. Pelleted feeds were air dried overnight before storing in 20 kg storage bags. At the end of feed production the following experimental diets used for this study were obtained: 50 %, 75% and 100 % PM each in a form of mash and pellets. A commercial broiler finisher diet used as a positive control in a pellet form,

Table 4.1. Different replacement levels of maize with pearl millet in broilers experimental diets and their nutritional composition (%)

Ingredient	**Inclusion levels (%) of pearl millet**			
	Commercial	**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-Minerals 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
Chemical Composition (calculated)				
CP	15.40	17.02	17.02	17.03
Calcium	0.6	0.3	0.3	0.3
Phosphorus	0.4	0.5	0.6	0.6
Dry Matter	-	91	92	92
Ash	-	4	4	4
ME MJ/kg	-	11.4	11.5	11.5

ME = Metabolizable Energy, CP = Crude Protein

Figure 4.1. Mixing procedure of the experimental diets

4.3.3. Sample preparation

Replicates (two) of representative samples for both individual main ingredients and experimental diets were collected from the top, middle, bottom and both sides of each storage bag. The samples were stored in airtight containers for proximate analysis.

4.3.4. Chemical Analysis

4.3.4.1. Crude protein

Chemical analysis was carried out using as fed (as is) samples. Crude protein (CP) for all samples was determined using the Kjeldahl method an in house method (AOAC, 2000), which determined the crude nitrogen content. Digestion was done with concentrated Sulphuric acid and selenium tablets were used as catalysts. Distillation was carried out followed by titration using hydrochloric acid to obtain the amount of crude nitrogen contained in each sample. Crude Protein was then calculated from crude nitrogen content using a general factor of 6.25. Since the results obtained from this analysis are on the 'as is' basis, calculations were done to get the results on 'dry matter' basis for comparison purposes.

4.3.4.2. Crude fiber analysis

Crude Fiber content was determined using the Ref. FOSS Application Note, based on Weende method that was developed in 1860 by Henneberg and Stohmann in German. The treatment of samples was done using Sulphuric acid and sodium hydroxide. The CF content was determined gravimetrically and converted from 'as is' basis to 'dry matter' basis for comparison purposes.

4.3.4.3. Phosphorus analysis

Phosphorus contents of all samples were determined using an in house method based on ISO 6491:1998. When using this method, ashed samples (samples combusted up to 550 °C) were dissolved in hydrochloric acid. A spectrophotometer was used to measure the phosphorus content of each sample, and the results obtained were converted to 'dry matter' basis for comparison purposes.

4.3.4.4. Calcium analysis

An in house method based on ISO 27085:2009 was used to determine the composition of calcium of samples. After ashing (burning samples up to 550 °C), samples were dissolved in hydrochloric acid and the contents of calcium was measured by means of optical emission spectroscopy by inductively coupled plasma.

4.3.4.5. Amino acid

Amino acid profiling including that of methionine and lysine was performed by ARC Irene Analytical Services in South Africa. An ultra-performance liquid chromatography technique (UPLC) was used for amino profiling.

4.3.4.6. Determination of total starch composition

A Megazyme Total Starch HK Assay Kit was used to determine total starch composition. 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.

4.3.4.6. Metabolizable Energy

Metabolizable Energy was determined using the equation as follows:

1. Firstly, the following equation was used to calculate the NFE (Nitrogen Free Extract)

NFE = 100 – (Moisture + Crude Protein (CP) + Ether Extract/fat (EE) +Crude Fibre (CF) + Ash)

2. Secondly, the DE (Digestible Energy) was determined using the equation by Noblet and Perez (1993) :

DE (MJ/kg) = 0.479CP % + 0.472EE % + 0.375NFE % - 21.2

3. Metabolizable Energy was then calculated using the equation by May and Bell, (1971) below:

ME (MJ/kg) = ((DE (MJ/kg) * (1.012 – (0.0019CP %)

Since the results obtained from the laboratory analysis are on 'dry matter basis', the equation below was used to convert these results to 'as is' basis for final mixing.

$$\text{Ingredient Nutrient Content (DM as is)} = \frac{\text{DM (Dry Matter basis)}}{100} \text{ X (100-Moisture)}$$

4.3.5. Data Analysis

The data were analyzed as described in Chapter 3, section 3.3. The data were analyzed as a 2 x 3 factorial arrangement of treatments, evaluating the effects of two (2) processing methods (mashing and pelleting) and three (3) replacement levels (50 %, 75 % and 100 %) and their interactions. The model used is outlined below:

$$Y_{ijk} = \mu + A_i + B_j + (AB)_{ij} + \varepsilon_{ijk} \qquad i = 1,\dots,a; \quad j = 1,\dots,b; \quad k = 1,\dots,n$$

That is

Yijk = replacement level + processing methods + replacement levels * processing methods + ɛijk

Where:

Yijk = observation k in level i of methods of feed processing (factor A) and level j of replacement levels (factor B).

μ = the overall mean

Ai = the effect of level i of the two feed processing methods

Bj = the effect of level j of the three replacement levels

εijk is the random error term

4.4. Results

4.4.1. Chemical composition of main ingredients used in experimental diets

When formulating the experimental diets, the crude protein contents were estimated to be 170.2 g/kg, 170.2 g/kg and 170.3 g/kg for the diets containing 50 %, 75 % and 100 % pearl millet grains as a replacement of maize respectively. However, the proximate analysis determined the crude protein contents for the respective diets to be 140 g/kg, 160 g/kg and 170 g/kg respectively. The proximate analysis indicated that crude protein (CP) content in pearl millet (110 g/kg) is 45 % higher ($P<0.05$) than that of maize (60 g/kg). Pearl millet also had more fat (52 g/kg) content than maize (43 g/kg). However, the fiber content in PM is higher than for maize. The chemical composition of maize, pearl millet and soybean meal are presented in Table 4.2.

Table 4.2. Nutritional composition of the 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/100g)	37,805	39,051

CP = Crude Protein, CF = Crude Fiber, EE = Ether Extract, ADF = Acid Detergent Fibre, NDF = Neutral Detergent Fiber, Ca = Calcium, P = Phosphorus

The two ingredients (pearl millet and maize) showed differences in the amino acid profiles. The results showed that amino acids such as lysine, leucine, methionine, glycine, arginine, threonine and alanine contained in pearl millet grains are 43 %, 20 %, 30 %, 17 %, 35 %, 29 % and 31 % are all significantly higher ($P<0.05$) than those found in maize as shown in Table 4.3..

Table 4.3. Amino acid profiles of the ingredients used to formulate the experimental diets.

Amino Acid Profile (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

4.4.2 Effects of pelleting on chemical composition of broiler diets

Results on the effects of pelleted feed on the nutritional composition of pearl millet based broiler diets are presented in Figures 4.3, 4.4 and Table 4.4 respectively. A significant ($P < 0.05$) interaction between the two processing methods (grinding and pelleting), and the three replacement levels (50 %, 75% and 100 %) was observed for CP (crude protein). Pelleted diets had significantly higher ($P<0.05$) CP contents when maize was replaced with PM at 50 % and 75 % replacement levels when compared to mash diets. The results also showed that pelleting did not affect the CP content for the 100 % PM replacement level diet significantly ($P > 0.05$).

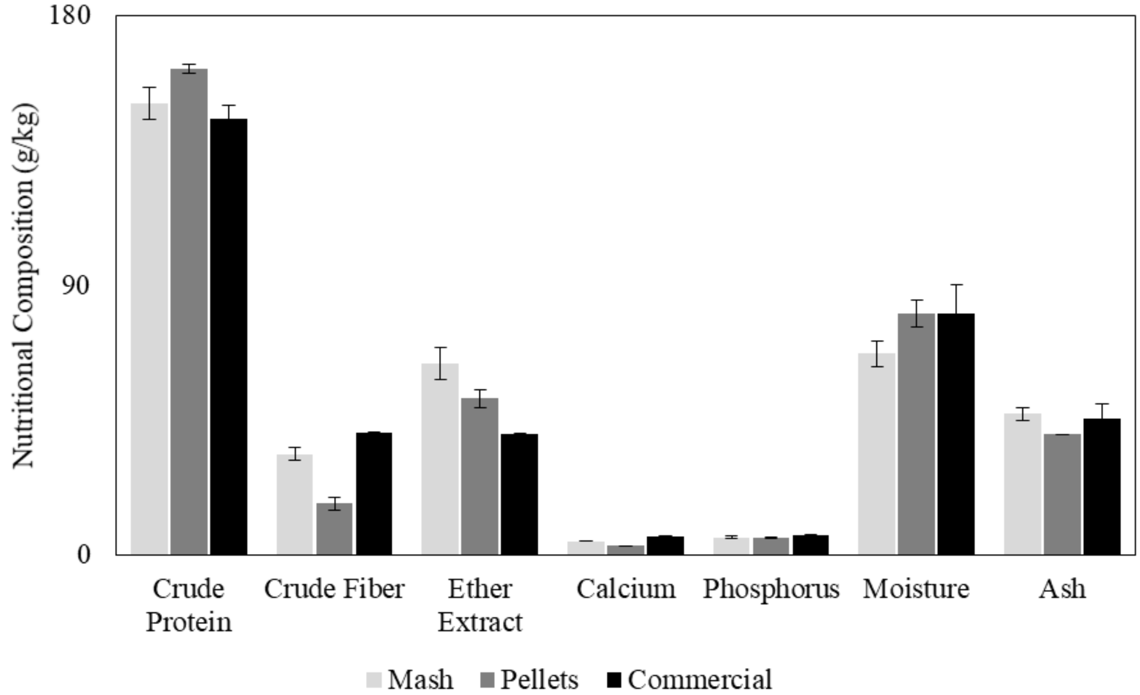

Figure 4.3. Effects of pelleting on nutritional composition (g/kg) of PM based broiler finisher diets

Table 4.4. Effects of experimental diets on nutritional composition (g/kg) of broiler finisher diets when maize is replaced with pearl millet grains at 50 %, 75 % and 100 % replacement levels

Nutrient (g/kg)	Mash Diets			Pelleted Diets					
	50 %	75 %	100 %	Commercial	50 %	75 %	100 %	p-value	±SEM
Dry Matter	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	31927	33199	33090	32279	30398	38353	35514		
ME (MJ/kg)	9.35	12.27	12.58	11.40	12.59	12.77	13.22		

Results from this study indicated that the contents of the CF in the experimental diets were significantly reduced by processing methods. However, there is little nutritional improvement by replacement levels, though not statistically significant (P>0.05) (Figure 4.4). There was no interaction observed (P>0.05) between processing methods and the replacement levels for the crude fibre (CF) contents of the experimental diets.

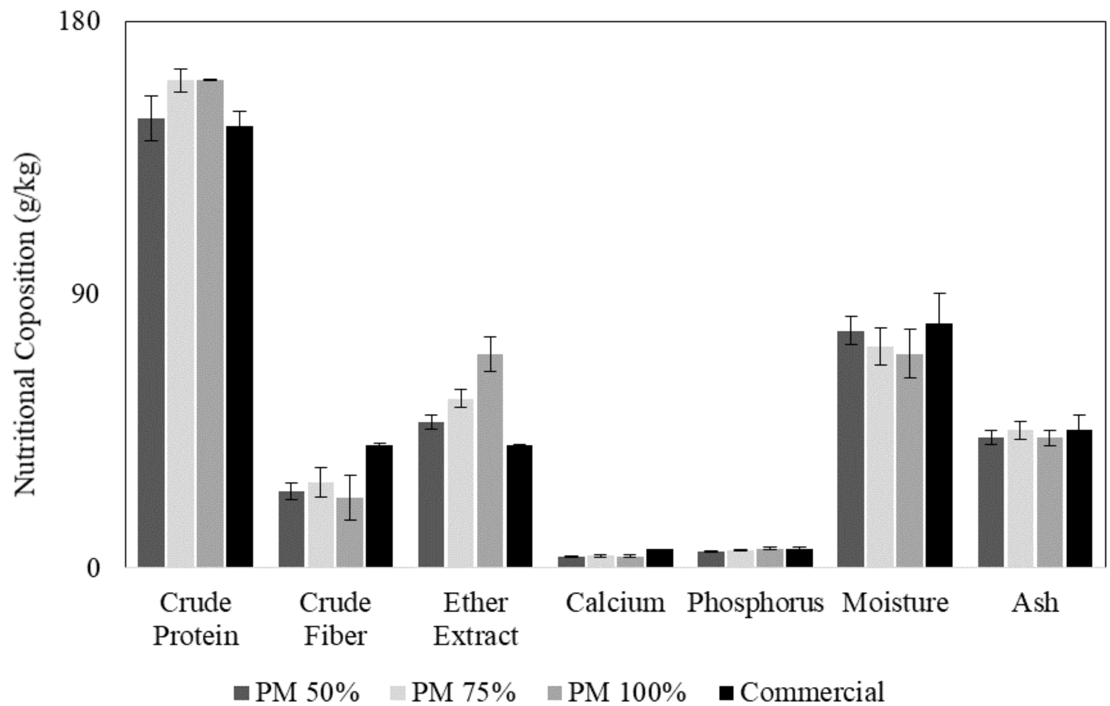

Figure 4.4. Effects of replacement levels on nutritional composition (g/kg) of PM based broiler finisher diets

There was a significant (P < 0.05) interaction between the two processing methods and the replacement levels for the ether extract content of the experimental diets. Whereby, the ether extract content for experimental diets with more PM grains was reduced significantly by pelleting much more than those with maize grains. Mashed diets had a significantly higher ether extract content (P>0.05) compared to the pelleted diets. The ether extract content significantly increased sequentially with increasing levels of replacements (P<0.05).

There was a significant (P < 0.05) interaction between the processing methods and the replacement levels for the calcium contents of the experimental diets. The amount of calcium content in the mash experimental diets increased (P < 0.05) significantly with the level of replacement. Furthermore, pelleting negatively influenced the amount of calcium content for PM based diets, whereby pelleted diets with more PM grains had significantly lower calcium compared to those with more maize grains.

4.5 Discussion

4.5.1. Chemical composition of main ingredients used in experimental diets

In this study, PM was observed to contain higher lysine, leucine, methionine, glycine, arginine, threonine and alanine contents than maize. These results are similar to those by Burton et al. (1972) who found pearl millet to be 40 % richer in lysine and methionine and 30 % more threonine compared to maize. Similar concentrations of amino acids in PM were reported by several researchers (Ejeta et al., 1987; Singh et al., 1987; Adeola and Rogler, 1994). According to Amato and Forrester (1995) the more balanced amino acid profile found in PM reduces the need to supplement PM based broiler diets with lysine and sulfur amino acids.

Although experimental diets were formulated to be iso-caloric (11.5 ME (MJ/kg) and iso-nitrogenous (17% CP) using the Pearson square feed formulation equation and a try and error feed formulation software, the proximate analysis results yielded different contents for crude protein. The amount of protein contents obtained from the feed formulation software when maize was replaced with pearl millet at 50 %, 75 % and 100 % replacement levels were 18 %, 6 % and 0.6 % higher than those from proximate analysis. Based on these results, the prediction accuracy of the feed formulation software seemed to have increased with the increasing replacement level. Limited information is available on how different cereals may influence proximate analysis results for broiler diets formulated with a trial and error method of feed formulation. In this study the CP content of the total replacement (100 % PM) diet from proximate analysis was much more similar to the one obtained from the try and error feed formulation method as compared to the 50 % and 75 % PM replacement diet. More research is required to relate the effects of cereal feed ingredients on the chemical composition of broiler diets when the trial and error as a feed formulation method is used.

4.5.2. Effects of pelleting on chemical composition of broiler diets

Feed processing is generally known to possibly affect the chemical composition, nutritive quality as well as the functionality of food products. In this study, pelleted diets were found to have more CP contents than the mash diets. Interestingly, pelleting did not affect the CP contents for the total replacement (100 % PM) broiler diet. According to Medel et al. (2004), both the physical (e.g. reduced particles) and chemical (e.g. molecular structures of feed components) changes resulting from feed processing may either reduce or increase the nutritional quality of feeds.

The increased contents of CP by pelleting indicated by the results of 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 due to the destruction of enzyme inhibitors present on the native form of proteins. This may result in an exposure of nutritive components, which were initial encapsulated in the endosperm, enhancing enzymes activity, as a result of protein denaturation (Sivhus, 2017).

As highlighted above, results of this study indicated that pelleting had no significant effects on CP contents for the total replacement (100 % PM) broiler diet. These results may suggest that, the normal pelleting temperatures (about 80 ºC), used to pellet experimental diets for this study, was only enough to induce structural changes, resulting in protein denaturation, of maize based diets but not for PM based diets. In other words, these finding suggests that the source of protein may influence the extent of denaturation during normal pelleting temperatures. This may mean that when pelleting at normal pelleting temperatures (60 – 90 ºC) it is easier to denature protein sourced from maize as compared to that of 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 occurs as a result of a considerable change in secondary, tertiary and quaternary structures, is said to occur as a result of higher temperature, moisture and friction applications during pelleting (Wood, 1987; Thomas et al., 1997). There is limited information on effects of pelleting on the CP content of PM based broiler feeds; therefore, there was no study found to compare these findings.

