# EFFECTS OF DIETARY INCLUSION OF DRIED GOAT RUMEN CONTENTS ON PERFORMANCE OF BROILER AND LAYER CHICKENS

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**A Thesis Submitted to the Graduate School in Partial Fulfilment of the Requirements for the Doctor of Philosophy Degree in Animal Nutrition of Egerton University**

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## DECLARATION AND RECOMMENDATION

### Declaration

This thesis is my original work and has never been presented for the award of a degree in this or any other University

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### Recommendation

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## DEDICATION

This work is dedicated to my farther, the late Mr. Ssenyonga Vicent and my mother Mrs. Kyakuha Resty who laid a great foundation for my education. Also, to my wife Kangume Martha, my son Mwesigwa Murungi Medard and my daughter Mwesigwa Reinette for patience and persistence during the time of this study. Finally, to my grandmother Nakacwa Rosemary for the endless care and support.

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**ABSTRACT**

Poultry farmers use a variety of non-conventional feed ingredients including rumen contents (RC) in order to be competitive. However, lack of appropriate knowledge on RC use limits famers to achieve optimum production. This study evaluated extent of use of RC in livestock diets and the effect of dried goat rumen contents (DGRC) as a partial replacement for fishmeal in broiler and layer diets was investigated in a bid to reduce feed costs. Extent of RC use in livestock diets was done by administering questionnaires to 100 livestock farmers randomly selected in the Districts of Kampala, Wakiso and Mukono. Performance of broiler and layer chickens on DGRC based diets was evaluated through two experimental set ups. Goat rumen contents used in the experiment were got from Kampala city abattoir following slaughter. The rumen content was sun dried, milled and incorporated in diets as partial substitute to fish meal at 0, 5 and 10% levels. Dietary treatments were formulated to meet layer and broiler nutritional requirements. Experimental birds at 21days and 3 months for broilers and layers respectively were randomly allocated to experimental diets in a triplicate completely randomized design (CRD). In both experiments, a total of ten (10) birds in a cage were used as the experimental units. The broiler and layer experiments lasted for 21 days and 8 months respectively. In the broiler experiment, data was collected on feed intake, digestibility, growth, blood, carcass, organ, and meat sensory parameters. In layers, data was collected on growth, egg production and egg sensory parameters. Partial budget analysis was used to evaluate the economic benefit of incorporating DGRC in broiler and layer diets. The results showed differences in use of rumen contents in the study areas ($P<0.001$). Kampala District had the highest percentage of farmers using rumen contents in livestock diets. Use of rumen contents was associated with the type of livestock reared ($X^2= 75.26$, $P<0.0001$). In broiler diets, use of 5% DGRC improved growth performance, carcass weights and organoleptic qualities of broiler meat across diets. Use of DGRC in broiler diets did not compromise birds' health and led to lowered total blood cholesterol (TC). In layers, use of DGRC had no effect ($P>0.05$) on egg appearance, odour and texture. However, use DGRC in the diets led to higher yellow yolk colour intensity ($P<0.05$). Use of 5 % DGRC in broiler diets improved profitability whereas in layers, use of DGRC was not profitable. In conclusion, RC were mostly used in pig and layer diets. Lack of knowledge on their effective RC inclusion levels affected farmers' ability to optimize production performance. The use of DGRC at 5 and 10% in broiler and layer diets respectively improved growth performance and increased egg yolk color intensity.

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| | |
|---|---|
| **AA** | Amino acids |
| **ADFI** | Average Daily Feed Intake |
| **AFBW** | Average Final Body Weight |
| **AIA** | Acid Insoluble Ash |
| **AIBW** | Average Initial Body Weight |
| **AME** | Apparent Metabolizable Energy |
| **ANFs** | Anti-Nutritional Factors |
| **BC** | Blood Cholesterol |
| **Ca** | Calcium |
| **CF** | Crude Fiber |
| **CP** | Crude Protein |
| **CRD** | Completely Randomised Design |
| **DGRC** | Dried goat rumen contents |
| **DM** | Dry Matter |
| **EE** | Ether Extract |
| **FAO** | Food Agriculture Organization of the United Nations |
| **FAOSTAT** | Food Agriculture Organinisation Statitics |
| **FCR** | Feed Conversion Ratio |
| **FSM** | Fish Meal |
| **GE** | Gross Energy |
| **HDEP** | Hen Day Egg Production |
| **HDL** | High Density Lipoproteins |
| **HH** | Household |
| **HHEP** | Hen House Egg Production |
| **LDL** | Low Density Lipoproteins |
| **MBM** | Meat and Bone Meal |
| **MC** | Moisture content |
| **ME** | Metabolisable Energy |
| **MHS** | Modified Hedonic Scale |
| **MMR** | Marginal Rate of Return |
| **N** | Nitrogen |

| | |
|---|---|
| **NCFS** | Non-Conventional Feed Stuffs |
| **NDF** | Neutral Detergent Fiber |
| **NFE** | Nitrogen Free Extract |
| **NR** | Net Revenue |
| **NRC** | National Research Council |
| **P** | Phosphorus |
| **RBC** | Red blood cells |
| **SCFA** | Short Chain Fatty Acids |
| **SEM** | Standard Error of the Mean |
| **TDT** | Triangular Difference Test |
| **TVC** | Total Variable Costs |
| **UBOS** | Uganda Bureau of Standards |
| **UIA** | Uganda Investment Authority |
| **UN** | United Nations |
| **VFAs** | Volatile Fatty Acids |
| **WHC** | Water Holding Capacity |
| **YI** | Yolk Index |