Although not significant, the present study revealed that the cruder fiber contents of both experimental diets were negatively affected by pelleting significantly ($P<0.05$). In addition to further reduction of particle sizes by the pelleting machine, the reduction in fiber contents due to pelleting may be attributed to increased solubility of the fibers in pearl millet grains. Hydrothermal pressures and shearing forces of feed processing are reported to disrupts cell walls and structures of high fiber components of feeds (Saunders et al., 1969), influencing the degradability as well as the solubility of fiber components of feeds (Bjorck et al., 1984).

This study has shown that mash diets had more fat (ether extract) content as compared to the pelleted diets. Pelleting involves the application of heat and moisture this could be the reason of reduced fat in pelleted diets. Pelleting negatively influenced the amount of calcium contents in the experimental diets. Calcium is one of the minerals and vitamins that may be negatively affected by the application of high temperatures during pelleting therefore, it is always advisable to supplement the diets through vitamins-minerals premixes. According to Abdollahi (2011), very high conditioning and pelleting temperatures used by industrial machines during feed production aimed at producing high quality pellets tend to neglect the nutritive quality of pellets. Proximate analysis of the experimental broiler diets for this study revealed that pelleting had no effect on ash, dry matter and phosphorus contents of all diets. This study is therefore important as a way of contributing to the body of knowledge with respect to processing PM based diets in arid to semi-arid regions especially in Namibia. The importance of researching on the effects of feed processing on the nutritional composition and nutrients quality thereof has been overlooked by researchers who for some unknown reasons were only interested on the effects of feed processing on the performance of broilers. The knowledge of how different feed processing methods affects the nutrient quality and composition may give an idea of how much supplementation is required for improved broiler performance. The oversupply of nutrients may contribute to unnecessary alleviated costs of chicken feeds. The excess nutrients excreted by birds may also cause environmental pollution threatening the lives of all of its habitants.

4.5.3 Effects of replacement levels on the chemical composition of broiler diets

Findings of this study highlighted that, PM based broiler diets had significantly ($P < 0.05$) higher CP content compared to maize based diets. The high contents of CP in PM based broiler diets may be attributed to the high CP and amino acid contents in found in PM grains compared to maize as indicated in section 4.5.1 of this Chapter. Although the exact mechanism underlying the effects of increased levels of CP contents for PM is not clear, given the absence of literature to back up the findings of this study, it is clear to the author that PM contains attractive nutritional factors. According to Appleby (2010), the quality of the CP content in feed ingredients is determined by the balanced profile of the essential amino acids rather than the dietary CP levels. More PM was used to substitute soybean meal due to its high CP, doing so reduced the amount of soybean used in PM based diet.

The replacement levels were observed to have reduced the contents of crude fibre in the experimental diets. The reduced contents of fibre in experimental diets with more pearl millet may be due to the susceptibility of pearl millet fibre structures to grinding. This important finding of the present study calls for further research to work on the idea of incorporating pearl millet bran in broiler diets as a mean to add more fibre to the diet while reducing feed costs. Protein sources such as Kalahari melon seed meal may be used as a replacement of soybean meal in PM based diet since.

Results obtained from the present study revealed that the increased levels of PM as a replacement of maize in broiler diets increased fat (ether extract) contents. The high content of fat in PM based diets may be attributed to the high contents of fat in PM grains as revealed by the proximate analysis of this study. Amini and Ruiz-Feria (2007) indicated that PM has higher oil content than corn, averaging 5%. According to Jacob (2013) linolenic acid makes up 4% of the total fatty acids in the oil, making PM a good source of omega-3 fatty acids compared to maize.

The amount of calcium contents in the experimental diets increased ($P < 0.05$) significantly with the level of replacement. These findings could be a result of high contents of calcium found in PM compared to maize.

4.6. Conclusion

According to the results obtained from this study PM grains have higher CP and ether Extract content than maize. Pearl millet was also found have higher fat content and better amino acids profile than maize. The CP contents of PM based broiler diets determined by the try an error feed formulation method were not exactly the same as those from proximate analysis.

Pelleted diets had more CP contents than the mash. A numerical reduction of fiber content in broiler diets as a result of pelleting was observed in this study and this has a potential advantage of increasing overall digestibility of PM based diets. Mash diets had more fat (ether extract) contents as compared to the pelleted diets and this has a potential of making the birds put on more fat which may be undesirable to modern day health conscious consumers.

4.7. References

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CHAPTER 5: EFFECTS OF PELLETING PEARL MILLET BASED DIETS ON THE GROWTH PERFORMANCE OF BROILER CHICKENS

5.1. Abstract

The main objective of this study was to investigate the effects of pelleting on the growth performance of broiler chickens when maize is replaced with pearl millet (PM). One hundred and ninety six day old Cobb-500 broiler chicks were obtained from Namib Poultry Industries and raised on a two phase feeding regime (i.e. starter for the first 3 weeks and finisher for last three weeks). Broilers were fed on the same commercial starter diet for the first three weeks. Different experimental diets were supplied during the finisher phase where the control was a commercial feed without PM. The experimental design used was a 2 x 3 factorial arrangement of treatments evaluating two feed processing methods (grinding and pelleting) and 3 replacement levels (50 %, 75 % and 100 %). Pelleting had no significant effects ($P > 0.05$) on average feed intake of broilers, although birds fed on mash diets consumed more feeds compared to those fed on pellets. Pelleted diets produced broilers with heaviest final body weight as compared to those fed on mash diets, though the difference was not significant ($P > 0.05$). Pelleting had no significant effects ($P > 0.05$) on average weight gain of broiler chickens in the finisher stage. The present study found no significant effect ($P > 0.05$) on the FCR of broiler chickens due to pelleting during the finisher phase although, although the FCR tended to be lower for pelleted PM based diets. Pelleting did not significantly ($P > 0.05$) affect mortality rate of broiler chickens. Replacement levels had no significant influence on the body weights or weight gain of broiler chickens ($P > 0.05$). However, a numerical

increment tended to occur for weigh gain as the replacement level of maize with PM grains increased i.e. as more PM was included. The present study found no significant effect on the FCR of broiler chickens by replacement levels. It can be concluded from this study that, maize can totally be replaced with PM without any detrimental effects to the growth performance of broilers. Furthermore, PM based diets can successfully be pelleted without any detrimental effects to the production performance of broiler chickens. Based on the findings of this study, it can be concluded that replacement of maize with PM grains in broiler diets commands the similar broiler production performance even in the pelleted form.

5.2. Introduction

Feed costs have constantly been on the rise over the past years which prompted poultry nutritionists all over the world to opt for researching on the potential of locally available ingredients in poultry feeding. Maize which has been used as a major energy source in least cost poultry diets and has been imported cheaply over the years by many nations including Namibia has recently faced major demands increasing its costs and spurring its replacement with locally available high energy cereal grains. Ranked the fourth most important tropical food cereal in the world (Andrews and Bramel-Cox 1994), pearl millet is known as a drought resistant cereal crop (Lee and Hanna, 2002) that grows in arid to semi-arid environments with low fertile soils and limited amount of moisture.

Research has established that the use of pearl millet grains in poultry feeds as a replacement of maize has a potential to reduce costs of ever-increasing ingredient costs

(Hafeni, 2013). Nutrition-wise pearl millet is known and praised for its high protein contents and better balanced amino acid profile. It is said to be 8 % - 60 % higher in protein, 40 % richer in lysine and methionine and 30 % more threonine compared to maize depending on variety used (Burton et al., 1972; Singh and Perez-Maldonado, 2003). Replacing maize with pearl millet in broiler diets minimizes the requirements of protein rich feed ingredients as well as the amino acids supplementation (Behnke, 1994). Due to its high crude protein content, the use of PM grains in broiler diets reduces the amount of soybean meal required and potentially reducing feed costs. Protein being the most expensive feed ingredient in compounded feeds, especially to some African countries such as Namibia, even a slight reduction in the amount of soybean meal required to formulate broiler diets may result in a considerable reduction in feed costs. Therefore, using PM which is high in protein is said to reduce the amount of soybean meal required, to formulate broiler finisher diets thereby reducing the costs of feeds considerably (Hafeni, 2013).

Several feed processing methods are believed to increase feed value resulting in high productivity (Abdelgadir and Morrill, 1995). The choice of the processing method is mainly influenced by the availability and affordability of the equipment and infrastructure involved in addition to the operation skills required (Behnke, 1996). Poultry feed processing technologies are not fully utilized in developing countries such as Namibia. In recent years an increasing interest in poultry farming and high costs of feed ingredients fueled the search for cheaper feed alternatives for increased poultry production in Namibia.

Grinding combined with mixing results in a mixture referred to as “Mashed diet” which is fed right after thorough mixing of all the ingredients. Grinding of ingredients such as maize and pearl millet grains are said to reduce the particle size and increase surface area of the feed thus increasing its accessibility by enzymes to work on it once eaten by the birds. Studies have shown that feeding pearl millet as a replacement of maize in iso-caloric and iso- nitrogenous mashed diets yielded equivalent results (Sullivan et al., 1990; Hafeni, 2013).

Optimal feed intake throughout the growing period is said to determine the successful development of broilers (Ghazi et al., 2012). A number of factors such as environmental temperature, nutrient density of diet and physical quality of feeds influence the feed intake which may result in significant broiler growth (Kamran et al., 2004). Further processing methods, such as conditioning and pelleting are believed to improve feed quality by enhancing palatability which results in increased feed intake by the birds (Abdollahi, 2011). With the use of mechanical pressure, moisture and heat, pelleting of a mashed diet is mainly used to agglomerate smaller feed particles (Peisker, 2006). Behnke and Beyer (2002) determined that economics of poultry production is enhanced by feeding pelleted feeds which tends to improve feed efficiency and growth performance of broiler chickens. According to Behnke (1994), in addition to improved nutritive value of feeds and decreased ingredient segregation, pelleting may decrease feed wastage and reduce energy spent on ingestion. There is little information on the effect of pelleting PM based diets on broiler performance. The objective of the present study was to investigate the effects of pelleting and replacement of maize with pearl millet in broiler finisher diets on growth performance and mortality rate of broiler chickens.

5.3. Materials and Methods

5.3.1. Study Site

The study was conducted at the Poultry Experimental Unit (Figures 5.1 and 5.2), Neudamm Campus of the University of Namibia situated between 22°50.568‛‛S and 17°37.048‛‛E (Altitude:1749m/5739ft) in the Khomas Region, which is located about 34 km east of Windhoek, the capital city of Namibia. It was carried out during July-August, which the winter period in Namibia.

Figure 5.1. Neudamm Poultry Experimental Unit

Temperatures during this period goes as low as -1 ˚C at Neudamm Campus. This necessitated the feeding of a standard maize based to all the chickens in the starter phase (first three weeks) and the experimental diets were given to the birds in the finisher phase (the last three weeks to table weight). The starter phase was therefore, taken as the adaptation period due to the extremely low temperatures at night at Neudamm.

Figure 5.2. Broiler experimental house

Birds housing and management

One hundred and ninety-six (196) day-old unsexed Cobb 500 broiler chickens were purchased from Namib Poultry Industries. On arrival, all of the broiler chicks were placed in a previously well heated brooder house (animal nutrition laboratory) with infra-red bulbs, feed and fresh water with a stress pack to calm the chicks down after transportation. Upon arrival, the chicks were actively eating and drinking water at one day of age (Figure 5.3a).

Figure 5.3. a) One day-old broilers (n = 196), b) Two weeks old broilers (n =196), c) Heating of the experimental house d) Broilers eating experimental diets e) Broiler drinkers: Positioning of drinkers and feeders used in this study f) Removal of wood shavings: cleaning the chicken pens.

The chickens acclimatized well during the brooding period, and no fatalities observed during this period (Figure 5.3b). Infrared bulbs were utilized in addition to heated drums to generate a conducive environment for the chickens (Figure 5.3c). Three charcoal heated drums were placed in the house just before sun-set daily, throughout the experimental period (the finisher phase) which lasted for three weeks. Fresh feed was provided in hanged feeders every morning (Figure 5.3d). Plastic drinkers were cleaned and fresh water provided twice every day (Figure 5.3e). The wood shavings used as litter had to be turned every two days and changed twice a week to manage challenges that could have been brought about by water spilling and excrement (Figure 5.3f).

5.3.2. Description of the experimental design and treatments

A Completely Randomized Design (CRD) was adopted due to the narrow weight range from 850 to 950 g at the end of starter phase of feeding. Cobb-500 broiler breed was used since it is the most commonly available commercial broiler bird in Southern Africa. A 2x3 factorial arrangement of treatments was used to evaluate 2 processing methods (grinding and pelleting) and 3 diets containing different levels pearl millet (Okashana 2 cultivar) (50 %, 75 % and 100 % replacement of maize with PM).

The diets with pearl millet as a replacement of maize in broiler diets at 50 %, 75 % and 100 % levels were formulated as described in Chapter 4, section 4.3.2.3. The experimental diets were formulated to be iso-caloric (11.5 MJ/kg ME) and iso-nitrogenous (17% CP) (Table 4.1 in Chapter 4) The experimental diets fed in form of pellets were pelleted by the student using a Pelletizer (ZPELA062016, model KL120) (a pelleting machine as shown in Figure 5.9) which is fitted with a flat die ring of 3 mm sized holes and capable of producing 70-100 kg of feed per hour. Commercial control diet (a positive control in a form of pellets) was purchased from Animal Feed Company. The experimental dietary treatments were applied as follow; the 50, 75 and 100% replacement of maize with PM fed in a form of either pellets of mash. Each of the experimental diets, including the control diet, had two replicates with an average of 14 birds in each replicate.

Figure 5.4. Pelleting machine: the pelleting machine used to pellet the experimental diets

5.3.3. Bird Rearing

The environmental temperature of the brooder house was maintained at 31 ºC for the first week and eventually reduced gradually to 21 ºC by end of experiment. As a precautionary measure, considering the winter months in which this experiment was carried out, a two-phase feeding regime, comprised of three (3) weeks starter phase and three (3) weeks finisher phase, was utilized since older birds tend to deal with stress better than younger birds. A starter diet (crumbles) purchased from an Animal Feed Company was used throughout the starting phase of production to ensure uniformity before the introduction of the experimental diets and this constituted the adaptation period. At the end of the first three (3) weeks (starter phase), broiler chickens were transferred to the experimental house and randomly allocated to 14 experimental demarcation units (12 units for the 6 experimental diets of two replicates with about 14 birds each and 2 units for the control diet with similar settings). Each of the experimental pens was had 10 cm deep litter layer of clean sawdust (wood shavings).

The dietary (mash or pelleted) treatments were replicated twice and randomly assigned to the experimental units housing 14 chickens each. The experimental house was fitted with infra-red bulbs and a build-in fan to help control the temperature and ensure proper ventilation. During the night, as most of the time low temperatures prevailed at Neudamm Campus, supplemental heat was provided with charcoal fired heater in the specially designed drums. Three (3) charcoal drums were strategically placed in the chicken house to distribute heat uniformly with the help of the inbuilt fan. This exercise was carried out throughout the final phase of feeding which lasted for three (3) weeks. Fresh feed and water was provided ad libitum throughout the whole experiment. Initially the bird were vaccinated for New Castle Disease and treated with Stress pack as recommended by the Ministry of Agriculture, Water and Forestry of Namibia.

5.3.4. Data Collection

Iron steel feeders suspended from the inner roof of the house directed into each experimental unit were filled up with feeds and leftovers recorded every day. Feed intake was determined as the difference of feed given and feed left at the end of each day. Body weights were determined by weighing and recording the weights of all chickens in each of the experimental unit, on a weekly basis. Feed conversion ratio (FCR) was determined by dividing the average amount of feed intake per day per chicken by the average amount of weight gained per day per chicken. Mortality was recorded daily. The mortality rate was calculated as a function of the number of deaths per diet divided by the total number of birds in each diet (n = 28) diet multiplied by 100.

5.3.5. Data Analysis

The data were analyzed as described in Chapter 3, section 3.4. The effects of two (2) processing methods and three replacement levels and their interactions on the performance of broilers were evaluated using a 2 x 3 factorial arrangement of treatments as indicated in the statistical linear model in Chapter 4, section 4.3.5.

5.4. Results

5.4.1. Daily Feed Intake

A significant ($P < 0.05$) interaction was observed between the two processing methods (mashing and pelleting) and the three replacement levels for the daily feed intake. In mash diets, the daily feed intake of the group of broilers fed on 100 % PM mash diet was significantly ($P < 0.05$) higher than those were fed on the 50 % and 75 % PM mash diets (Figure 5.5). In pelleted diets, when maize is replaced with PM at 50 %, 75% and 100 % PM levels, similar increasing daily feed intake were observed.