# CHAPTER ONE

# INTRODUCTION

## 1.1. Background information

Poultry is a collective term that refers to rearing of birds for meat and egg production (Pym, 2013). Poultry include chickens, ducks, guinea fowls and geese. Over the last five decades, the poultry sector has been expanding and becoming more consolidated primarily due to the strong demand for poultry products (meat and eggs) making it possibly one of the most growing sectors (Vaarst *et al*., 2015). Despite poultry farming being a very important source of livelihood especially in the rural communities (FAO, 2004; Pym, 2013), the sector still faces numerous challenges especially with regard to feeding (Sugiharto *et al*., 2019). While investigating the performance of laying birds fed diets varying in energy and protein, Jain *et al*. (2018) reported feed price volatility as the biggest problem facing the poultry enterprise. Some farmers abandon poultry business in circumstances where they cannot cope with high feed prices. This calls for innovative approaches that will permit extensive and sustainable poultry production. In the poultry industry, protein feed ingredients are the most expensive (Raphaël *et al*., 2015; Rochell, 2018). Protein feed sources are got from both animal and plant sources. However, plant protein sources are usually of low biological value with low lysine and methionine (Saima *et al*., 2008) as compared to protein sources from animal origin. Fishmeal is the main animal protein source used in ration formulation because it has a higher nutrient bio availability in terms of essential amino acids profile as well as fats, vitamins and minerals when compared to most protein sources (Blair, 2018; Frempong *et al*., 2019; Raza *et al*., 2015). However, the prevailing market prices for fish meal are too high and therefore not affordable to most livestock farming communities. Thus, when fish meal is used solely as a protein source in animal diets, it increases the prices of complete diets and sometimes irregular supplies of fish meal occur due to scarcity (Mohanta, 2012). More so, because fish meal is very expensive, it is always subjected to adulteration with other materials such as sand, ash and lake shells by feed suppliers and stockists. As such, substitution of fish meal with cheaper protein sources may not only reduce the production cost of balanced poultry feeds but also the levels of adulteration. Feed adulteration results in poor feed intake, nutrient digestibility, weight gain, feed conversion ratio (FCR) which makes the feed unsafe for the animals. Finding alternative feed ingredient sources to the highly priced fish meal is not only vital in poultry feed cost reduction but also key to the sustainability of the poultry business (Jazi *et al*., 2017; Tufarelli *et al*., 2018). However, for this to be realized, alternative feed sources must be of good nutritional value for better bird's performance and quality of poultry products such as meat and eggs. Several approaches have been employed in the poultry business in order to reduce the high feed prices (Jazi *et al*., 2017; Prayogi, 2011), including use of insects such as maggots and earthworms as alternative animal product based protein sources to fish meal (Frempong *et al*., 2019; Oteri *et al*., 2004; Sogbesan *et al*., 2007). The use of slaughter house wastes for instance rumen contents as feed ingredient is a practice that is not in wide use in the Ugandan livestock feed systems.

In Uganda, just like in many developing countries, enormous volumes of wastes are produced by the various slaughter houses across the country which makes it an increasing burden in terms of disposal in both urban and rural areas. Improper waste disposal is and continues to be a major health concern to human and the environment (Cherdthong *et al*., 2014; Katongole *et al*., 2009; Komakech *et al*., 2014; Mwesigwa *et al*., 2013; Shurson, 2020; Uddin *et al*., 2018). Most of the big abattoirs are concentrated around major urban centers such as Kampala, the capital city of Uganda. This is because of the high population which creates a readily available market for beef. As such, thousands of animals are slaughtered on a daily basis in a congested area leading to production of large volumes of waste. As a result, waste disposal is increasingly becoming a major challenge in most urban areas. The attitude of human towards solving this problem seems not forthcoming, either because they lack knowledge to mitigate its negative impacts or resources for the proper disposal of abattoir wastes are limited (Uddin *et al*., 2018). Because of this, the government of Uganda issued a directive of taking over all city abattoirs in a bid to improve hygiene and safety (New Vision, 2014). Feeding livestock with slaughter house wastes reduces feed cost and safe guards the environment against pollution (Bekele *et al*., 2020; Cuadros *et al*., 2011; Dairo *et al*., 2021; Esonu *et al*., 2006; Uddin *et al*., 2018). It is also one of the ways of contributing to self-sufficiency in protein use and makes possible the integration of animal products into livestock feeds.

Rumen content is the partially digested feed mainly found in the fore stomach of ruminant animals and has been reported to be fairly rich in crude protein (Agbabiaka, 2012; Cherdthong, 2020; Elfaki & Abdelatti, 2016) as it contains microbial protein from bacteria, anaerobic fungi and protozoa. Rumen content is also an important source of energy and vitamins, most especially vitamin B complex. Previous studies in relation to rumen content use in livestock diets has been reported in literature. For instance, Rajkumar *et al*. (2017) reported use of buffalo rumen content in poultry diet that was found to contain a crude protein content (CP) of 8.5% and crude fiber (CF) of 34.1%. On the other hand, a study by Sakaba *et al.* (2018) found cattle rumen content to contain CF of 48.1% and CP of 14.73%, while sheep rumen content was found to contain CF and CP of 48.7% and 15.5% respectively.

Variability in rumen content compostion is due to differences with respect to animal type, feeding regime, feed resource diversity and selection of pastures by various animals (Cherdthong *et al*., 2014; Togun *et al*., 2010). However, what is not clear is the seasonal variability with respect to rumen content nutritional composition. Such information form a basis not only for the proper timing of rumen content (RC) collection but also as a guide for its efficient use in animal feeds. More so, in the dry season, forages become coarse and too fibrous with little nutritional benefit to the animal.

The degree of forage selection during grazing or browsing differs with the type of animal whereby small ruminants (goats) tend to go more for forages that are young, tender and highly nutritious than large ruminants (Sanon *et al*., 2007). Studies have also demonstrated a significant correlation between species selection as well as chemical composition of the diet and season of use (Taylor *et al*., 1997). As such, goats tend to go for plants that are more nutritious (low lignification, high CP and low tannin) and therefore, tender portions of the forage are more preferred. This observation is further expounded by Nudda *et al*. (2020) who reported that as the preferred goat feed materials are removed from the paddock, goats reduce their dry matter (DM) intake instead of consuming forage with higher fiber content. This emphasizes that, nutritional quality remains paramount in the goats feeding strategy. Diet selection by goats is primarily determined by the variety of plant species and the relative abundance of each (Dias & Abdalla, 2020; Mellado, 2016; Taylor *et al*., 1997). Studies have also indicated that depending on the amount used, incorporation of animal wastes in diets could lead to development of off-flavor odours and undesirable colour in meat and eggs which affects the acceptability of animal products to consumers. Such information is lacking in the Uganda livestock industry and would therefore guide farmers on safety and appropriateness of animal waste use in poultry production. In relation to the above, rumen content (RC) from small ruminants seems to be of better quality compared to that from large ruminants and therefore forms a basis for this study which seeks to evaluate wet season rumen content from small ruminants (goats) as alternative protein source to fish meal in broiler and layer diets.

## 1.2 Statement of the problem

Feed constitute 60-70% of the cost incurred in poultry production, hence many farmers grapple with feed related costs. However, in order to remain vibrant and competitive in the poultry business operations, farmers use various non-conversional feed ingredients to substitute the expensive feed ingredients like fish meal. In recent times, farmers in Uganda use abattoir wastes including rumen contents as dietary ingredients but with limited information on effective inclusion levels. This compromises the performance of broiler and layer chickens. Despite having relative high crude protein levels and xanthophyll (a precursor of vitamin A) which can enhance egg yolk pigmentation. Furthermore, because of long stay and improper processing, rumen contents tend to have a repulsive smell which affects its acceptance by the animals. Therefore, farmers' awareness is needed in terms of effective inclusion levels of rumen contents in poultry diets for improved performance of growing birds. On the other hand, inappropriate use of rumen contents in dietary rations affects digestibility, growth rate, blood metabolites, carcass characteristics, carcass composition and consumer acceptability of broiler meat. In laying birds, inappropriate dietary inclusion of rumen contents can influence the point of lay, laying percentage, egg quality and acceptability of eggs to the consumers which eventually impacts on profitability. Therefore, information in relation to the proper use of rumen contents in broiler and layer diets is crucial and will help poultry farmers remain competitive and break even in an era of increasing prices of conventional feed ingredients.

## 1.3 Objectives

### 1.3.1 Broad objective

This study seeks to contribute to sustainable poultry production through utilization of goat rumen contents as alternative to animal protein supplement for chicken

### 1.3.2 Specific objectives

i. To determine extent of use of rumen contents in livestock diets among farmers in Uganda
ii. To determine effects of dried goat rumen content based diets on digestibility, growth rate and carcass characteristics of broiler chicken
iii. To determine the effect of inclusion of dried goat rumen content in broiler chicken diets on blood characteristics, carcass composition and sensory attributes
iv. To determine the effect of dried goat rumen content-based diets on point of lay, laying percentage, egg quality and sensory attributes
v. To determine costs and benefits associated with use of dried goat rumen content in both broiler and layer diets

## 1.4 Hypotheses

The following hypotheses were postulated for this study;

i. Extent of rumen contents use in livestock diets does not differ significantly among farmers in Uganda
ii. Dried goat rumen content-based diets has no significant effects on growth rate, digestibility and carcass characteristics in broiler chicken
iii. Inclusion of dried goat rumen content in broiler chicken diets has no significant effect on blood composition, carcass composition and sensory attributes
iv. Dried rumen content-based diets does not significantly affect point of lay, laying percentage, egg characteristics and egg sensory attributes
v. There are no significant economic benefits associated with use of dried goat rumen content-based diets in broiler and layer chicken diets

## 1.5 Justification

In Uganda, high feed prices, availability and quality are the major challenges affecting poultry production. This has led to some farmers abandoning the business because of the inability to cope up with these challenges. Therefore, there is need to search for abundant locally available alternative poultry feed ingredients that would reduce the feed cost without compromising growth rate, egg and meat quality. In Uganda, enormous volumes of rumen contents are discharged by the various slaughter houses across the country which is a burden in terms of disposal and also pose a danger to the environment. Rumen content has been reported to be fairly high in crude protein (Agbabiaka, 2012) as it contains microbial protein from bacteria, anaerobic fungi, and protozoa. Furthermore, goats tend to go for more nutritious plants and plant parts (low lignification, high CP and low tannin) and therefore, goats tend to have rumen contents of higher nutritive value, with finer particle size and a large surface area for enzyme action compared to large ruminants. Studies have indicated that depending on the amount used, incorporation of rumen contents in diets could lead to development of off-flavor odour and undesirable colour in meat and eggs which affects the acceptability of animal products by consumers. Utilization of goat rumen content as alternative to animal protein sources could reduce not only feed costs in poultry production but would also address the disposal problem associated with key slaughter byproducts. However, there is need to determine the most appropriate rumen content inclusion levels in poultry diets that guarantees performance without compromising chicken growth rate, meat, egg quality and the economic benefits. Therefore, this study determined the effects of using dried goat rumen content-based diets on chicken growth rate, egg production, egg and meat quality and economic viability in Uganda.

## 1.6 Scope/ limitations/ assumptions

Rumen contents were obtained from slaughtered goats in the wet season as opposed to dry season. It is assumed that during this period forages are more nutritious and tender than those from the dry season. As such, since goats are browsers, fresh tender leaves and grasses that are more nutritious are preferred which may result in finer rumen content, that is less fibrous and more nutritious than rumen contents from large ruminants (bulk feeders). However, drying of the collected rumen content in the wet season was a serious challenge, as it was constantly affected by onsets of rain. This resulted in prolonged days/ time of drying rumen contents. Additionally, during drying, rampant rains would submerge the rumen contents and wash it away which made the drying process become more complicated.

Stench/bad smell from rumen content as a result of prolonged storage prior to proper drying was also one of the limitations encountered. Stench affected the proper working conditions and health of abattoir workers.

Contaminants in the rumen contents like thorns, sharp metal objects were also a big problem. The contaminants required sorting which would sometimes pierce and inflict damage on hands of abattoir workers despite wearing protective gears.

Since goat rumen contents were collected in a 200 litre plastic drums following slaughtering, lifting of the full drums was a great challenge as it required a lot of manpower.

There was also limited space in the abattoir which complicated the storage of rumen contents following the drying process. As such, additional storage space was secured elsewhere which was costly.

Clogging of the milling machine occasionally occurred during milling of dried rumen contents which resulted in price increment per kilogram milled.

The area where rumen contents were collected from was peri- urban with a lot of idlers around the abattoir premises. This predisposed the drums and black polythene bags used for drying rumen contents to theft which hindered the drying process.