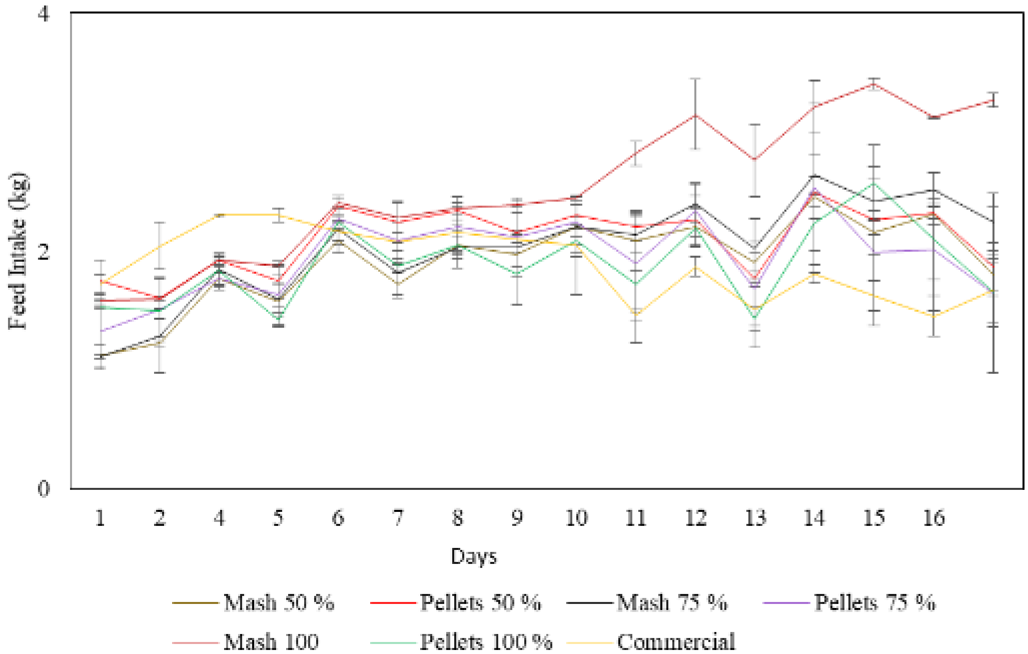

Figure 5.5. Effects of different experimental diets on daily feed intake of broilers

Results of this study indicated that neither processing method nor replacement levels affected the daily feed intakes of birds at a finisher stage of broiler production significantly (P > 0.05). However, the present study showed a numerical reduction in daily feed intake for birds which were fed on the commercial diet. Although not significant, in the first week of the experiment, broiler chickens fed on mash 50 % PM and mash 75 % PM consumed the lowest amount of feeds. However, an obvious constant increase in feed consumption has been observed for the whole experimental period for these two diets. In the third week of the experiment, birds fed on mash 50 % PM recorded the highest feed intake following those fed on mash 100 % PM.

In this study although not significant, broilers fed on pelleted experimental diets recorded higher daily feed intakes in the first week of the experiment but lower in the third week of the experiment compared those fed on mash experimental diets (Figure 5.6).

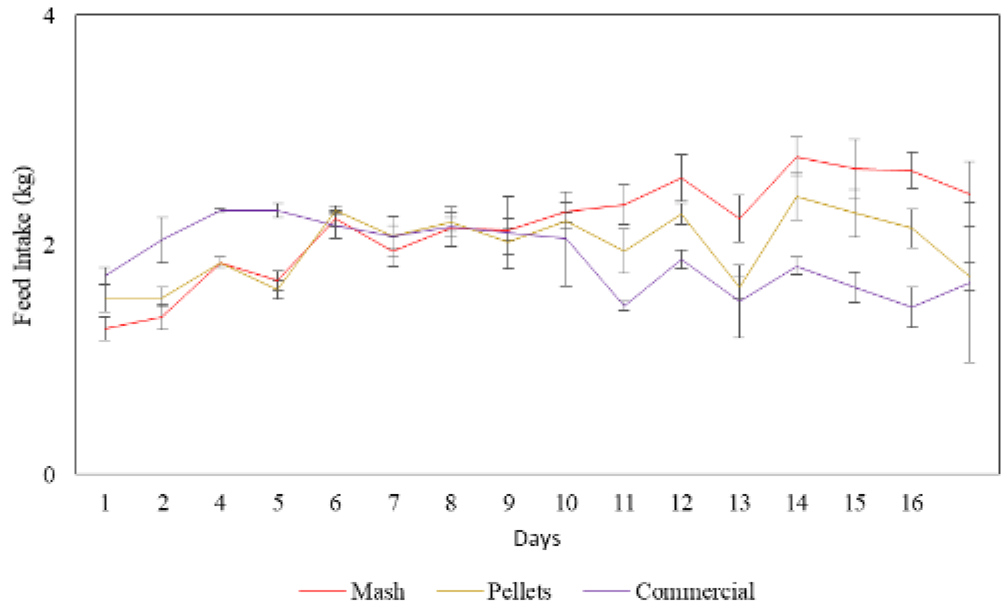

Figure 5.6. Effects of different processing methods on feed intake of broilers

5.4.2. Live body weight and weight gained

Results from this study indicated that there was no significant interaction (P>0.05) observed between processing methods and the replacement levels for both the average feed intake, body weight, weight gain and FCR (feed conversion ratio) of the dietary treatments. Furthermore, neither processing methods nor replacement levels were observed to significantly affect (P>0.05) both the average feed intake, body weight, weight gain and FCR (feed conversion ratio) of broiler chickens (Figure 5.7).

Numerically, results from this study indicated that on average, birds fed on the mash diets consumed more feeds to gain weights equivalent to those fed on pelleted diets.

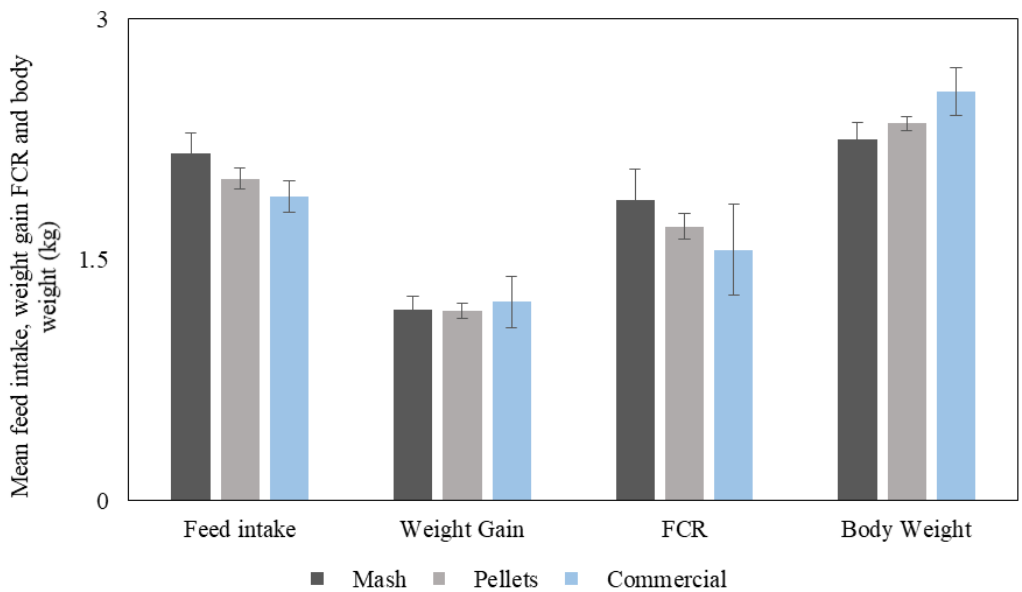

Figure 5.7. Effects of methods of feed processing on the average mean feed intake, weight gain, FCR and body weights of broiler chickens

Although not statistically significant (P > 0.05), results from the present study indicated that, when maize was replaced with PM at 50 %, broilers gained more weight while equal or less amounts of feed was consumed when maize was replaced with PM at 75 % and 100 % levels (Figure 5.8).

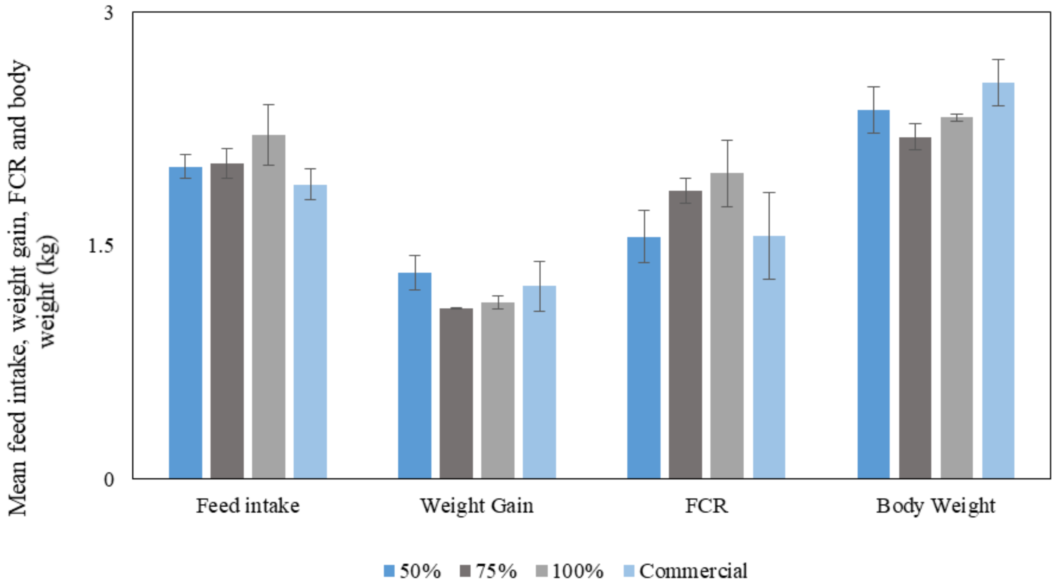

Figure 5.8. Effects of replacement levels on mean average of feed intake, weight gain, FCR and body weights of broiler chickens

Regardless of the processing method, the present study recorded a slight increase in the FCR as the replacement level increased; with the 100 % PM replacement level recording the highest and 50 % PM the lowest FCR. Replacing maize with PM at 50 % recorded the best FCR which is similar to that of the commercial diet with even better (lowest) FCR observed for mash 50 % PM diet (Table 5.1).

Table 5.1. Effects of different experimental diets on the mean average of feed intake, weight gain, FCR and body weights mortality rate of broilers

	Control Diet	SEM	Mash Replacement level (%)			SEM	Pellets Replacement level (%)			SEM	P-value	MxP
Parameter	**Commercial**		**50**	**75**	**100**		**50**	**75**	**100**			
Feed intake (kg)	1.895	0.098	1.92	2.03	2.54	0.104	2.10	2.03	1.89	0.084	0.162	0.024
Weight gain (kg)	1.240	0.160	1.35	1.10	1.12	0.065	1.30	1.10	1.15	0.065	0.949	0.949
FCR	1.565	0.281	1.49	1.85	2.29	0.141	1.63	1.85	1.64	0.837	0.396	0.243
Body weight (kg)	2.550	0.150	2.35	2.10	2.30	0.080	2.40	2.30	2.35	0.479	0.467	0.865

SEM = Processing Methods Standard Error of mean, MxP = Interaction of processing methods and replacement levels

5.4.4. Mortality Rate

Results from the present study indicated that, there was no significant interaction ($P > 0.05$) observed between processing methods and the replacement levels for the mortality rate. Furthermore, different methods of feed processing and varying replacement levels had no significant ($P > 0.05$) effects on mortality rate of broiler chickens. However, the present study recorded higher mortality rate for pelleted PM based diets compared to mash diets. The commercial diet which was used as a control for this study recorded the highest mortality rate (Table 5.2).

Table 5.2. Effects of pelleting and different replacement levels on the mean average of mortality rate (%) of broilers

	Replacement Levels	**Mortality rate (%)**
Mash	50 %	10±3.33
	75 %	10±3.33
	100 %	3.34±3.34
Pellets	50 %	17.7±2.31
	75 %	16.7±16.67
	100 %	11.5±11.54
Control	-	29.7±1.10

SEM = Standard Error of mean

5.5. Discussion

A significant interaction was observed among the methods of feed processing and replacement levels for the daily feed intake. This interaction could be related to the significantly reduced feed consumption by broilers particularly fed on the positive control (commercial) diet and a significantly increased daily feed intake by the birds fed on mash 100 % PM. Broilers fed mash 100 % PM diet consumed significantly more feed than all the other experimental diets regardless of the processing method or replacement level. This high feed consumption by birds fed mash 100 % PM could be partly attributed to feed wastage in addition to the authentic constant feed intake increment unique to all mash diets as compared to those fed pelleted diets. These results are in a contradiction with those by Ghazi et al. (2012) who reported higher feed consumption for pelleted diets compared to mash diets. This observation is partly in disagreement with the studies by Choi et al. (1986) and Nir et al. (1994) who indicated that broilers tend to eat more of pelleted diet improving the growth rate, since results of this study recorded heavier birds for pelleted diets with less feed intake.

Although not significant, results from this study indicated a slight reduction in daily feed intake by the broiler chickens fed on maize based diets as compared to PM based diets. The increased daily feed intake by broilers fed PM based diets may suggest improved palatability as a result of high fat and energy contents in PM compared to maize, as indicated by the results in Chapter 4. These results are in support of previous researchers who reported that the oil contents of feeds may enhance growth by improving the palatability of feed (Fuller, 1981; Moran, 1986). This is in line with the well-known fact that birds generally eat to satisfy their energy requirements since birds consume more of low energy diet and less of high energy diet (Valkonen et al., 2008).)

Results from this study indicated that there was no significant interaction observed between processing methods and the replacement levels for both the average feed intake, body weight, weight gain and FCR (feed conversion ratio) of the dietary treatments. Furthermore, neither pelleting nor replacement levels significantly influenced the average feed intake, body weight, weight gain nor FCR (feed conversion ratio) of broiler chickens.

Although not significant, pelleted diets produced broilers with heavier final body weight as compared to those fed on mash diets. The heavier body weight recorded in this study for birds fed on pelleted diets may indicate the superiority of pelleted diets over the mash. These results are in agreement with those by 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 those fed on a mash diet from week 1 to week 4 of the experiment. According to Munt et al. (1995) feeding mash diets significantly reduced the growth performance of broilers. A study by Kim and Chung (1996) indicated that broilers fed on mash diet had the lowest live body weight at 41 days as compared to those fed on crumble and pellet diets.

Results from this study indicated that on average, birds fed on the mash diets gain weights equivalent to those fed on pelleted diets. The weight gain observed for broilers fed on mash diets in the present study may be attributed to the positive feed intake increment recorded for birds fed on mash diets compared to a negative feed intake increment of broilers fed pelleted diets. The reduced feed intake by birds fed on pelleted diets in this study may be a result of extreme temperatures (very cold at night (lowest temperature recorded was -1 ºC) and very hot during the day (highest recorded 38 ºC)) experienced throughout the experimental period. These findings are further supported by more results of this study which indicated that ascites related mortality rate among the birds fed on pelleted diets was 39 % higher than that of mash diets. The significant of this finding is that PM can be used as a substitute for maize to command the same growth of broiler chickens and that processing costs may be reduced by presenting the PM based feed in mash form.

Regardless of the processing method, birds fed on 50% PM level of replacement gained slightly more weight compared to other replacement levels. The higher weight gain recorded for broiler chickens fed on 50% PM based diets as compared those fed 75 and 100% replacement levels may be partly related to a special combination of maize and PM which might have resulted in a more balanced amino acid profile for this diet, given the fact that PM grains has a more balanced amino acid profile from PM grains compared to that of maize grains. Essential amino acids are required for protein synthesis and rapid meat deposition in broilers (Wakibia, 2015). The results of this study are in agreement with Medugu et al. (2010) who observed no significant effect on weight gain for broilers fed maize (1788 g/bird) and those fed PM (1862 g/bird) based diets. More studies reported similar results when PM was used as a partial or complete replacement of maize in broilers diets (Hildago et al., 2004; Manwar and Madal, 2009; Kwari et al., 2014). However, Baurhoo et al. (2011a) and Ibe et al. (2014) reported highly significant ($P < 0.05$) weight gain for broilers fed PM based diets compared to those fed on maize based diets.

The present study found no significant effect on the FCR of broiler chickens by processing methods or replacement levels. This means comparable FCR can be obtained with PM instead of using maize in formulations. It also means, it may not be necessary to use extra energy and effort in pelleting PM based diets and hence potentially lowering feed costs for the farmers. However, numerically better FCR was recorded for broilers fed on pelleted diets as compared to those fed mash diets. This trend is in support of results by Ghazi et al. (2012) who reported better FCR in broilers fed on pellets than those fed on mash diets. Similar results were reported by Moran (1990) who reported that pelleted diets produced broilers with better feed efficiency as compared to broilers fed on mash diets. The present findings are in line with those reported by Hafeni (2013); Kwari et al (2014); Wakibia (2015) who found no differences in FCR of broilers fed PM and those fed maize based diets.

Results from the present study indicated that, there was no significant interaction ($P > 0.05$) observed between processing methods and the replacement levels for the mortality rate. Furthermore, pelleting and varying replacement levels did not significantly affect mortality rate of broiler chickens. Numerically, high mortality was recorded when broiler were fed on pelleted diets compared to mash diets. According to Samukange, a veterinarian doctor at Neudamm Campus of the University of Namibia, all deaths which took place throughout this whole experiment was due to a metabolic disorder known as ascites. Ascites syndrome is a condition characterized by excessive accumulation of fluid in the abdominal cavity and causes high mortality at 4 to 6 weeks of age (Ranson, 2005). Ascites is more common in regions with high elevations above 1200 meters especially during winter. High altitude regions are characterized by low atmospheric pressure which is associated with reduced oxygen levels in the air in addition to low temperature and humidity. The low temperatures are said to increase metabolic rates resulting in high demand for oxygen (which is already low at high altitudes), resulting in reduced growth (Esmail, 2012).