# CHAPTER TWO

# LITERATURE REVIEW

## 2.1 Overview of the East African feed industry

In East Africa, the feed industry is growing and is anticipated to grow further due to the high demand for animal products occasioned by the changing demand plus other factors such as increase in human population, urbanization and growth in per capita income. As such, to meet the growing animal protein demand, livestock production will have to be increased significantly which will result in an inevitable demand for livestock feeds (Westhoek *et al*., 2011). However, the increase in demand of livestock feeds comes with numerous challenges which includes availability of adequate feed stuffs with good quality (Nkya *et al*., 2007). Adulteration is also common with highly priced feed ingredients in most countries forming the East African block, this creates health hazards to both livestock and the final consumers. The main livestock feed stuffs used in the feed industry, consist of roughages, concentrates, minerals and vitamins. Raw materials used in the feed industry originate from cereals, legume, oil seed cakes and animal byproducts.

Fish meal is the largely used protein source feed ingredient and because of this, it has become very expensive beyond the reach of a common farmer. This, coupled with unreliable supply, necessitates its substitution with other cheaper protein sources (Boland *et al*., 2013; Cho & Kim, 2011). The higher pricing of feed ingredients in many cases has forced farmers to look for alternative feed ingredients for instance a mix with agro based byproducts like those from potato, vegetables, wheat, oil seeds and household wastes.

The feed industry in general lacks sufficient capacity for quality control which has led to livestock farmers registering significant losses due to purchase of substandard feeds for their livestock. Despite statutory bodies being put in place for quality control in East African countries, most feed manufacturers are unregistered, unregulated and more so difficulty to trace by the regulatory bodies. Due to these challenges, some farmers have taken the initiative to formulate their own feeds with a view of reducing feed costs as compared to buying commercially formulated feeds. However, this is done mostly without considering a variety of factors that come into play when determining the actual cost advantage, which includes assessing the quality of feed ingredients and determining the right inclusion levels (Kasule *et* *al*., 2014; Katongole *et al*., 2012). Due to these inefficiencies, performance and productivity of livestock on home made feeds has been poor with low or no profit margins. Katongole *et al.* (2012) attributed this to lack of knowledge on appropriate feed and feeding practices coupled with feed formulation incompetence by livestock farmers that leads to failure in meeting optimal nutrient requirements for the target animals. Besides this, there is potential for improvement in the feed industry if the constraints hampering its growth are addressed. This calls for extensive research in regard to exploitation of various non-convention feed ingredients to enable the sustainability of the feed industry in cases where one or more feed ingredients become unavailable or unaffordable to farming communities due to prohibitive prices (Mohanta, 2012). In addition, there is also need for supportive government policies in relation to feed regulations, this not only gives a formal frame work from which the feed industry operates but also shows commitment by the government to promote technically feasible options aimed at removing major barriers in order to stimulate more innovative approaches by stakeholders in the feed industry.

## 2.2 Poultry industry

Poultry are domesticated avian species that are raised for both meat and eggs. Poultry is a broad term that includes ducks, turkeys, geese, pigeons, ostriches and other game species for instance pigeons and quails. The poultry industry is one of the fastest growing animal industry in the world. Chicken constitute about 90% of the entire poultry population and are by far the most important species in all parts of the world (FAO, 2014). According to FAOSTAT (2015) the world egg production reached 68.26 Mt in 2013, representing an increase of 94.6% from 35.07 Mt in 1990. In Uganda, the poultry industry is also on the rise with an estimated 45.9 million birds of which 80% is comprised of indigenous chicken and 20% commercial types mainly composed of exotics (UBOS, 2014; UIA, 2014). The increase in poultry production is attributed to the prevention of animal diseases and improvement made in the livestock production systems by the government. This rise is further expected to save the Ugandan government millions of dollars which would otherwise be used in the importation of chicken meat and eggs from Brazil and South Africa (UBOS, 2014). Poultry meat and eggs are the most important food protein source for the world population for decades (Magdelaine, 2011). The rise in poultry production has also led to the concomitant increase in both poultry meat and egg production.

Poultry production in Uganda is categorized mainly into commercial and free range with wide variations among the two systems in terms of the number of birds kept, type of birds, bio security and management issues (Kirunda *et al*., 2010). The commercial system covers mainly production of improved breeds and of recent local breeds have also been introduced into this system under intensive confinement. Categorization of birds is also based on management systems for instance intensive, semi intensive and extensive of free range systems.

In the intensive system, birds are mainly kept indoors and involves use of more inputs in terms of housing, feeds and feeding, breeds and health as compared to the rest of the systems. This system is more market oriented with the broad objective of getting higher profit. As such, the number of chickens used in this system are relatively high (more than 200 chicken). Additionally, the chicken breeds (layer or broiler) used for this system are specialized and improved for better production performance. In Uganda, this system comprises of less than 20% of the total poultry population (Busulwa, 2009), and is mainly practiced in urban and peri-urban areas, targeting the markets for eggs and chicken meat that is predominant in these areas. In the intensive system, strict following of the recommended standard practices, such as breed of choice depending on production objectives, appropriate housing, feeding, health and disease control programs are adhered to.

In the semi-intensive system, birds are usually housed in a wire mesh with an open enclosure (run) to allow the movement of birds in order to search for food. The major feed sources for chicken in this system are insects, worms and grasses that are obtained from free scavenging, these may sometimes be supplemented with legumes, cereal grains during periods of feed scarcity. However, it is important to note that, the amount of feed offered is usually low and do commensurate to the nutritional requirements of the birds (Busulwa, 2009; FAO, 2014; Kirunda *et al*., 2010). This system consists of a small flock (5-10 birds) per household and the chicken are mostly indigenous breeds.

In the extensive system, birds are left to freely range as they largely dependent on scavenged feeds. Supplementation of feed is sometimes done in situations where birds are raised in larger numbers (FAO, 2014). This system is mostly practiced in rural settings for provision of animal protein source for household and also as a source for additional income. Just like in the semi intensive system, the breeds most kept in the extensive system are mostly indigenous and mainly depend on locally available feed materials.

Despite the remarkable progress registered in poultry industry as exhibited by the increased number of commercial farmers over the past years in Uganda and East Africa at large (EAFF, 2012), the industry still faces numerous challenges for instance, diseases and parasites, poor breeds, poor housing and inadequate slaughter facilities, high feed prices coupled with numerous adulterations. A strategy on how to improve the competitive of the poultry industry should therefore strive to improve production, productivity, market access, processing and value addition (EAFF, 2012). Efficient utilization of nonconventional feed ingredients is one of the cost effective approaches that will not only enable increased productivity in the poultry industry but also assist to improve food security in smallholders farming conditions (Kirunda *et al*., 2010).

### 2.3 Poultry feed industry

Proper chicken nutrition is essential for the flock health, production and survival. To ensure good growth, birds must be provided with well nutritionally balanced feeds in relation to strain used, body size, age, prevailing ambient temperature as well as level of physical activity (Klasing, 2016). It is well documented that in poultry just like in other animals, feeds constitute the biggest portion of production costs (60-70%) particularly in the intensive production system (Mohanta, 2012). As such, efforts should always be made to ensure efficient utilization of alternative feeds especially in food insecure areas (FAO, 2014). Care should be undertaken such that the alternative feedstuff brings no negative impact on both meat and egg production.

In Uganda, the feed industry is not well streamlined and has several players both legal and illegal. The illegal feed dealers are widely spread across the country and are characterized by poor feed handling facilities which lead to rampant feed contamination. Despite the role feed dealers play in ensuring easy access of livestock feeds by the farmers, the industry remains largely unregulated which has led to compromise in feed quality by many players. As a result, many farmers resort to buying feed ingredients and formulate their own feeds (Katongole *et al*., 2012). Despite this initiative, it does not save farmers from adulteration by unscrupulous feed dealers. Energy and protein feed sources are the most adulterated among feed ingredients. This is because they are the most expensive feed ingredients. Farmers have registered several losses due to poor quality feeds and many have been forced to leave the poultry business because of this problem.

Since most feed ingredients used in poultry are bulky, transportation of the feed ingredients makes the final product expensive. Seasonal feed variations make the outputs from the feed factories vary considerably which results in irregular supplies and prices for farmers. There is also feed quality inconsistency between various manufacturers and also within the same company from season to season (Katongole *et al*., 2012). In general, the feed processing industry lack technically qualified staff capable of executing laboratory activities for regular monitoring of feed quality.

### 2.3.1 Fish meal

Fish meal (FM) is the chief animal protein source used in the feed processing industry. This is because of its high protein content with excellent amino acid profile (AA), docosahexaenoic and eicosapentaenoic omega-3 fatty acids, minerals (iron, zinc), and vitamins which are often highly bioavailable (Beveridge *et al*., 2013; Daniel, 2018; Golden *et al*., 2016). Furthermore, it lacks anti-nutritional factors (ANFs), has high lipid nutritive value and many other constituents (Cho & Kim, 2011). Until recently, fish meal has been used as a major protein source in ration formulation with no serious problems of scarcity (Olsen & Hasan, 2012). However, the quantities of fish in the lakes has been decreasing year after year creating a worrying situation among feed manufacturers. This situation has been more so aggravated by competition with human, thereby making fish become scarce to the feed industry. As such, the market price of fish has been sky-rocketing to levels beyond the reach of many livestock farmers. More so, because of the higher price of fish meal, it has been exposed to numerous adulterations by many feed dealers which has affected the performance of livestock. According to (Alexandratos *et al*. (2006), the world population is expected to triple by 2050 thereby increasing standards of living especially in developing countries which will eventually create a high demand for animal-derived protein. This necessitates exploration of novel and cheaper protein sources from non-convectional feed sources in order to sustain the feed industry. Through this pathway, over reliance on fish meal and other animal protein sources would be reduced (Boland *et al*., 2013). However, complete replacement of fish meal in the feed industry remains a daunting challenge. This is particularly because the candidate feed ingredient to be used as an alternative ought to have similar nutritional characteristics as those of fish meal which rules out most potential feed ingredients (Daniel, 2018; Valente *et al*., 2016). As such, partial replacement of fish meal remains the most feasible alternative. However, in future as research advances with new discoveries and innovations, fish meal may no longer be a major feed ingredient and it may be likely that diets with no fish meal will become popular.

### 2.3.2 Non-conventional feed stuffs

The non-conventional feedstuffs (NCFS) is the term used to refer to feed stuffs that have not been traditionally used in livestock feeding and are not normally used in production commercial rations for livestock (Aniebo *et al*., 2009). These feedstuffs include a variety of feeds from perennial and annual crops and byproducts from both animal and industrial processing. Byproducts from animal processing may include rumen contents while those from industrial processing include brewers waste, single cell protein, palm press fiber, maize bran, wheat bran and pollards, and byproducts from citrus fruits and vegetables processing (Oguri *et al*., 2013).

The use of NCFS in livestock diets is justified by serious shortages in animal feeds especially of the conventional type (Katongole *et al*., 2009; Oladunjoye & Ojebiyi, 2010) which do not compete with human food. Since NCFS are mostly agricultural byproducts, they could partially be used to fill the gap in feed supply if properly processed and therefore contribute to the sustainability of the feed industry by imparting nutrients to the rations. However, caution is needed when using NCFS in animal feeds as some contains potential ant-nutritional factors (Welker *et al*., 2016), nature of the feed having low apparent digestibility (Gatlin *et al*., 2007), low amino acid profile and less palatable (Torstensen *et al*., 2008) , damage to the intestines (Yu *et al*., 2015) that could comprise animal performance. It is therefore imperative to examine NCFS critically and where possible enhance their acceptability by the animals in order to improve intake and digestibility (Sharma & Arora, 2011).

The main constraints to use of NCFS in animal diets are collection, dehydration in order to reduce high moisture content (MC) to recommend levels (<10%) and the detoxification processes. In such case, in order to remain viable, the processing technologies that are economical and practical are used. Open sun drying and use of solar driers are some of the techniques that are used to reduce high moisture content in NCFS followed by milling into fine particles depending on the animal in question.

## 2.4 Use of animal slaughter wastes in livestock diets

Slaughter house by-products are defined as parts of the slaughter animals that do not directly contribute to human nutrition (Alao *et al*., 2017). It is estimated that more than half of the live animal weight is lost in form of various products such as organs, fat, skin, intestinal contents, bone and blood. As a result, revenue is lost and the cost of disposal is also high (Meeker, 2009). These wastes can be collected and processed into useful raw materials that can be used both in animal feed and pet food by the rendering industry (Komakech *et al*., 2014). Products of the rendering industry include meat and bone meal (MBM), meat meal, poultry meal, hydrolyzed feather meal, blood meal, fish meal and animal fats (Komakech *et al*., 2014). In most developing countries effective technologies to process slaughter waste products into safe usable products are not available and therefore rely mostly on rudimentally processing methods like open sun drying.