The altitude at the Neudamm Campus of the University of Namibia is estimated to be at 1749m/5739ft. Furthermore, this study was carried out in July-August winter period of the year in Namibia. The winter temperatures during this period of the year were as low as -2 ˚C at Neudamm Campus. Moreover, the chicken houses at Neudamm Farm are typical poultry housing prevalent to most parts of the country, without any completely environmentally controlled housing infrastructures in place. Regardless, high incidences of ascites syndrome were recorded in birds fed pelleted diets compared to those fed mash diets. These results are inconsistence with findings by Ghazi et al. (2012), who reported greater mortalities for birds fed pelleted feed than those receiving mash feed. A study by Nir et al (1995) reported increased mortality in male broilers fed pelleted diets compared to those mash diet. The same authors revealed that females were less susceptible to ascites than males fed pelleted diets.

5.6. Conclusion

Results from this study showed that broilers fed on pelleted experimental diets recorded higher daily feed intakes in the first week of the experiment and lower in the final week of the experiment compared those fed on mash diets, resulting in similar weight gains recorded at the end of the experiment. Furthermore, on average, birds fed on mash diets consumed more feeds to gain weights equivalent to those fed on pelleted diets. This study also highlighted the best combination of PM and maize grains to be 50 % replacement level, whereby broilers recorded less average feed intake, highest weight gain and best FCR. Pelleting had no significant effects of mortality rate of broiler chickens when maize is replaced with PM. Replacing maize with PM grains in broiler diets yielded weight gains similar to that of the commercial diet. Based on the findings of this study, it can be concluded that replacement of maize with PM grains in broiler diets commands the same broiler production performance even in the pelleted form.

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CHAPTER 6: EFFECTS OF PELLETING PEARL MILLET BASED DIETS ON THE CARCASS CHARACTERISTICS, GIZZARD AND PROVENTRICULUS DEVELOPMENT OF BROILERS

6.1. Abstract

This study aimed at determining the influence of pelleting and replacing maize with pearl millet (PM) on the carcass characteristics, gizzard and proventriculus development of Cobb 500 broiler chickens. One hundred and ninety six day old Cobb-500 broiler chicks were fed on the same starter for the first three weeks. Different experimental diets, with two replicates each, were supplied during the finisher phase. At the end of the experimental trial (finisher phase) which lasted for three weeks; four birds of average weights were selected from each experimental diet and slaughtered. Parameters studied included; live, dressing, carcass, breast, thigh, abdominal fat, gizzard, proventriculus and heart weights. A completely randomized design (CRD) with a 2 x 3 factorial arrangement of treatments was used to evaluate two feed processing methods (grinding and pelleting), three replacement levels (50 %, 75 % and 100 %) and their interactions. This study showed that both pelleting and replacement levels had no significant effect on the carcass weight and development of the gizzard and proventriculus. Furthermore, results from this study revealed that replacing maize with PM had no significant ($P > 0.05$) effect on carcass characteristics of broiler chickens. However, broilers fed on pelleted diets had significantly ($P < 0.05$) higher breast, thigh, abdominal fat and gizzard with content weights when compared to those fed on mash diets. In conclusion, although pelleting had no significant effects on the carcass weights, results from this study revealed feeding

pelleted diets resulted birds with heavier valued cuts (breast and thing) which usually fetches high prices in the market, which may potentially increase the income returns for broiler producers.

6.2. Introduction

Genetic selection for improved growth rate has resulted in fast-growing broiler strains attaining 2 kg of their body weight within 5 weeks, with feed intake of 3 kg (Choct, 2009). The effects of genetic selection are said to be reflected in the functions of the central nervous system, endocrine and immune functions, digestion, metabolism, growth pattern, and carcass composition and structure (Khajavi et al., 2003; Dawkins and Layton, 2012).

The high quality broiler chicken seems to be the one with more breast meat and less abdominal fat content. The most valuable broiler cuts tend to be the breast, thigh and drumstick muscles because they contribute the highest proportions of edible meat. According to Nasr and Kheiri (2011), the amount of dietary protein and lysine in feed may influence the proportion of the breast, thigh and drumstick muscles, although the breast muscle tends to develop faster. Some researchers indicated that replacing maize with PM in broilers diets had no significant effects on the breast, thigh and drumstick muscles (Rao et al., 2004; Wakibia, 2015).

Poultry production performance is said to be greatly influenced by the physical forms and particle sizes of the feed offered to the birds (Amerah et al., 2007). According to

Agunbiade (2000) and Adeyemi et al. (2008) pelleting of broiler diets resulted into higher percentage of the most expensive commercial chicken cuts namely, dressing, breast meat, drumstick and thigh weights. Moreover, feed particle size reduction as a result of feed processing is said to have effects on the development of different segments of the digestive tract in birds. Scientific studies by Gabriel et al. (2003) and Amerah et al. (2008) showed that digestive tract development; growth performance, feed passage rate and the utilization of nutrient by birds can be affected by the size of feed particles. When compared to finely ground feed particle sizes, coarse grinding may result in lower feed per gain irrespective of the type of grain used (Amerah et al., 2008).

According to Nir et al. (1995) and Svihus et al. (2004), when diets are in mash form grain particle size is more critical as compared to when in pellets form. In other words, particle sizes may not have as much influence, in terms of performance, when in a pelleted form as compared to mash. However, these findings are in contradiction with those of a study by Nir and Ptichi (2001) who showed that broiler performance may be affected by particle size even after pelleting due to the fact that pellets dissolves when it gets into the crop after consumption. According to Amerah et al. (2007), particle size variation in feed is greatly influenced by grain type, when grinding due to different particle size distribution, although passing through the same screen size opening in a hammer mill.

High contents of abdominal fat can be associated with lower feed efficiency as well as some economic losses during evisceration, when the abdominal fat is removed especially when chickens are sold in cuts (Emmerson, 1997). What these findings seems suggest is that, high contents of abdominal fat might results in lower feed efficiency especially when chicken is sold in cuts since the abdominal fat is removed before marketing. Since abdominal fat may result in some economical losses at marketing, it is critical to understand the factors influencing high accumulation of abdominal fat in broilers. According to Temim et al. (2000) and Zeng et al. (2015), the energy in feed is mostly diverted from fatty tissue growth into the lean tissue accumulation as a result of increased dietary protein, reducing the carcass fat content. Since increasing of the amount of protein might protein might be costly, reduction of energy level of feed might result in reduced amount of abdominal fat. A study by Fan et al. (2008) reported a significant reduction in the amount of abdominal fat relative to live weight of broilers resulting from a reduced amount of energy in the feeds.

Researchers have found out that crude protein (CP) and amino acid (AA) contents in diets seem to influence the weight gain and carcass composition of broilers. This is because according to Zeng et al., (2015) reduced amount of CP contents in poultry feeds does not only decrease the carcass protein but it also increases the fat composition of the carcass. In the case of AA a significant reduction in abdominal fat composition as a result of increased lysine and methionine in broiler diets have been reported (Andi, 2012). Pearl millet grain is known to be rich in fat and essential amino acids such as lysine and methionine as indicated in Chapter 4 of this study. A study by Singh et al. (2009) reported that birds fed on PM based diets did yield 4 - 7 % more breast muscle and 22 % less abdominal fat compared to those fed on sorghum based diets. Although PM grains contain higher fat contents than sorghum grains, a study by Singh et al. (2009) suggested that the extra fat in the PM grain is more readily converted to muscle as compared to the fat in sorghum grains. These authors further suggested for a further investigation in order to understand the cause of higher protein deposition and lower fat deposition in tissues of broilers fed PM diets although iso-caloric and iso-nitrogenous diets were fed. Moreover, further investigation is required to look into the lipoproteins and total cholesterol concentration in serum of broilers fed PM based diets (Singh et al., 2009).

A study by Wakibia et al. (2015), demonstrated that replacing maize with PM in broilers diet had not significant effects on breast muscle weight, abdominal fat and gizzard weight. However, a study by Sharma et al. (2012) reported a significant reduction in breast muscle weight of broilers fed on PM based diet as compared to those fed maize. Furthermore, Singh et al. (2009) and Rao et al. (2004) reported higher abdominal fat for sorghum and yellow maize fed broilers compared to PM fed broilers. Moreover, some researchers reported higher weights of gizzards for the broilers fed on the maize based diets compared to those fed on the PM based diet (Yunusa et al., 2014; Kwari et al., 2014). There is limited information on the effects of pelleted pearl millet based diets on the digestive tract and carcass characteristics of broilers. This study therefore, aimed at determining the influence of pelleting and different replacement levels on the carcass characteristics, gizzard and proventriculus development of Cobb 500 broiler chickens. In this study, PM based diets were formulated to replace maize proportionately at three (50 %, 75 % and 100 %) different levels.

6.3. Materials and Methods

6.3.1. Study site

The study site is as described in Chapter 3 section 3.1 and Chapter 5, section 5.3.1.

6.3.2. Experimental diets and treatments

The description of experimental diets and treatments are as explained in Chapter 5 section 5.3.2.

6.3.3. Birds, Housing and Management

The information on birds, housing and management is as described in Chapter 5 section 5.3.3.

6.3.4. Experimental design and data Collection

A Completely Randomized Design with 2x3 factorial arrangement of treatments was used to evaluate 2 processing methods (grinding and pelleting) and 3 diets of different PM replacement levels (50 %, 75 % and 100 %) with a commercial diet used as a positive control, and as explained in details in Chapter 5, section 5.3.2. At the end of the experiment which lasted for three (3) weeks; 4 birds of average weights were selected from each diet were slaughtered following an overnight fasting with *ad libitum* water supply. Before slaughter, live weight of each bird was determined. Birds were humanely slaughtered by cervical dislocation before bleeding by cutting the jugular vein. After thorough bleeding, scalding was performed by immersing the carcass in hot water followed by de-feathering and evisceration. Dressing weight was recorded as the weight of carcass after blood drainage, de-feathering and removal of the head. Carcass weight was recorded as the weight after evisceration, when all the internal organs were removed. Abdominal fat, gizzard and heart were collected and their weights were determined before discarding. Breast and a left thigh meat were carefully cut off, weighed and stored in air tight plastic containers in ice water before they were stored in a freezer at -20 ºC.

6.3.5. Data Analysis

The data was analyzed as described in Chapter 3, section 3.4. Gizzard and proventriculus development as well as the carcass characteristics data for individual birds were considered as the experimental unit. Furthermore, the random component explaining variation among experimental units of each diet where considered along with the random component explaining variation within experimental unit, among subsamples of the same experimental unit as shown in the model below:

$$Y_{ijk} = \mu + \tau_i + \varepsilon_{ij} + \delta_{ijk} \qquad i = 1, 2, \ldots, t$$

$$j = 1, 2, \ldots, r$$

$$k = 1, 2, \ldots, s$$

That is

Y_{ijk} = replacement level + processing methods + replacement levels * processing methods + ε_{ijk} + chicken (cage)

Where

Y_{ijk} = observation for the *k*-th subsample (chicken) on the *j*-th experimental unit (replicates) of the *i*-th treatment (diet)

μ = overall mean, a constant

$\tau_i = \mu_{i...} - \mu$ = *i*-th treatment (diet) effect

ε_{ij} = random component explaining variation among experimental unit (which is replicate in this study) on the same treatment

δ_{ijk} = random component explaining variation within experimental unit (replicate), among subsamples (chickens) of the same experimental unit.

6.4. Results

6.4.1. Carcass characteristics

There was no significant interaction (P>0.05) observed between processing methods and the replacement levels for live weight, dressing weight, heart weight, breast weight, thigh weight, abdominal fat. However, a significant interaction (P<0.05) was observed between processing methods and replacement levels for carcass weight. Although not statistically significant (P>0.05), mash diets recorded an increase in carcass weight as the replacement level increased. In pelleted diets, although not statistically significant (P>0.05) a reduction in carcass weight was observed as the replacement level increased, with the pelleted 100 % PM diet recording the lowest carcass weight. Although not statistically different, broilers fed on 50 % PM pellets recorded the highest carcass weight compared to other experimental diets (Table 6.1).

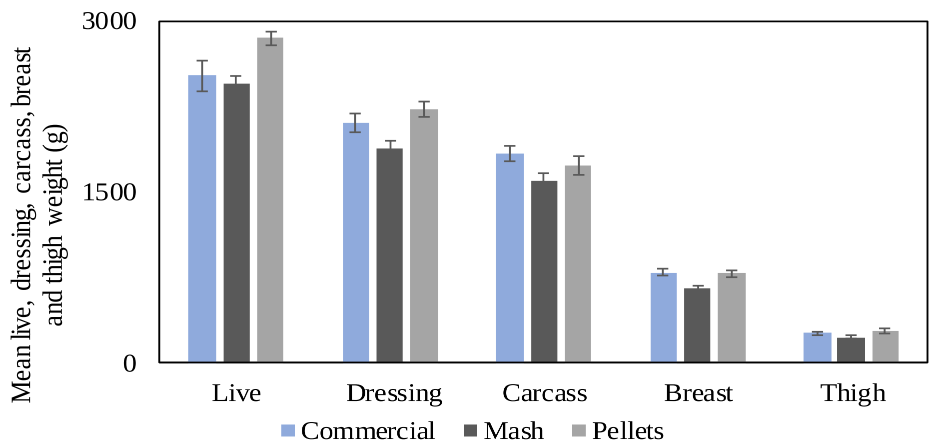
Table 6.1. Effects of different experimental diets on a live weight, dressing weight, carcass weight, breast weight, thigh weight, abdominal and heart weights of broilers.

	Control Diet	SEM	Mash Replacement level (%)			SEM	Pellets Replacement level (%)			SEM	MxP
Parameter	**Commercial**		**50**	**75**	**100**		**50**	**75**	**100**		
Live weight (g)	2524	132.45	2368.8	2417.5	2555.0	67.84	2963.8	2758.8	2830.0	63.74	0.383
Dressing weight (g)	2104	79.57	1798.8	1835.0	2022.5	59.22	2257.5	2228.8	2192.8	71.43	0.431
Carcass weight (g)	1834	69.60	1522.5	1563.8	1725.0	63.43	1930.0	1752.5	1522.5	82.08	0.039
Breast weight (g)	7988	32.87	636.25	635.00	711.25	19.23	825.0	790.00	746.25	26.77	0.144
Thigh weight (g)	2663	14.77	206.25	227.50	252.50	10.45	305.0	302.5	241.250	18.57	0.075
Abdominal fat weight (g)	38.75	2.39	31.25	36.25	33.75	1.86	41.25	52.50	48.750	2.98	0.722
Heart weight (g)	15.00	0.00	10.00	12.50	15.00	0.97	12.50	11.25	11.25	0.711	0.070

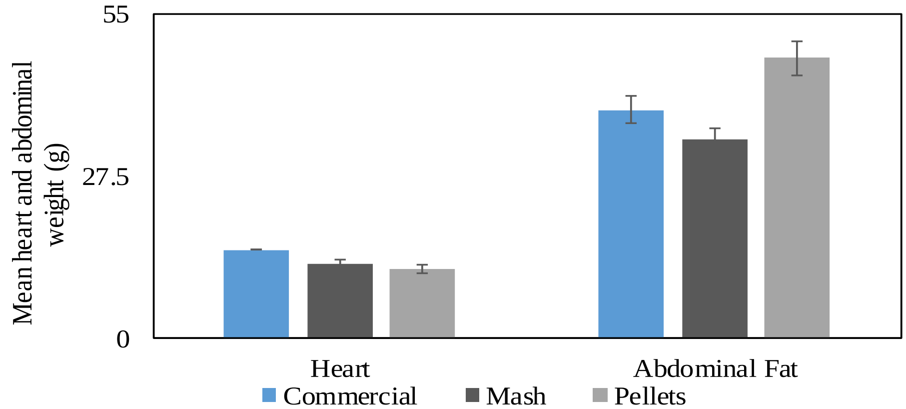
SEM = Processing Methods Standard Error of mean, MxP = Interaction of processing methods and replacement levels. In this study, dressing weight was recorded as the weight of carcass after blood drainage, de-feathering and removal of the head.

Pelleting was observed to significantly ($P < 0.05$) affect the live weight, dressing weight, breast weight, thigh weight and abdominal fat weight of broilers (Table 6.1). The results of this study indicated that broilers fed on pellets had significantly ($P < 0.05$) higher live weight, dressing weight, breast weight, and thigh weight compared to those fed on mash diets. Among the pelleted diets, birds fed on 50 % PM pellets recorded the highest live and dressing weights while those were fed on commercial diet recorded the lowest live and dressing weights (Figure 6.1a).

Broiler chickens fed on pelleted diets had significantly higher ($P < 0.05$) abdominal fat weight compared to those fed on mash diets (Figure 6.2b). Among the pelleted diets, PM based diets recorded significantly more abdominal fat with 75 % PM recording the highest and 50 % PM recording the lowest (Figure 6.1b). A similar trend was observed among the mash diets whereby 75 % PM replacement level showed the highest whereas 50 % PM recorded the lowest abdominal fat content.



a)



b)

Figure 6.1. Effects of feed processing methods on a) live weight, dressing weight, carcass weight, breast weight and thigh weight, b) abdominal fat and heart weights

Feeding pelleted diets to broilers had no significant (P > 0.05) effects on the live weight and heart weight (Table 6.1). Results from this study revealed that replacement levels had no significant (P > 0.05) effects on the live weight, dressing weight, carcass weight, breast weight, thigh weight and abdominal fat (Figure 6.3).