The use of rumen contents and other agro-based byproducts in animal feeds is justified by the need to reduce the high cost of feeds through the use of cheaper and locally available alternatives especially, those that have no nutritional value to humans (Oladunjoye & Ojebiyi, 2010). The conversion of wastes into animal feeds not only enhances flexibility in feed formulation but also the need to maximize the economic and environmental benefits in disposal of slaughterhouse byproducts (Jayathilakan *et al*., 2012; Sorathiya *et al*., 2014; Uddin *et al*., 2018). This calls for interventions that can efficiently recycle these byproducts into useful products such as animal feed ingredients (Aniebo *et al*., 2009).

### 2.4.1 Rumen contents

Rumen contents are also called digesta, is made up of undigested feed eaten by the ruminant animal, it also contains a lot of microorganism that play a key role in feed degradation, and protein synthesis, fatty acids and vitamin production (Jayathilakan *et al*., 2012). In most cases rumen contents are considered as a waste, as such, they are normally disposed improperly which acts has led to air pollution, ground water pollution through leaching and eutrophication. Recovery of rumen contents from abattoirs offer a great opportunity for their use as alternative nutrient sources to complement the limited feed resources (Bishop, 2007; Lead *et al*., 2005). However, rumen contents must be subjected to proper processing for them to be of high significance to the livestock industry (Agbabiaka, 2012; Amata, 2014; Cherdthong *et al.,* 2014; Yitbarek *et al*., 2016). Rumen contents are high in fiber, hence supplements that facilitate digestion of fiber for instance enzymes may be utilised when using rumen contents in dietary formulation especially, for monogastric animals (Birendra *et al*., 2018). Precautionary measures are also needed when using rumen content feedstuff as it is characterized by high crude fiber (CF), high moisture content and bad smell which hinders its acceptability by the animals (Adeniji & Balogun, 2005). The high moisture content of rumen content (Plate 1) and low dry matter (DM), make the rumen content bulky which complicates its transportation and storage. The rumen content may also contain anti-nutritional factors (ANFs) which may affect its proper utilization. However, anti-nutritional factors can be reduced by thermal processing that increases the nutritional value and protein level of the feed in some cases (Adeyemo & Longe, 2007). This is because as the ANFs get eliminated, the protein in the plant products also get freed hence increasing their accessibility by the animal. However, Okpanachi *et al*. (2011) found no anti-nutritional substances (ANFs) in rumen content justifying its use in animal feeds.

**Plate 1.** Rumen content being dumped at Kampala city abattoir (Photo credit: Mwesigwa Robert)

**2.4.2 Overview of the different forms of rumen utilization**

Since rumen contents are associated anti-nutritional factors (AFs), several approaches have been employed to improve its nutritional composition and acceptability to livestock. For example, ensiling rumen content with molasses and straw (Ferdowsi *et al*., 2012) has been shown to increase the dry matter (DM) and carbohydrate sources for feeding ruminants, in other cases rumen contents has been mixed with poultry droppings and was reported to improve on intake, digestion of dry matter in sheep (Fajemisin *et al*., 2010). In broilers, Elfaki & Abdelatti (2015) supplemented dry rumen contents with enzymes which led to a significant improvement in growth rate and with no negative effect on blood plasma biochemical parameters. In layers, mixing rumen content with blood meal increased the rate of lay and egg weights (Adeniji & Balogun, 2005). From the fore mentioned literature, it is evident that nutritional enhancement of rumen contents is possible for improved livestock performance. Rumen content nutritional composition is to some extent influenced by the type of feed consumed by the animal prior to slaughter (Ghosh & Dey, 1993). It is also possible that variation in rumen content composition occurs in different ruminants.

Rumen content has also been utilized in ruminant diets like goats, lambs and cows with no adverse effects on digestibility of nutrients, growth and feed utilization efficiency (Alao *et al*., 2017; Al-Wazeer, 2016; Osman *et al*., 2004).

### 2.4.3 Rumen microbial composition

The rumen is a complex organ with a consortia of micro organisms comprising of prokaryotic bacteria and archaea, eukaryotic fungi and protozoa that aid in the fermentation of ingested plant material. The rumen microbiota is responsible for conversion of ingested plant material leading to the production of microbial protein and volatile fatty acids (VFA) such as acetate, propionate and butyrate which provide approximately 70–85% of the nutrients absorbed by the ruminant (Bergman, 1990; Noel *et al*., 2017). Plant polysaccharides that cannot be degraded by the mammalian host enzymes can also be fermented by rumen microbes to products that can be utilized by the ruminant. The rate at which the various array of fermentation products are produced in the rumen regulate the composition and yield of the main commercial products from farmed ruminants, such as  milk, meat and wool (Gado *et al*., 2009). In a study that evaluated the diversity of rumen microbial community in dairy cows, theta were grazed on rye-grass and clover pasture over seasons, revealed variations in microbial biomass and composition as the nutritional composition of the pastures changed with season (Noel *et al*., 2017). The type of diet eaten by the ruminant not only affects the rumen bacterial community structure but also determines the substrates available for rumen fermentation (Henderson *et al.,* 2015). Additionally, geographic area (RamÅ¡ak *et al*., 2000),  ruminant species (An *et al*., 2005), animal-to-animal variation (Welkie *et al*., 2010), rumen developmental status (Jami *et al*., 2013), lactation and photoperiod (McEwan *et al*., 2005) also affect rumen microbial composition in the rumen. Although variations in the host diet and environmental conditions have been shown to affect the microbial composition, more is still unknown on rumen microbial protein accumulation in relation to animal effect and seasonality (McEwan *et al*., 2005). Elucidating on such effects can help generate information on the timing of rumen content collection for efficient use in the animal feed industry.

### 2.4.4 Effects of incorporating dietary rumen content on performance of birds

Most experiments have reported dietary inclusion of rumen content leading to increase in feed intake and body weight gain in birds (Esonu *et al*., 2004; Inci *et al*., 2013). Several studies have attributed the improvement in performance to higher microbial protein content, long chain fatty acids and partially digested feed protein (Okorie, 2005). And more so, since dried rumen content contain high fiber content, this makes animals to increase feed intake inorder to get more of the nutrients in the feed (Esonu *et al*., 2004). Dietary crude fiber has also been reported to activate the intestinal peristaltic movement resulting in more enzyme production and therefore improved efficiency in nutrient digestion (Esonu *et al*., 2004). The effects of weight gain in broiler birds fed diets in which dried rumen content has been incorporated is more felt when the feeds are supplemented with enzyme. Enzymes are known to reduce intestinal content viscosity, enhance digestion and absorption of nutrients, especially fat and protein, improve apparent metabolizable energy (AME) value of the diets which eventually leads to improvement in feed intake and reduced beak impaction and eventually decrease vent plugging size of gastrointestinal tract (Morales *et al*., 2016; Saleh *et al*., 2003;Wang *et al*., 2005).

In relation to intestinal organs, reports indicate increased gizzard weight and caecum length in birds fed dried rumen content basal diets or supplement. During digestion the gizzard perform a lot of work in breakdown of ingested feed stuff, this is more so when the feed is high in fiber as such gizzard musculature increases. This effect may also be felt within the caecum length where its lengths normally increases. These findings also revealed that, there is no adverse effects associated with use of dried rumen content on blood plasma constituents. The reduction in cost of production and cost of feed in broilers fed dried rumen content (DGRC) suggested that, the use of DGRC is an economically feasible alternative in chicken production (Wang *et al*., 2005).

**2.4.5 Effects of feeding rumen contents on haematological parameters in broilers**

Haematology is defined as the field that encompasses the number and shape (morphology) of blood elements which comprise of red blood cells (RBC), white blood cells (WBC) and platelets (thrombocytes). Blood packed cell volume (PCV), haemoglobin (Hb) and mean corpuscular hemoglobin (MCH) in circulating avian erythrocytes are not only important in anemia diagnosis but also show the capacity of bone marrow to produce red blood cells (Chineke *et al*., 2006). Studies conducted on use of rumen contents in layers revealed no significant effect on red blood cells, white blood cells and packed cell volume (Gebrehawariat *et al*., 2016) at the end of the experiment as the values were within the normal ranges. Red blood cells (RBC) facilitate oxygen transport from the heart to all body parts and removal of carbon dioxide from tissues to the lungs with the help of haemoglobin. White blood cells (WBC) on the other hand protect the body against pathogen invasion (Osman *et al*., 2004;

Saladin, 2001). The lack of significance in the values of RBC and WBC following inclusion of rumen contents in diets for layers signify that their functions were uninterrupted.

The values of MCV, MCH and MCHC are also termed as red cell indices. They are useful in elucidating the etiology of anemias and also vital in the assessment of nutritional status of chicken as a result of type of feed ingested (Olabanji *et al*., 2007). While evaluating camel rumen content as a feed for broiler chickens Makinde *et al.* (2017) found values of MCV MCH and MCHC within the normal ranges at 0, 5, 10 and 15% inclusion.

Also, important as a blood constituent, is the level of cholesterol and triglycerides. Cholesterol results from synthesis of both fat that is consumed and the fat that is endogenously produced within cells. High levels of cholesterol in blood predisposes the animal to high risk of cardiovascular diseases. Triglycerides synthesis takes place in the liver from fatty acids, protein and glucose when their levels are way above the needs of the body are stored in adipose tissue. Lipid metabolites in blood including levels of triglycerides, total cholesterol and lipoprotein fractions relate to the intensity of metabolism taking place in an organism.

Monitoring of blood elements is beneficial in the poultry industry for it provides vital information about poultry health status from which necessary remedies can be initiated by the farmer for the sustainability of the poultry business (Olabanji *et al*., 2007; Saliu *et al*., 2012). The kind of diet an animal is exposed to have varying effects on blood parameters indicative of how good or bad the diet is to livestock health (Adeyeye *et al*., 2017; Iheukwumere & Herbert, 2003; Oloruntola *et al*., 2018). Other than diet, it further known that genotype of the animal and environmental conditions also influence haematological parameters in poultry. Additionally, the level of fiber in the diet especially cellulose not only improve gut morphology but also influences lipid metabolism in the liver and levels of blood serum lipid profile in broilers (Abdollahi *et al*., 2016; Safaa *et al*., 2014).

According to Bounous *et al*. (2000), normal hematological parameters in chicken are in the following ranges; Packed cell volume (PCV): 13.9-14.1, Haemoglobin (Hb): 11.60-13.68 g/dl, Red blood cells (RBC): 2.5-3.5 x$10^6$µl, White blood cells (WBC): 12-30 x$10^9$l, MCV: 90-140 fL, MCH: 26.0-35.0 Pg/cell and MCHC: 32.41-33.37 %.

### 2.4.6 Limitations of using rumen contents in livestock diets

Despite the various positive attributes that come with the use of rumen contents in livestock diets, it should be noted that ruminant diets mostly rely on acquisition forages and other feed stuffs that are subject to contamination. This therefore increases the risk of spread of bacteria and chemical contaminants in digestive system of ruminants up to the final consumers (Lange *et al*., 2018; Okunola *et al*., 2019; Wanapat, 2004). There are several concerns that comes with the use of rumen contents as a protein replacement in livestock diets. For instance, the issue of contamination by pathogens need to be addressed with utmost attention as pathogens from animal host mainly from the gastrointestinal tract (GIT) compromises the quality of rumen contents. Thus, the health of the animal from which the rumen contents are obtained should be put into consideration and animal hosts should be confirmed of being free from pathogens.