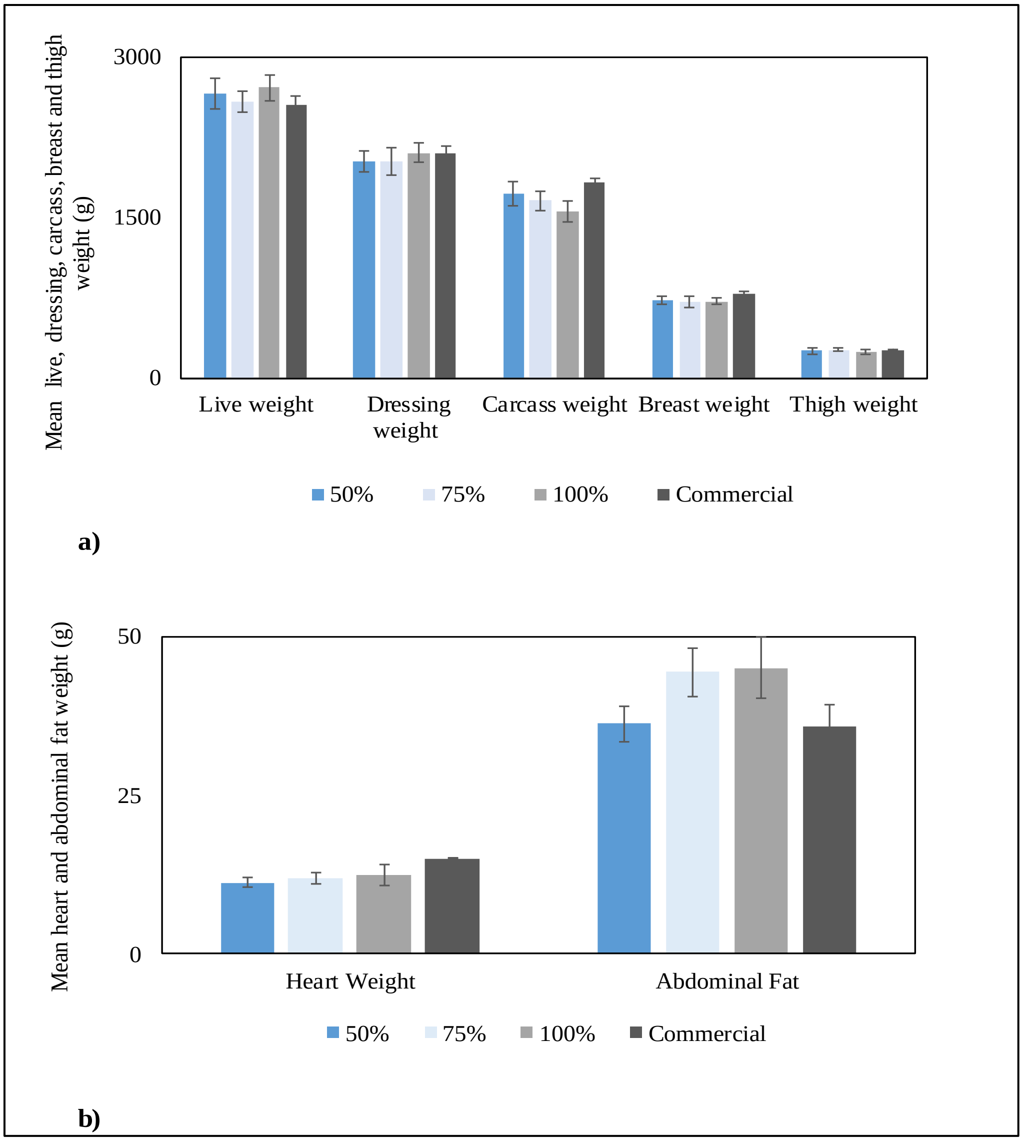
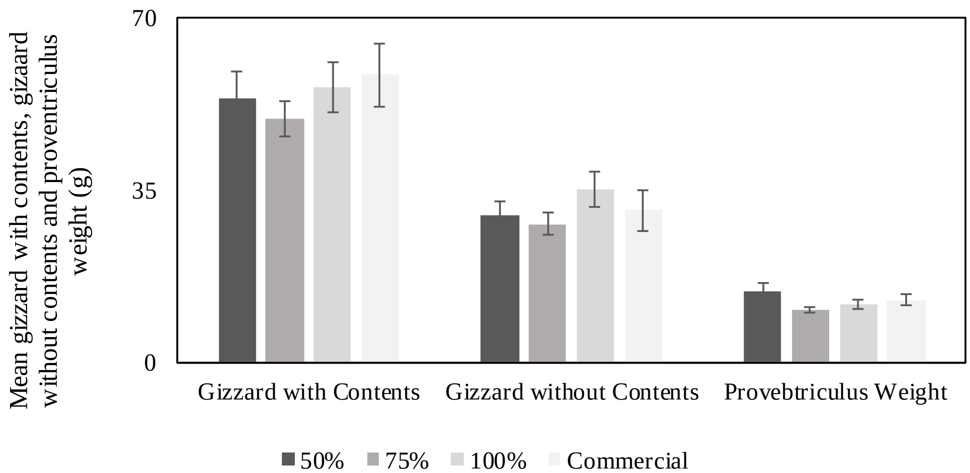


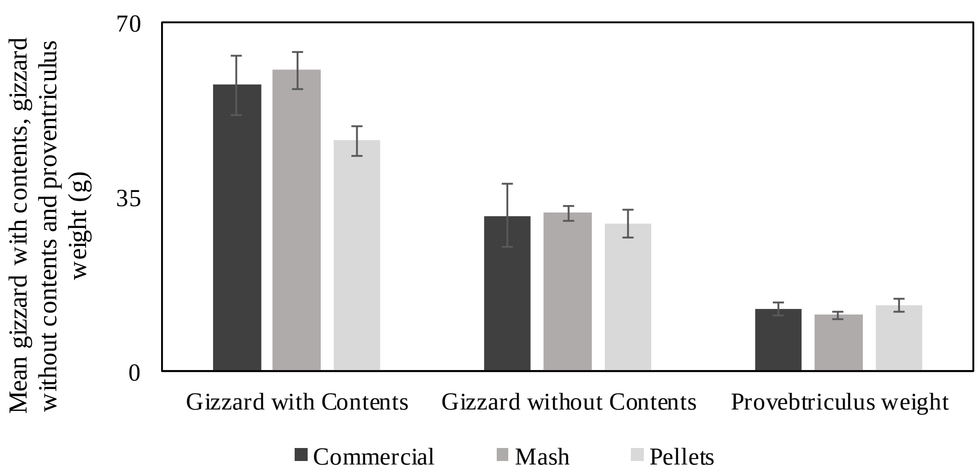
Figure 6.2. Effects of replacement levels on a) live weight, dressing weight, carcass weight, breast weight and thigh weight, b) abdominal fat and heart weights

6.4.2. Gizzard and proventriculus

There was no significant interaction observed between processing methods and the replacement levels for gizzard with contents, gizzard without contents and proventriculus weights. Furthermore, replacement levels had no significant effect on the weight of the gizzard with contents, gizzard without contents and proventriculus weight. Pelleting had significant effects ($P < 0.05$) on the weight for gizzard with contents but not on weights for gizzard without contents. Broilers fed on pellets tended to have heavier proventriculus as compared to those fed on mash diets, with commercial diet having the heaviest proventriculus.



a)



b)

Figure 6.4. Effects of a) processing methods and b) replacement levels on gizzards with and without contents and proventriculus

6.5. Discussion

6.5.1. Carcass characteristics

This study revealed that replacement levels had no significant ($P > 0.05$) effect on all of the carcass characteristics of broiler chickens. These results may suggest that PM grains can successfully replace pearl millet without adverse effects on the carcass characteristics of broiler chickens. These results are in agreement with Rao et al. (2004) who indicated that replacing maize with PM in broilers diets had no significant effects on the breast, thigh and drumstick muscles. Similar results were reported by Wakibia et al. (2015) who demonstrated that replacing maize with PM in broilers diet had not significant effects on breast muscle weight, abdominal fat and gizzard weight. Conversely, Sharma et al. (2012) reported a significant reduction in breast muscle weight of broilers fed on PM based diets as compared to those fed maize. Furthermore, Rao et al. (2004) and Singh et al. (2009) reported higher abdominal fat for sorghum and yellow maize fed broilers compared to PM fed broilers.

6.5.1.1. Live, dressing and carcass weights

Broilers fed on pelleted diets had significantly higher live and dressing weights compared to those fed on mash diets. However, methods of feed processing had no significant effect ($P < 0.05$) on the carcass weights of broilers. These findings may suggest that, the high live and dressing weights of broilers fed on pellets are a result of more blood (since broilers tend to consume more water) (Calet, 1965), heavier internal organs and other organs such as shanks, head, feathers etc., but does not necessarily mean more higher carcass weights when feeding pellets compared to mash diets. These results are in agreement with studies by Agunbiade (2000) and Adeyemi et al. (2008) who reported that pelleting of broiler diets resulted into higher percentage of dressing weight. However, the findings of this study are in contradiction with studies by Torres et al. (2013) and Corzo et al. (2011) who reported that feeding broilers with pellets resulted in higher carcass weights compared to those fed on mash diets.

Results from this study recorded a significant interaction between processing methods and replacement levels for carcass weight. In this study, mash and pelleted diets recorded a numerical increment and reduction of carcass weight with increased replacement levels, respectively. In other words, increased replacement levels increased and reduced carcass weights for broilers fed on mash and pellets, respectively. Whereby, birds fed on mash diets with more PM grains recorded heavier carcass weights than those fed on mash diets with less amounts of PM grains. Furthermore, birds fed on pelleted diets with more PM grains recorded lighter carcass weight compared to those fed on pelleted diets with less PM grains. The interaction between processing methods and replacement levels observed in these results for carcass weight may suggest that, when feeding mash diets to broiler chickens, a total replacement (100 % PM) of maize with PM may results in heavier carcass weight. However, when feeding pelleted diets, the heaviest carcass weights may be obtained at 50 % replacement level. In other words, 50 % PM replacement is the optimum replacement level when feeding pelleted diets to broilers, any additional PM may result in reduced carcass weights. Neither processing methods nor replacement levels influenced carcass weight significantly.

6.5.1.2. Breast and thigh meat weights

The results of this study indicated that there was no significant interaction between processing methods and replacement levels for breast and thigh meat weights. However, broilers fed on pellets had significantly ($P < 0.05$) higher breast and thigh weights compared to those fed on mash diets. Numerically, broilers fed on pellets yielded heavier breast meat as a percentage of the carcass weight; with 100 % PM pelleted diet producing birds with the heaviest breast meat. Feeding pelleted diets to broilers tended to result in heavier breast and thigh meat weights as compared to mash diets. These findings are in contradiction with results reported by Ahmed and Abbas (2013) which indicated that pelleting had no significant effects on carcass characteristics. However, results of this study are in agreement with several researchers who reported that pelleting of broiler diets yielded broilers with superior breast meat and thigh weights compared to those fed on mash diets (Agunbiade, 2000; Adeyemi et al., 2008). Furthermore, Corzo et al. (2011) reported that feeding a diet with 64 % pellets resulted in broilers with superior breast meat weight when compared to those fed on mash diet. A study by Sarvestani et al. (2006) also reported similar results whereby the breast and thigh meat weights from broiler chickens fed on pellets were significantly greater than those fed on mash.

6.5.1.3. Abdominal fat

Broiler chickens fed on pelleted diets had significantly higher abdominal fat compared to those fed on mash diets. Among the pelleted diets, PM based diets recorded higher abdominal fat weights with 75 % PM recording the highest and 50 % PM recording the lowest. A similar trend has been observed among the mash diets whereby a proportion of

75 % PM recorded the highest abdominal fat content while 50 % replacement level recorded the lowest. The results in this study are in line with research findings by Sarvestani (2006) and Attia et al. (2014) who reported that feeding pelleted diets increased abdominal fat compared to that of broilers fed mash diets. However, findings of this study are in contradiction with those by Ahmed and Abbas (2013) who did not find any significant difference in abdominal fat contents for broilers fed on pellets and mash diets. Furthermore, these results are in disagreement with Torres et al. (2013) who reported that the dietary inclusion of PM results in higher abdominal fat deposition.

6.5.1.4. Heart

Feeding pelleted diets to broilers had no significant effects on the heart weight. These findings may suggest that, although broilers fed on pellets had higher slaughter weights, their heart weights are similar to those fed on mash diets. These findings are in agreement with Ahmed and Abbas (2013) who reported that pelleting had no significant influence on the heart weight. However, findings of this study are in disagreement with Sarvestani et al. (2006) who reported heavier heart weights for broilers fed on pelleted diets compared to those fed on mash diets.

6.4.2. Gizzard and proventriculus

The results of this study revealed that processing methods had no significant effect ($P < 0.05$) on the weight for gizzard. Pelleting tended to decrease gizzard weights and increase the proventriculus weight. The significant reduction of gizzard with contents weights and a numerical increase of proventriculus weights for broilers fed pellets perhaps is a result of reduced grinding activity resulting from feeding pelleted feeds. These findings may suggest that gizzards for broiler fed on pellets are underdeveloped due to underutilization since they are only used as a passage and to a less extend as storage of feeds. Furthermore, the enlarged proventriculus may suggest a fast feed passage rate through the gizzard due to small feed particle sizes fed in form of pellets, resulting in over utilization of the proventriculus. These findings are similar to Hassan and El-Seihk (2010) result, which showed a reduction in gizzard percentage and digestive tract weight for ducks fed pelleted diets as compared to those fed mash diets. Attia et al. (2014) reported similar results whereby pelleting decreased gizzard weights and caecum length for broilers. Additionally, feeding birds with pelleted diets has been reported to decrease the weights of both gizzard and small intestine weights as compared to feeding mash diets (Nir et al., 1995). According to Taylor and Jones (2004), the underdeveloped gizzard due to feeding broilers with processed feeds (especially pelleted diets) results in an enlarged proventriculus and Cummings (1994) related these findings to the gizzard working as a transit rather than a grinding organ. Several researchers indicated that, the slow passage of feed through the gizzard maximizes the exposure of nutrients to digestive enzymes improving the nutrient digestibility and energy utilization (Nir et al., 1994; Carre, 2000).

This study indicated that replacement levels had no significant effect on the gizzard with contents, gizzard without contents and proventriculus weights. These results may suggest that PM grains can successfully be utilized in broiler diets as a total replacement of maize without any adverse effects on the gizzard and proventriculus weights. These results are in agreement with Wakibia et al. (2015) who demonstrated that replacing maize with PM in broilers diet had not significant effects on gizzard weight. But they contradict some researchers who reports of higher gizzard weights for broilers fed on the maize based diets compared to those fed on the PM based diet (Yunusa et al., 2014; Kwari et al., 2014).

6.5. Conclusion

Overall, the study revealed that replacing maize with PM had no significant effects on the carcass characteristics and gizzard and proventriculus development of broilers. Pelleting significantly increased breast, thigh, and abdominal fat weights. However, pelleting did not affect carcass weight and gizzard with contents significantly. A numerical reduction in heart weight was observed with increased PM replacement level for pelleted diets while the opposite was true for the mash diets. Although not significant, birds fed on mash diets had heavier gizzard without contents weights and smaller proventriculus weights compared to those fed on pelleted diets. Feeding pellets to broilers may have increased the rate at which feed passes through the gizzards due their smaller particle sizes, minimizing the exposure of nutrients to digestive enzymes, compromising the nutrient digestibility and energy utilization. When fed as mash, broiler diets with more PM grains recorded heavier carcass weights while the opposite was true for pelleted diets. In other words, feeding PM based diets in mash form resulted in better carcass weights compared to those fed on PM based diets in pellet form. In conclusion, pelleting PM based diets reduced overall carcass weight while increasing breast and thigh weights of broilers. Therefore, the choice of whether to feed mash or pellets to broilers should be based on the target i.e the producer who aims to sell their chicken in cuts may choose to feed pelleted PM based diets while the producer who aims to sell whole chicken may choose to feed PM based diets in mash form.

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CHAPTER 7: EFFECTS OF PELLETING ON THE COST EFFICIENCY OF BROILER PRODUCTION WHEN MAIZE IS REPLACED WITH PEARL MILLET

7.1. Abstract

This study aimed to determine the effects of pelleting on cost efficiency of broilers when maize is replaced with PM grains. One hundred and ninety six day old Cobb-500 broilers were fed on the same starter for the first three weeks. Different experimental diets, with two replicates each, were supplied during the finisher phase. Feeds costs were calculated based on the prices of ingredients used to formulate the experimental diets. A completely randomized design with a 2 x 3 factorial arrangement of treatments was used to evaluate two feed processing methods and three replacement levels. Inclusion of PM in broiler diets reduced the amount of soybean meal required by 29%, reducing the costs of feeds by 3.9%. Replacement levels significantly ($P<0.05$) increased the total costs of feed consumed by broilers. Replacement levels had no significant effect on cost of feeds required per 1 kg of weight gain. Replacement levels tended to significantly increase total revenue and gross profit. Pelleting had no significant effects on the cost of feeds required per 1 kg of weight gain (feed cost efficiency). Although not significant, mash diets recorded high total revenue and gross margin as compared to pelleted diets. It can therefore be concluded that similar production costs may be incurred when maize is replaced with PM in broiler diets. Although PM is more expensive than maize in Namibia, PM usage reduces the amount of soybean meal required, thus reducing the costs of feeds.

7.2. Introduction

Feed costs have been constantly on the rise over the past years which prompted poultry to research for potential local ingredients. Maize has been used as a major energy source in least cost poultry diets and has been imported cheaply over the years by many nations including Namibia. Increment in maize costs has driven efforts to replace it with locally available high energy cereal grains. Ranked fourth most important tropical food cereal in the world (Andrews and Bramel-Cox 1994), pearl millet (PM) is known as a drought resistant cereal crop (Lee and Hanna, 2002) that grows in arid to semi-arid environments with low fertile soils and limited amount of moisture. About 83 500 ton of rain fed PM were recorded in 2017 as compared to 43 536 ton rain fed maize produced in Namibia (NAB, 2018). Furthermore, only ten out of 25 active millers registered with NAB are PM millers (NAB, 2018), although more PM is produced under rain fed in Namibia compared to maize. Moreover, most of the maize produced is marketed, while only 2 486 ton of PM produced was marketed (NAB, 2018). These limited number of millers in Namibia may be a great indicator of market scarcity for PM. High PM production recorded compared to maize, regardless the limited market, may suggest that there is a potential for PM production in Namibia.

Pearl millet is known to have 8 % - 60 % higher protein, 40 % richer in lysine and methionine and 30 % more threonine when compared to maize (Burton et al., 1972; Singh and Perez-Maldonado, 2003). Therefore, replacing maize with pearl millet in broiler diets may minimize the requirements of protein rich feed ingredients as well as the amino acids supplementation (Behnke, 1994).

Several feed processing methods are believed to increase feed value resulting in high productivity. The choice of the processing method is mainly influenced by the availability and affordability of the equipment and infrastructure involved in addition to the operational skills required (Behnke, 1996). Poultry feed processing technologies are not fully utilized in developing countries such as Namibia. In recent years, an increasing interest in poultry farming and high costs of feed ingredients fueled the search for local feed alternatives for enhanced poultry production in Namibia.

Grinding combined with mixing results in a mixture referred to as "Mash diet" which is fed right after thorough mixing of the ingredients. Grinding of ingredients such as maize and pearl millet grains is said to reduces the particle size, increasing surface area of the feed increasing its accessibility by enzymes to work on it once eaten by the birds. Replacement of maize with pearl millet in mash poultry diets received quite a reasonable amount of research attention in the past few decades. Studies have shown that feeding pearl millet as a replacement of maize in iso-caloric and iso-nitrogenous mash diets yields equivalent results (Sullivan et al., 1990; Hafeni, 2013).

Research has shown that processing methods, such as conditioning and pelleting are believed to improve feed quality by enhancing palatability which results in increased feed intake by the birds (Abdollahi, 2011). According to Peisker (2006) the use of mechanical pressure, moisture and heat, pelleting of a mashed diet is mainly used to agglomerate smaller feed particles. Economics of poultry production is believed to be enhanced by feeding pelleted feeds which tends to improve feed efficiency and growth performance of broiler chickens Behnke and Beyer (2002). In addition to improved nutritive value of feeds and decreased ingredient segregation, factors influencing growth performance of broilers fed pellets may include decreased feed wastage and reduce energy spent on ingestion (Behnke, 1994).

Soybean meal is not grown in Namibia therefore it is almost impossible for local famers to source. Only one company in Namibia which is able to import large quantities of soybean meal is able to produce chicken feeds. The reduction in the amount of soybean meal required for poultry feed formulation means that an alternative plant protein source which is accessible locally and is well adapted to semi-arid Namibian environmental conditions may be used to reduce the costs of chicken feeds considerably. Research by Hanafi et al. (2014) showed that replacing maize with PM in broiler diets results in substantial partial substitution of the protein source, which may further reduce feed costs.

Poultry production in Namibia has been very low until 2012 when a commercial broiler company Namib Poultry Industries was established. Until now, there is only one feed company in Namibia which supply poultry feeds to both the commercial broiler company and most of the emerging producers. More efforts need to be invested in feed production using ingredients which can be sourced locally in Namibia. Limited scientific information is available on how feed processing may influence the feeding value of locally available ingredients for the local poultry market and possible exports. As a result, there seem to be a strong belief that maize and soybean meal are the best chicken feed ingredients although the local farmers can hardly produce them given the fact that Namibia is an arid country. Some farmers invest a lot in water for irrigation in efforts to produce maize. Pearl millet can be grown at a minimum cost and most farmers in the villages depend on it for survival. More research studies are required to investigate the nutrient compositions and nutritional qualities of local feed ingredients as well as their response to value addition by means various processing techniques in order to further support the findings in Chapter 4 of this study. Chapters 5 and 6 of this dissertation indicated that PM can successfully replace maize and fed as a mash or pellets without adverse effects on growth performance, carcass characteristics, and gizzard and proventriculus weights for broiler chickens. This study aimed at determining the effects of pelleting on the cost efficacy of broiler production when maize is replaced with PM at 50, 75 and 100% replacement levels.

7.3. Materials and Methods

7.3.1. Study site

The study site is as described in Chapter 3 section 3.1 and Chapter 4 section 4.3.

7.3.2. Experimental diets and treatments

The description of experimental diets and treatments is as explained in Chapter 5 section 5.3.2.

7.3.3. Birds, Housing and Management

The information on birds, housing and management practices used is as described in Chapter 5 section 5.3.3.

7.3.4. Experimental design and data Collection

The information on experimental design and data collection is as described in Chapters 5 and 6 in sections 5.3.4 and 6.3.4 respectively. Feeds and feeding costs were determined based on the prices of ingredients used. Prices of maize (N$5.12) and pearl millet used in this study were based on the formal market prices (as of 2018) obtained from Namibia Agronomic Board (NAB, 2017), whereby maize prices are determined by South Africa and those of pearl millet are determined by Namibian authorities. In order to safeguard the orderly marketing environment and stimulate additional production and marketing of PM in Namibia, the price of PM is based on an agreement between organized producers and millers (NAB, 2018). According to NAB (2018), the price of PM is mainly depended on the production per ha and adjusted annually by the NAB, with real input and inflation. The PM producer price for 2018 was set at N$5 223.00 per ton (i.e. N$5.22 per kg, N$94.48 per lata of 18.1 kg). The broiler meat selling price usually depends on the cuts e.g. the price for drumsticks is mostly estimated to be about N$47.99 per kg while a pack of mixed cuts costs N$31.33 per kg (based on the local market as of July 2019, see Appendix 6). These above prices were averaged to get the price (N$39.66) used to calculate revenues and profit margins for this study. Calculations of cost per kg of feed for each experimental diet was calculated using a diet cost structure in excel spreadsheet (Appendix 5). In this study, the cost efficiency of pelleting and replacement levels was determined as feed cost per kg relative to weight gain per kg, based on the equation proposed by Bellaver et al. (1985) as quoted by Martins et al. (2016).

$$Y_i = \frac{Q \text{ X } P_i}{G_i}$$

Where Y_i is the feed cost per kg of weight gain of the i^{th} treatment; P_i is the price per kg feed fed in the i^{th} treatment; Q_i is the amount of feed intake in the i^{th} treatment; and G_i is the weight gain weight obtained in the i^{th} treatment. Mash and pellet costs were adjusted based on the 18 % pelleting cost reported by Houndonougbo et al. (2012), respectively. Mash and pellet diets were adjusted for feed wastage as reported by Gadzirayi (2006), respectively.

7.3.5. Data Analysis

The data were analyzed as a 2x3 factorial arrangement of treatments as described in Chapter 3 and Chapter 4.

7.4. Results

The present study observed that, the amount of soybean meal required as a protein source reduced (29.1 %, 25.2 %, 23 % and 20.8 %) with increased amount of PM (0%, 37.4 %, 58 % and 79.2 %) (Table 7.1).

Table 7.1. Replacement levels of maize with pearl millet

Replacement levels (%)		**0**	**50**	**75**	**100**
Ingredients inclusion rate (%)	Maize	70.9	37.4	19	0
	Pearl millet	0	37.4	58	79.2
	Soybean Meal	29.1	25.2	23	20.8
	Other	1.25	1.25	1.25	1.25

Inclusion of PM in broiler diets as a replacement of maize reduced the amount of soybean meal required in broiler feeds by 29% thereby reducing the costs of feeds by 4% (Table 7.2). In the present study, there was no significant interaction ($P>0.05$) between processing methods and replacement levels observed for cost per kg of feed, cost efficiency, total feed cost, gross margin and total revenue (Table 7.2).

Table 7.2. Effects of different experimental diets on the mean average of cost per kg of feed, cost efficiency, total feed cost, total revenue and gross margin of broilers.

	Control Diet	SEM	Mash			SEM	Pellets			SEM	MxP
			Replacement level (%)				Replacement level (%)				
Parameter	**Commercial**		**50**	**75**	**100**		**50**	**75**	**100**		
Cost per kg of feed (N$)	7.49	0.000	6.22	6.15	6.08	0.026	7.34	7.26	7.18	0.029	1.000
Cost efficiency (N$)	11.13	2.000	7.12	8.78	10.72	0.870	11.29	12.78	11.21	0.547	1.000
Total feed cost (N$)	13.48	0.700	9.18	9.62	11.89	0.591	14.67	14.01	12.90	0.508	1.000
Gross Margin (N$)	29.92	6.300	38.08	28.71	27.31	3.363	30.83	24.32	27.36	1.605	1.000
Total revenue (N$)	43.40	5.600	47.25	38.33	39.20	3.025	45.50	38.33	40.3	1.633	1.000

SEM = processing methods standard errors of mean, MxP = Interaction of processing methods and replacement levels

Results from the present study revealed that pelleting had no significant (P > 0.05) effects on the cost per kg of feed, cost efficiency, gross margin and total revenue (Figure 7.1). However, pelleting increased feed costs significantly (P < 0.05).

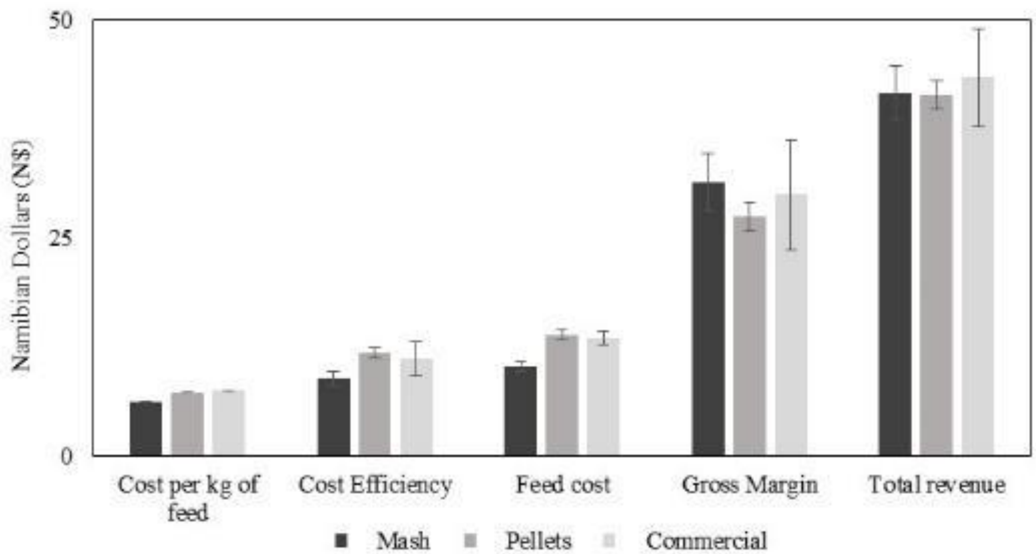

Figure 7.1. Effects of methods of feed processing on cost per kg of feed, cost efficiency, total weight gain cost, total feed cost, gross margin and total revenue.

According to the results from the present study, replacement levels had no significant (P > 0.05) effects on cost per kg of feed, cost efficiency, total feed cost, total revenue and gross margin (Figure7.2).

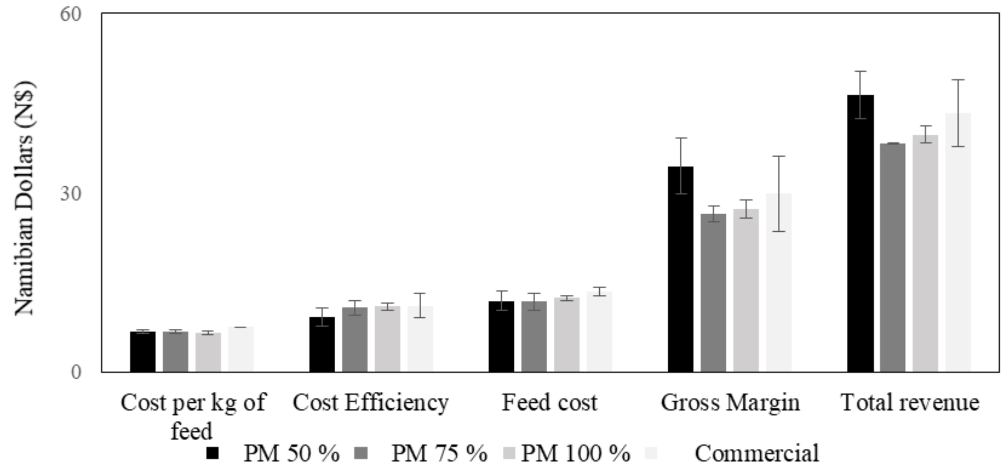

Figure 7.2. Effects of replacement levels on cost per kg of feed, cost efficiency, total weight gain cost, total feed intake cost, total revenue and gross profit.

7.5. Discussion

According to the results of this study, pelleting had no significant effects on the cost of feeds required per 1 kg of weight gain. These findings may suggest that feeding broilers may incur similar cost of feeds required per 1 kg of weight gain whether the feed is supplied in a form of mash or pellets. The significantly higher feed costs and slightly low gross margin for pelleted diets may suggest that broilers fed on pellets diets gained reasonable amount of weights given the amount and prices of feeds consumed to cover up feed costs incurred. These findings are in agreement with Behnke and Beyer (2002) who suggested that the economics of poultry production is enhanced by feeding pelleted feeds which tends to improve feed efficiency and growth performance of broiler chickens. Furthermore, results from this study support findings by Behnke (1994) who stated that pelleting may include decrease feed wastage and reduce energy spent on ingestion. All of the research findings seem to suggest that the extra costs incurred in the process of pelleting are covered up by improved growth performance resulting gross margin equivalent to those fed on mash diets.

Although results from this study indicated that replacing maize with PM during the finisher stage of broiler production had no significant effects on the production costs of broiler diets, a numerical reduction in the amount of soybean meal required as a protein source as been observed. Whereby, inclusion of PM in broiler diets as a replacement of maize reduced the amount of soybean meal required in broiler feeds by 29% thereby reducing the costs of feeds by 4%. These findings may suggest that less soybean meal is required when maize is replaced with PM creating new opportunities and possibilities of identifying locally available protein sources with reasonable protein contents to replace soybean meal in poultry diets. These findings of the present study are in agreement with Baurhoo et al. (2011b) who reported that broilers fed on PM based diets required less soybean meal as compared to corn based diets. Hanafi et al. (2014) who reported similar results suggested that the high protein contents of PM may result in substantial partial substitution of the protein source.

According to the results of this study, PM replacement levels had no significant effects on the total costs of feed consumed by broilers. It was also observed in the present study that replacement levels had no significant effect on cost per 1 kg of weight gain. These results may suggest that, broilers fed on PM based diets consumed slightly more feeds resulting in slightly increased feeding costs compared to those fed on maize based diets and yield similar cost of feeds required per 1 kg of weight gain for PM and maize based diets. These findings are in a disagreement with Rao et al. (2002) who reported lower costs of feed required per one kg of weight gain in broilers fed PM grains compared to those fed maize based diets. These findings are also in a disagreement with another research by Elangovan et al. (2003) who reported significantly less costs when broilers are fed PM diets compared to maize based diets. These disagreements maybe due to different prices of PM grains and maize encountered by different researchers in their respective geographical areas.

7.6. Conclusion

Pelleting had no significant effects on the cost of feeds required per 1 kg of weight gain. Mash diets recorded slightly high (not significant) gross margin as compared to pelleted diets. Due to similar gross margins observed when feeding broilers mash or pellets broiler producers may choose to use either of them based on their preferences. Replacing maize with PM during had no significant effects on the feed production costs of broiler diets. Replacement levels had no significant effect on cost per 1 kg of weight gain. Although PM Namibian prices were quite high at the time this study was carried out, PM usage reduced the amount soybean meal required, especially in total replacement diet, resulting in slightly reduced costs feeds. It can therefore be concluded that similar poultry production costs may be incurred when maize is replaced with PM.

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CHAPTER 8: GENERAL DISCUSSION, CONCLUSION AND RECOMMENDATIONS

8.1. General Discussion

In this era of ever increasing prices of poultry feed ingredients, alternative nutrient sources and applicable feed processing techniques are required to reduce feed costs and limit physical and nutritional feed wastage. Poultry diets formulated to contain all the recommended components, required to meet poultry nutrient requirements, utilizing local feed ingredients, may not only avail quality feed to less privileged poultry farmers found in villages and poor communities of most African countries including Namibia, but it may also reduce costs of feeds. Feed processing techniques such as grinding, mixing, conditioning and pelleting may improve poultry production. However, scientific studies are required to identify the conditions under which these techniques should be applied in order to reduce unnecessary feed costs and nutrient wastage. The oversupply of nutrients may contribute to unnecessary feed processing costs and make poultry production unviable especially at small to medium scale of production. The excess nutrients excreted by birds may also cause environmental pollution threatening the lives of all of its habitants.

Pelleting as the most preferred method of feed processing may not only incur additional energy and labor costs but it may also implicate feeds nutritional quality especially when high temperatures are employed during feed conditioning prior to pelleting. Nutritional wastage mostly occurs when focus is placed more on producing high quality pellets which is mostly achieved through the application of high temperatures during conditioning and pelleting processes resulting in lower nutrient availability (Abdollahi, 2011). A study by Olson and Lagervall (1962) indicated that the level of vitamin A in pelleted diets dropped by 36 % in three months of storage compared to 6 % in mash diets. Patton and Rauls (1938) reported that feeding pellets to broilers increased water consumption by 31 % resulting in excessive litter dampness which poses health risks due to harboring of large numbers of parasites such as coccidia and accumulation of ammonia and carbon monoxide gases.

Appleby (2010) indicated that the quality of the CP content in feed ingredients is determined by the balanced profile of the essential amino acids rather than the dietary CP levels. Essential amino acids in broiler diets are required for protein synthesis and rapid meat deposition in broilers (Wakibia, 2015). According to Jacob (2013) linolenic acid makes up 4% of the total fatty acids in the oil, making PM (pearl millet) a good source of omega-3 fatty acids compared to maize. In an attempt to understand the nutritional composition for the Okashana-2, an improved Namibian PM cultivar and its potential as a replacement of maize in broiler diets, the present study (Chapter 4) indicated that PM had significantly high crude protein (CP), fat, lysine, leucine, methionine, glycine, arginine, threonine and alanine contents compared to maize. Results from Chapter 4 further indicated that PM based broiler diets contains high CP, fat and calcium contents compared to maize diets.

According to Sunde (1972) if done properly, heating raw feed ingredients may result in better availability of nutrients. High protein contents in pelleted diets can be related to protein denaturation caused by higher temperature, moisture and friction applications during pelleting (Thomas et al., 1997). Hydrothermal pressures and shearing forces of feed processing are reported to disrupts cell walls and structures of high fibre components of feeds (Saunders et al., 1969), influencing the degradability as well as the solubility of fibre components of feeds (Bjorck et al., 1984). The present study (Chapter 4) revealed that pelleted diets had more CP and fat contents than the mash diets. Furthermore, results from the present study (Chapter 4) indicated that pelleting significantly reduced the crude fibre, calcium and fat contents of broiler diets. However, pelleting had no significant effects on ash, dry matter and phosphorus contents of broiler diets.

A number of researchers obtained different results on the effects of replacing maize with PM grains in broiler diets. While some researchers reported no significant effect on weight gain (Hildago et al., 2004; Manwar and Madal, 2009; Medugu et al., 2010; Kwari et al., 2014), several other researchers reported high weight gains for broilers fed on PM based diets compared to maize based diets (Baurhoo et al., 2011a; Ibe et al., 2014). The present study (Chapter 5) revealed that replacing maize with PM has no significant influence on the live body weights, weight gain and FCR of broiler chickens. Furthermore, broilers fed the PM based diets consumed significantly more feed compared to those fed maize based diets. Although several researchers reported that feeding mash diets reduces the growth performance of broiler chickens significantly (Munt et al., 1995; Kim and Chung, 1996; Ghazi et al., 2012), results from the present study (Chapter 5) has shown that pelleting PM based diets had no significant effects on the live body weights and weight gain of broilers. Although these results contradicts what is normally seen where pellets command higher weight gains that may outweigh the extra costs of pelleting, it is clear from the findings of this study that pelleting may only command high weight gains whenever for maize based diets but not for PM based diets. The practical significance of this study is that PM substitution for maize may be carried out without the need to pelletize hence reducing feed costs and may potentially make poultry production especially at small to medium scale more viable. According to the results of the present study (Chapter 5), pelleting did not significantly affect mortality rate of broiler chickens. However, numerically high mortality was recorded among broilers fed on pelleted diets compared to mash diets while a numerical reduction in mortality was observed for broilers fed on PM based diets compared to those fed on maize based diets. Further work is needed to find out if PM based diets have better stress reduction properties.

Different research studies yielded variable findings on the effects of replacing maize with PM on carcass characteristics of broilers. A study by Rao et al. (2004) indicated that replacing maize with PM in broilers diets had no significant effects on the breast, thigh and drumstick muscles. Similar results were reported by Wakibia et al. (2015) who demonstrated that replacing maize with PM in broilers diet had not significant effects on breast muscle weight, abdominal fat and gizzard weight. However, Sharma et al. (2012) reported a significant reduction in breast muscle weight of broilers fed on PM based as compared to those fed maize. Furthermore, Singh et al. (2009) and Rao et al. (2004) reported higher abdominal fat for sorghum and yellow maize fed broilers compared to

PM fed broilers. In the present study (Chapter 6), replacing maize with PM grains at various replacement levels had no significant effect on all of the carcass characteristics of broiler chickens.

Pelleting is the most preferred method of feed processing poultry in many parts of the world. This may be due to the availability of strong scientific evidence proving how pelleting improves growth performance and higher percentage of dressing weight of broilers (Agunbiade, 2000; Adeyemi et al., 2008). Results of the present study (Chapter, 6) have shown that pelleting had no significant effect on the carcass weights of broilers. Broilers fed on pelleted PM based diets recorded less carcass weights compared to those fed on pelleted maize based diets. Based on these findings, maize may be replaced with PM up to 100 %, in broiler diets, when fed as mash for improved carcass weights. These results may suggest that high slaughter and dressing weight for broilers fed on pelleted diets does not necessarily mean higher carcass weights when feeding pellets compared to mash diets. According to Calet (1965), the high slaughter and dressing weights of broilers fed on pelleted diets maybe a result of more blood, since broilers tend to consume more water when fed on pellets. A 2 mm sieve was used to grind both PM and maize grains used in the present study and it was recorded that broilers fed on PM based diets consumed more feed than those fed on maize based diets. A study by Baurhoo et al. (2011a) reported that when PM is less effectively ground, broilers consumed less feed and at the same time recorded better feed efficiency compared to those fed on corn based diets.

Data reported in Chapter 6 showed that replacing maize with PM had no significant effect on the gizzard and proventriculus weights. Furthermore, results from the present study (Chapter 6) indicated that, although not significant, birds fed on mash diets had heavier gizzard without contents weights and smaller proventriculus weights compared to those fed on pelleted diets. Although not significant these findings are in line with other researchers who reported that pelleting reduces gizzard percentage and digestive tract weight for ducks (Hassan and El-Seihk, 2010) and broilers (Attia et al., 2014).

Feeding PM based diets in the form of mash may present an advantage of reducing feed costs by cutting out costs of pelleting and reducing costs of soybean meals, since less soybean meal is required for PM based broiler diets. Results from the present study (Chapter 7) indicated that replacing maize with PM up to 100 % replacement level had no significant effects on feed production costs of broiler diets. However, inclusion of PM in broiler diets reduced the amount of soybean meal required by 29%, reducing the costs of feeds by 3.9%. Although replacing maize with PM increased the total costs of feed consumed by broilers significantly, a significant increase in gross margin for broiler fed on PM based diets was obtained in the present study (Chapter 7). Pelleting had no significant effects on the cost of feeds required per 1 kg of live weight gain. However, mash diets recorded lower feed costs which rendered higher gross margin as compared to pelleted diets.

8.2. General Conclusion

Results from this study also indicated that, when broiler production is practiced in semi-arid highland savanna areas with typical high altitude environmental conditions, birds fed on mash diets gained more weight than those fed pelleted diets. A combined effect of grinding and pelleting indicated that pearl millet based broiler diets contain high CP, fat and calcium contents compared to maize based diets, therefore, pelleting pearl millet based diets may be not be beneficial to commercial broiler farmer with environmentally with poor housing infrastructures like those found at Neudamm Campus. Pelleting significantly reduced crude fibre, calcium and fat contents of broiler diets. Pelleting had no significant effects on the live body weights and weight gain of broilers. Chickens fed on PM based diets consumed significantly more feed compared to those fed maize based diets, resulting in slightly higher weight gains than fed on maize based diets. Furthermore, this study indicated that birds fed on mash PM based diets gained more weight than those fed on pelleted diets. Replacing maize with PM grains at various replacement levels had no significant effect on all of the carcass characteristics of broiler chickens. Moreover, broilers fed on pelleted PM based diets recorded less carcass weights compared to those fed on pelleted maize based diets. Neither pelleting nor replacement of maize with PM had significant effects on the development of the digestive tract of broilers. Pelleting and replacement of maize with PM had no significant effects on feed production costs of broiler diets. Although replacing maize with PM increased the total costs of feed consumed by broilers significantly, these costs were recovered through significantly increased total revenue and gross profit recorded for broilers fed on PM based diets.

8.3. Recommendations

The CP contents of PM based broiler diets determined by the try an error feed formulation method were not exactly the same but to those from proximate analysis. Further scientific studies are recommended to investigate the possible ways of minimizing errors when using try-an-error method of feed formulation.

Results from the present study indicated that pelleted diets had more CP contents than the mash diets; this is in addition to the fact that pelleting has an advantage of supplying protein to broiler birds per each mouthful. Furthermore, the present study recorded high mortality rate in birds fed on pellets as compared to mash diets. Moreover, results from this study clearly indicated that pelleted diets produced heavier birds which increased susceptibility of broilers to environmental conditions, resulting in reduced feed consumption, weight gain and high mortality due to ascites. However, feeding mash diets increased feed consumption resulting in increased weight gain and reduced mortality due to ascites. More research is recommended to study the effects of different housing facilities on production performance of broiler chickens fed on pellets as compared to those fed on mash diets.

The present study showed that mash diets had more fat (ether extract) contents as compared to the pelleted diets. Research indicated that fat may enhance growth by improving the palatability of feed. More scientific studies are recommended to investigate the effects of feeding mash and pellets on feed consumption and growth performance of broilers fed on PM based diets.

Feeding pellets to broilers may have increased the rate at which feed passes through the gizzards due their smaller particle sizes, minimizing the exposure of nutrients to digestive enzymes, compromising the nutrient digestibility and energy utilization. Research is recommended to study the effects of particle sizes for PM based diets on passage rate and nutrient digestibility in broiler chickens.

Although PM Namibian prices were quite high at the time this study was carried out, PM usage reduced the amount soybean meal required, especially in total replacement diet, resulting in reduced costs feeds. Research is recommended to study the costs of pearl millet and maize production in Namibia. The study should aim to enable researchers to recommend the production of more pearl millet grains under irrigation projects instead of maize which requires a lot of water.

8.4. References

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APPENDICES

APPENDIX 1. FEED MIXING BY HANDS

Feed mixing was done by hand in this study because there was no mixer available.

Picture by: Sesilia Shihepo, 2017

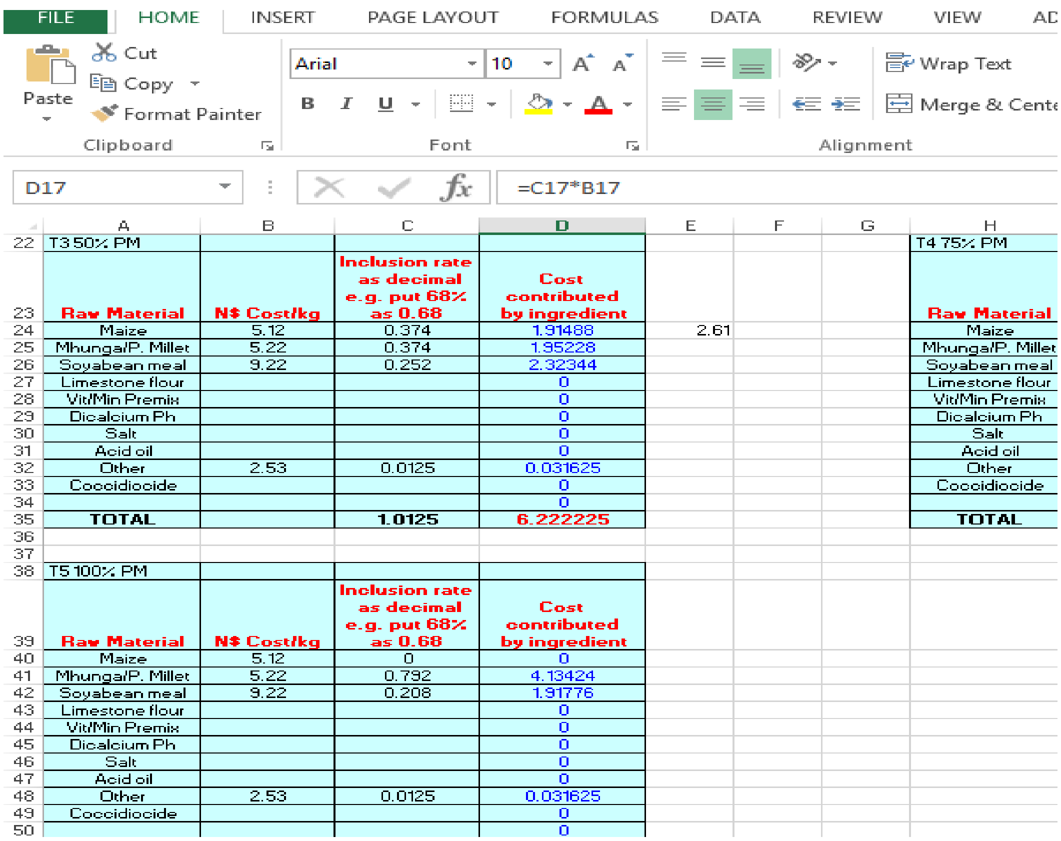
APPENDIX 2. FEED INTAKE RECORDING DATA SHEET

Date:			
Diet Replicate 1	**Feeds Left-over**	**Diet Replicate 2**	**Feeds Left-Over**
50 % Mash		50 % Mash	
75 % Mash		75 % Mash	
100 % Pellets		100 % Pellets	
100 % Mash		100 % Mash	
0 % Mash		0 % Mash	
75 % Pellets		75 % Pellets	
50 % pellets		50 % pellets	
0 % Pellets		0 % Pellets	

APPENDIX 3. WEIGHT GAIN RECORDING DATA SHEET

Date:			
Chicken Number	Weight 1	Weight 2	Weight 3
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			

APPENDIX 5: EXCEL SPREADSHEET FOR A DIET COST STRUCTURE USED TO CALCULATE COST PER KG OF FEED (Screenshot)



	A	B	C	D	E	F	G	H
22	T3 50% PM							T4 75% PM
23	Raw Material	N$ Cost/kg	Inclusion rate as decimal e.g. put 68% as 0.68	Cost contributed by ingredient				Raw Material
24	Maize	5.12	0.374	1.91488	2.61			Maize
25	Mhunga/P. Millet	5.22	0.374	1.95228				Mhunga/P. Millet
26	Soyabean meal	9.22	0.252	2.32344				Soyabean meal
27	Limestone flour			0				Limestone flour
28	Vit/Min Premix			0				Vit/Min Premix
29	Dicalcium Ph			0				Dicalcium Ph
30	Salt			0				Salt
31	Acid oil			0				Acid oil
32	Other	2.53	0.0125	0.031625				Other
33	Coccidiocide			0				Coccidiocide
34				0				
35	TOTAL		1.0125	6.222225				TOTAL
36								
37								
38	T5 100% PM							
39	Raw Material	N$ Cost/kg	Inclusion rate as decimal e.g. put 68% as 0.68	Cost contributed by ingredient				
40	Maize	5.12	0	0				
41	Mhunga/P. Millet	5.22	0.792	4.13424				
42	Soyabean meal	9.22	0.208	1.91776				
43	Limestone flour			0				
44	Vit/Min Premix			0				
45	Dicalcium Ph			0				
46	Salt			0				
47	Acid oil			0				
48	Other	2.53	0.0125	0.031625				
49	Coccidiocide			0				
50				0				

APPENDIX 6. PICK N PAY CHICKEN PRICES

Pick n Pay
Inspired by you
A division of W.U.M. Properties Limited

Quotation

Date: 23/07/2019

Customer Details

UNIVERSTY OF NAMIBIA
Neudamm Campus
Sesilia Shikepo
Cell: 0812271138

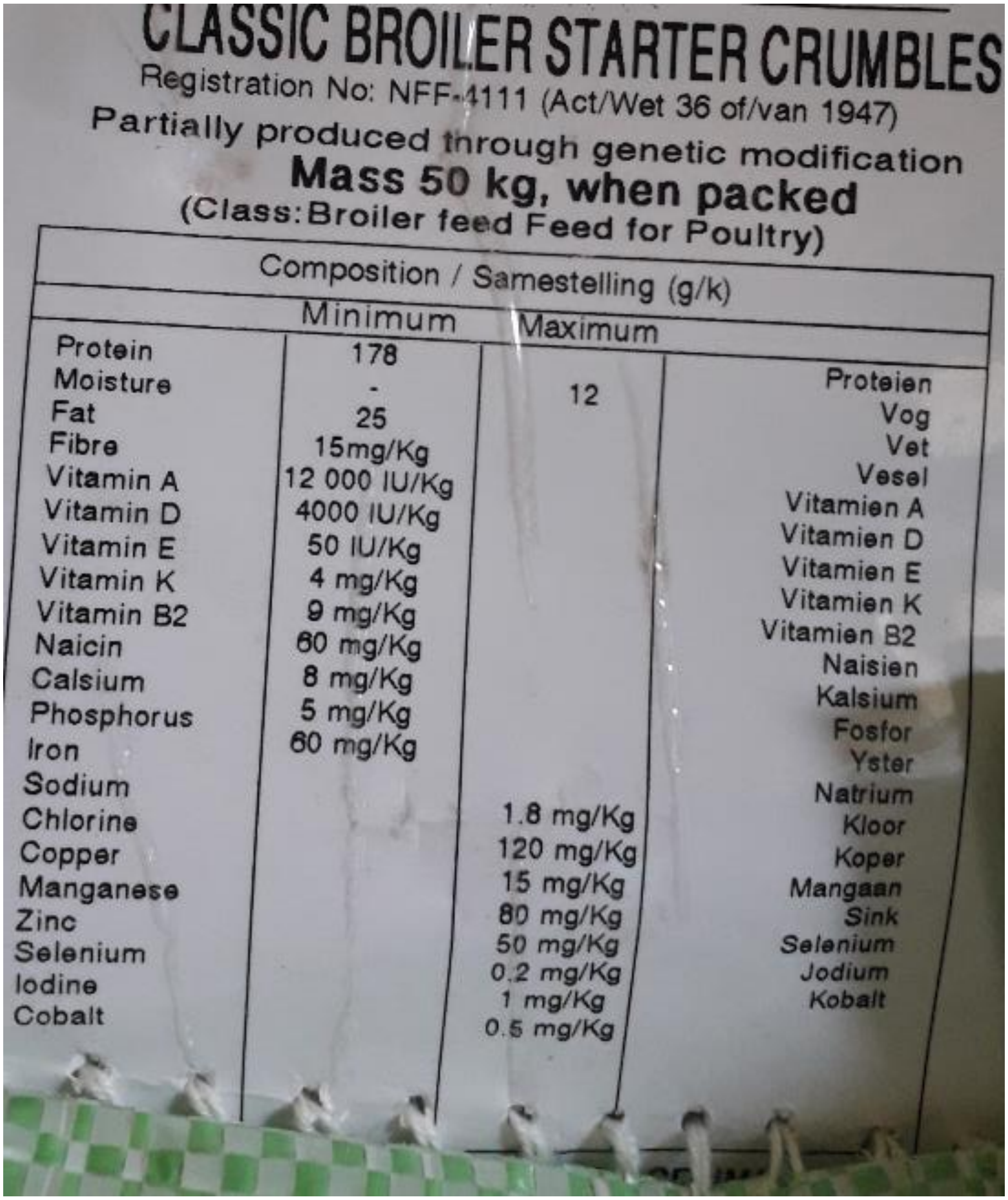
PNP Branch Details

Name: Pick n Pay Wernhil
Tel. Nr.: 061-226544
Fax Nr.: 061-231572

Price/kg	Description of Product	Package Size Unit/kg	Quantity	N$ Unit Price (Incl. Vat)	Total (Incl. Vat)
31.33	Real good Chick Mix 1.5kg	1.5 kg	1	46.99	46.99
47.99	Real good Chick Drumsticks	1.5 kg	1	71.99	71.99

n Pay
Signature: Grace
Prices subject to change - Delivery not included
TO CHANGE

APPENDIX 7. STARTER DIET NUTRITIONAL COMPOSITION



	Minimum	Maximum	
Protein	178		Proteien
Moisture	-	12	Vog
Fat	25		Vet
Fibre	15mg/Kg		Vesel
Vitamin A	12 000 IU/Kg		Vitamien A
Vitamin D	4000 IU/Kg		Vitamien D
Vitamin E	50 IU/Kg		Vitamien E
Vitamin K	4 mg/Kg		Vitamien K
Vitamin B2	9 mg/Kg		Vitamien B2
Naicin	60 mg/Kg		Naisien
Calsium	8 mg/Kg		Kalsium
Phosphorus	5 mg/Kg		Fosfor
Iron	60 mg/Kg		Yster
Sodium			Natrium
Chlorine		1.8 mg/Kg	Kloor
Copper		120 mg/Kg	Koper
Manganese		15 mg/Kg	Mangaan
Zinc		80 mg/Kg	Sink
Selenium		50 mg/Kg	Selenium
Iodine		0.2 mg/Kg	Jodium
Cobalt		1 mg/Kg	Kobalt
		0.5 mg/Kg	

APPENDIX 8. ETHICAL CLEARANCE CERTIFICATE

UNAM

UNIVERSITY OF NAMIBIA

ETHICAL CLEARANCE CERTIFICATE

Ethical Clearance Reference Number: FANR/25/2015 **Date: 6 March, 2015**

This Ethical Clearance Certificate is issued by the University of Namibia Research Ethics Committee (UREC) in accordance with the University of Namibia's Research Ethics Policy and Guidelines. Ethical approval is given in respect of undertakings contained in the Research Project outlined below. This Certificate is issued on the recommendations of the ethical evaluation done by the Faculty/Centre/Campus Research & Publications Committee sitting with the Postgraduate Studies Committee.

Title of Project: INFLUENCE OF MASHING, PELLETING AND CRUMBLIZING PEARL MILLET BASED DIETS AS PROCESSING METHODS ON FEED QUALITY AND PERFORMANCE OF COBB 500 BROILERS CHICKENS

Nature/Level of Project: Doctorate

Researcher: Sesilia Hafeni

Student Number : 200411489

Host Department & Faculty: Faculty of Agriculture and Natural Resources

Supervisor : Prof. Irvin D.T. Mpofu; (Main) (Co) Dr. Patricia N. Petrus

Take note of the following:

(a) Any significant changes in the conditions or undertakings outlined in the approved Proposal must be communicated to the UREC. An application to make amendments may be necessary.

(b) Any breaches of ethical undertakings or practices that have an impact on ethical conduct of the research must be reported to the UREC.

(c) The Principal Researcher must report issues of ethical compliance to the UREC (through the Chairperson of the Faculty/Centre/Campus Research & Publications Committee) at the end of the Project or as may be requested by UREC.

(d) The UREC retains the right to:

(i). withdraw or amend this Ethical Clearance if any unethical practices (as outlined in the Research Ethics Policy) have been detected or suspected,

(ii). request for an ethical compliance report at any point during the course of the research.

UREC wishes you the best in your research.

Prof. I. Mapaure
UNAM Research Coordinator
ON BEHALF OF UREC

APPENDIX 9. SPSS DATA ANALYSIS OUTPUTS

Descriptive Statistics

		N	Mean	
ProcessingMethod		Statistic	Statistic	Std. Error
Commercial	Chicken Live Weight	4	2523.7500000	132.45085567
	Chicken Dressing Weight	4	2103.7500000	79.56587941
	Carcass Weight	4	1833.7500000	69.59331266
	Gizzard with no Contents	4	57.5000000	5.95119036
	Gizzard without Contents	4	31.2500000	6.25000000
	Gizzard with contents as % live wt	4	2.2944661	.26189737
	Gizzard without contents as % live wt	4	1.2592892	.27580816
	Gizzard with contents as % dressing wt	4	2.7328474	.26517615
	Gizzard without contents as % dressing wt	4	1.4729707	.26820767
	Provebtriculus Weight	4	12.5000000	1.44337567
	Heart Weight	4	15.0000000	.00000000
	Abdominal Fat	4	38.7500000	2.39356777
	Breast Weight	4	798.7500000	32.87444550
	Thign Weight	4	266.2500000	14.77258158
	% Fat of carcass weight	4	2.8181818	.17407766
	% Breast meat of carcass weight	4	43.5971342	1.28875834
	% Thign meat of carcass weight	4	14.5915816	1.03070215
	Valid N (listwise)	4		
Mash	Chicken Live Weight	12	2447.0833333	67.84412374
	Chicken Dressing Weight	12	1885.4166667	59.21985978
	Carcass Weight	12	1603.7500000	63.42534684
	Gizzard with no Contents	12	60.4166667	3.71617744

	Gizzard without Contents	12	31.6666667	1.54886730
	Gizzard with contents as % live wt	12	2.5010744	.18747678
	Gizzard without contents as % live wt	12	1.3167802	.09599576
	Gizzard with contents as % dressing wt	12	3.2326787	.22092577
	Gizzard without contents as % dressing wt	12	1.7103573	.12401181
	Provebtriculus Weight	12	11.2500000	.65279121
	Heart Weight	12	12.5000000	.97312368
	Abdominal Fat	12	33.7500000	1.85915018
	Breast Weight	12	660.8333333	19.22586379
	Thign Weight	12	228.7500000	10.44692575
	% Fat of carcass weight	12	2.4545455	.13521092
	% Breast meat of carcass weight	12	41.6242304	1.34314263
	% Thign meat of carcass weight	12	14.3327618	.53585804
	Valid N (listwise)	12		
Pellets	Chicken Live Weight	12	2850.8333333	63.73724868
	Chicken Dressing Weight	12	2226.6666667	71.42842713
	Carcass Weight	12	1735.0000000	82.08227580
	Gizzard with no Contents	12	46.2500000	2.95964013
	Gizzard without Contents	12	29.5833333	2.78376879
	Gizzard with contents as % live wt	12	1.6202206	.09367686
	Gizzard without contents as % live wt	12	1.0353228	.09031979
	Gizzard with contents as % dressing wt	12	2.1041590	.15240866
	Gizzard without contents as % dressing wt	12	1.3413785	.13155552
	Provebtriculus Weight	12	13.3333333	1.28117686

	Heart Weight	12	11.6666667	.71066905
	Abdominal Fat	12	47.5000000	2.98354071
	Breast Weight	12	787.0833333	26.76679828
	Thign Weight	12	282.9166667	18.57069145
	% Fat of carcass weight	12	3.4545455	.21698478
	% Breast meat of carcass weight	12	46.1153424	2.00611200
	% Thign meat of carcass weight	12	16.3327231	.70310213
	Valid N (listwise)	12		

Univariate Analysis of Variance

Notes

Output Created		12-JUL-2019 12:52:40
Comments		
Input	Data	C:\Users\Sesilia\OneDrive\Documents\PhD VIVA VOICE EXAM 28 March 2019\Actual Final PhD VIVA VOCE Presentation1\data entry by Mrs Charamba slaughter and organs weights.sav
	Active Dataset	DataSet1
	Filter	<none>
	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	28
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on all cases with valid data for all variables in the model.

Syntax		UNIANOVA LiveWeight BY Replicate ChickenCode Diet /METHOD=SSTYPE(3) /INTERCEPT=INCLUDE /POSTHOC=Diet(DUNCAN) /PRINT DESCRIPTIVE /CRITERIA=ALPHA(.05) /DESIGN=Diet ChickenCode(Replicate).
Resources	Processor Time	00:00:00.08
	Elapsed Time	00:00:00.16

Tests of Between-Subjects Effects

Dependent Variable: Chicken Live Weight

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1298350.000[a]	9	144261.111	2.387	.056
Intercept	193831032.143	1	193831032.143	3207.300	.000
Diet	1193117.857	6	198852.976	3.290	.023
ChickenCode(Replicate)	105232.143	3	35077.381	.580	.635
Error	1087817.857	18	60434.325		
Total	196217200.000	28			
Corrected Total	2386167.857	27			

a. R Squared = .544 (Adjusted R Squared = .316)

Post Hoc Tests

Diets

Homogeneous Subsets

Chicken Live Weight

Duncan[a,b]

Diets	N	Subset 1	2	3
50% PM Mash	4	2368.7500000		
75% PM Mash	4	2417.5000000		
0% PM Pellets	4	2523.7500000	2523.7500000	
100% PM Mash	4	2555.0000000	2555.0000000	
75% PM Pellets	4	2758.7500000	2758.7500000	2758.7500000
100% PM Pellets	4		2830.0000000	2830.0000000
50% PM Pellets	4			2963.7500000
Sig.		.057	.122	.279

Means for groups in homogeneous subsets are displayed.

Based on observed means.

The error term is Mean Square(Error) = 60434.325.

a. Uses Harmonic Mean Sample Size = 4.000.

b. Alpha = .05.

Univariate Analysis of Variance

Notes

Output Created		12-JUL-2019 13:08:33
Comments		
Input	Data	C:\Users\Sesilia\OneDrive\Documents\PhD VIVA VOICE EXAM 28 March 2019\Actual Final PhD VIVA VOCE Presentation1\data entry by Mrs Charamba slaughter and organs weights.sav
	Active Dataset	DataSet1
	Filter	<none>

	Weight	<none>
	Split File	<none>
	N of Rows in Working Data File	28
Missing Value Handling	Definition of Missing	User-defined missing values are treated as missing.
	Cases Used	Statistics are based on all cases with valid data for all variables in the model.
Syntax		UNIANOVA LiveWeight BY Replicate ChickenCode Inclusionlevel ProcessingMethod /METHOD=SSTYPE(3) /INTERCEPT=INCLUDE /PRINT DESCRIPTIVE /CRITERIA=ALPHA(.05) /DESIGN=Inclusionlevel ProcessingMethod Inclusionlevel*ProcessingMethod ChickenCode(Replicate).
Resources	Processor Time	00:00:00.02
	Elapsed Time	00:00:00.22

Between-Subjects Factors

		Value Label	N
Replicates	1.00000	Replicate 1	14
	2.00000	Replicate 2	14
Chicken Coding	1.00000	Chicken Number 2	14
	2.00000	Chicken Number 2	14
Inclusionlevel	50.00		8
	75.00		8
	100.00		6
	Commercial		6

ProcessingMethod	Commercial		4
	Mash		12
	Pellets		12

Tests of Between-Subjects Effects

Dependent Variable: Chicken Live Weight

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1299779.167[a]	10	129977.917	2.034	.095
Intercept	175693494.455	1	175693494.455	2749.282	.000
Inclusionlevel	69749.146	3	23249.715	.364	.780
ProcessingMethod	847369.608	2	423684.804	6.630	.007
Inclusionlevel * ProcessingMethod	93024.104	2	46512.052	.728	.497
ChickenCode(Replicate)	92261.310	3	30753.770	.481	.700
Error	1086388.690	17	63905.217		
Total	196217200.000	28			
Corrected Total	2386167.857	27			

a. R Squared = .545 (Adjusted R Squared = .277)

```
UNIANOVA LiveWeight BY Replicate ChickenCode Inclusionlevel ProcessingMethod
  /METHOD=SSTYPE(3)
  /INTERCEPT=INCLUDE
  /POSTHOC=Inclusionlevel ProcessingMethod(DUNCAN)
  /PRINT DESCRIPTIVE
  /CRITERIA=ALPHA(.05)
  /DESIGN=Inclusionlevel ProcessingMethod Inclusionlevel*ProcessingMethod ChickenCode(Replicate).
```

Tests of Between-Subjects Effects

Dependent Variable: Chicken Live Weight

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1299779.167[a]	10	129977.917	2.034	.095
Intercept	175693494.455	1	175693494.455	2749.282	.000
Inclusionlevel	69749.146	3	23249.715	.364	.780
ProcessingMethod	847369.608	2	423684.804	6.630	.007
Inclusionlevel * ProcessingMethod	93024.104	2	46512.052	.728	.497
ChickenCode(Replicate)	92261.310	3	30753.770	.481	.700
Error	1086388.690	17	63905.217		
Total	196217200.000	28			
Corrected Total	2386167.857	27			

a. R Squared = .545 (Adjusted R Squared = .277)

Post Hoc Tests

Inclusionlevel

Homogeneous Subsets

Chicken Live Weight

Duncan[a,b,c]

Inclusionlevel	N	Subset 1
Commercial	6	2554.1666667
75.00	8	2588.1250000
50.00	8	2666.2500000

100.00	6	2718.3333333
Sig.		.284

Means for groups in homogeneous subsets are displayed.

Based on observed means.

The error term is Mean Square(Error) = 63905.217.

a. Uses Harmonic Mean Sample Size = 6.857.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

c. Alpha = .05.

ProcessingMethod

Homogeneous Subsets

Chicken Live Weight

Duncan[a,b,c]

ProcessingMethod	N	Subset 1	Subset 2
Mash	12	2447.0833333	
Commercial	4	2523.7500000	
Pellets	12		2850.8333333
Sig.		.573	1.000

Means for groups in homogeneous subsets are displayed.

Based on observed means.

The error term is Mean Square(Error) = 63905.217.

a. Uses Harmonic Mean Sample Size = 7.200.

b. The group sizes are unequal. The harmonic mean of the group sizes is used. Type I error levels are not guaranteed.

c. Alpha = .05.