Also, because ruminants feed on grasses, shrubs and forages, there is likelihood for anti-nutritional factors in these feed materials whose effects can be reflected in rumen contents. The antinutritional factors include; tannins, phytates, oxalates, saponnins, phenols, glycosides and alkaloids. The presence of antinutritional factors in feeds interfere with nutrient utilization and reduce feed efficiency and overall animal performance. For instance, tannins have been implicated in digestibility and protein use efficiency reduction (Agbabiaka, 2012; Huang *et al*., 2018). Similarly, phytic acid ties up phosphorous and renders it unavailable for digestion. As such, necessary precautions should be undertaken to ensure reduction of antinutrition factors in feedstuffs to levels that do not compromise animal performance. This calls for adequate processing of rumen contents prior to incorporation into animal feeds. Heat treatment, sun drying and pelleting of feeds are some of the processing methods that could reduce antinutritional factors and pathogen contamination (Abeke & Otu, 2008; Elfaki & Abdelatti, 2015; Ravindran *et al*., 2006; Schons *et al*., 2012). However, care should be undertaken while processing rumen contents to ensure that the integrity of amino acids (AA) is retained. This is because, the availability of amino acid contents and other nutrients/compounds retained after processing is influenced by the intensity of heat applied on the rumen (Makinde & Sonaiya, 2007).

On the other hand, the quality of rumen contents is also subject to variations in proximate composition mainly attributed to the different feeding regimes the animals are subjected to differences in pasture selectivity by the animals and vegetation nutritional composition (Agbabiaka, 2012; Togun *et al*., 2010). In some instances, the dried rumen contents must be subjected to milling in order to reduce the particle size for increased intake hence incurring additional costs. However, this also depends on a particular animal type to which the rumen contents are to be used. For example, there are reports where farmers do not mill rumen contents most especially when destined for pig feeding (Mwesigwa *et al*., 2020). Also, rumen contents are high in fiber content which may affect nutrient digestibility in animals as such optimum levels of use should be put into consideration.

Additionally, the level and concentration of toxic metals in dried rumen content also impacts a degree of limitation to rumen content use in livestock diets. The level of toxic elements in rumen contents depends on exposure of forage crops eaten by the animals, soil content, human and natural activities. Intensification of industries, urbanization and agricultural activities increases soil pollution by potentially toxic elements such as Lead (Pb) and Cadmium (Cd). The availability of these toxic elements in soil results in their absorption and circulation in plant tissues which increases their risk of contamination in the food chain (Arduini *et al*., 2004; Mantovi *et al*., 2003). Contaminated pastures if consumed by ruminants following grazing can lead to deposition of toxic metallic substances in meat, tissues and organs. Taggart *et al*. (2011) reported prevalence of heavy metals in meat from animals that were grazed on pastures close to mining areas.

Following digestion of the contaminated forage in the animal, toxic metals get excreted through faeces and eventually into the environment (Kim, 2012). For this reason, grazing and browsing animals are more prone to toxic metals than other livestock and this may be reflected in the rumen content (Kim, 2012). As such, while using rumen contents in livestock diets, emphasis should be taken to know where the animals were gotten from in order to minimize the risk of toxic elements in forages. Furthermore, efforts should be undertaken to determine the potential of heavy metals accumulation in the undigested rumen content for sustainability in food chain (Demirezen & Uruç, 2006; Loutfy *et al*., 2006).

### 2.5 Sensory evaluation of meat products

Sensory evaluation is a scientific discipline that is used to measure the properties of a product through human senses that includes sight, smell, hearing, taste and touch (Bratcher, 2013; Gengler, 2009; Wadhera & Capaldi-Phillips, 2014). Through the sensory evaluation it is then possible to identify, understand and respond to the consumer's needs and preference more efficiently (Liu *et al*., 2004; Saha *et al*., 2009). The food industry faces increased competition and new opportunities that need to be leveraged on in order to progressively remove trade barriers and expand markets (Cox, 2013). This necessitates quality improvements, extended shelf life, and increased productivity at lower production cost. Sensory analysis of food/meat products becomes part of this agenda. This discipline requires panels of human assessors on whom products are tasted and their responses recorded (Bratcher, 2013). In some instances, human taste senses are used in combination with instrumental techniques (Albrecht *et al*., 2019). Through human senses, people measure appearance, aroma, color, taste and texture using rated scales. Instrumental methods measure physical or chemical characteristics of a product (Solo, 2016). Just like many other analytical methods, sensory analysis face challenges emanating from variability among people used as testing instruments as such, it is important to minimize variability (Bratcher, 2013). Additionally, the instruments that are employed for sensory evaluation do not fully capture full human perception. To make the data more meaningful, there is need to employ both descriptive and consumer sensory panel techniques (Bratcher, 2013).

Descriptive analysis is classified as sensory analytical tests, whereby a panel of 8-12 people are screened and trained to evaluate an array of food products. The panel is used to determine qualitative and quantitative aspects of meat products attribute and the intensity of the attributes, which relates to flavor and texture profiles using reference standards (Civille & Oftedal, 2012; Solo, 2016). A panel of trained people with meat science background concentrate more on texture and flavor because appearance and aroma characteristics are controlled (Bratcher, 2013). Other attributes that are evaluated include, juiciness, muscle fiber tenderness, connective tissue amount, overall tenderness, and flavor intensity (Miller, 1994). A consumer panel comprised of trained and untrained panelists can conduct the consumer preference test and acceptability of a product using qualitative tests such as focus groups and quantitative tests such as preference and acceptance tests (Solo, 2016).

## 2.6 Layers

Laying hens are female chickens which are reared primarily for the purpose of egg production. There are different genetic strains for commercial egg production, despite this, egg laying capability is potentially determined by the quality of the pullets. Therefore, birds should be well managed and provided with feeds of good quality so as to meet the nutritional requirements capable of producing health birds with ideal body weight. A variable number of diets are used in feeding program for laying hens with differing nutrient levels as the bird grows (Mateos *et al*., 2002). However, the nutrients levels in the diets should be tailored specifically to cater for each developmental growth stage. Egg production is also hampered by the deficiency of various feed ingredients. Thus, to meet this severe challenge, the egg industry need to develop a more sustainable way aimed at maximizing production at the lowest possible cost (Godfray *et al*., 2010; Pimentel & Pimentel, 2003).

As the bird grows, its energy requirement decreases and thus addition of dietary fiber at this stage serves the purpose of maintaining low energy in the diets thereby avoiding excess weight gain which can occur through fat deposition. However, it is imperative to note that at tender age, young birds are fed low fiber diets since higher amounts at this stage leads to a decrease in energy ingestion, increase in digesta transit time and a reduction in nutrient digestibility (Mateos *et al*., 2002) thus impairing growth performance of birds.

### 2.6.1 Effects of diets based on rumen contents on layer's growth performance

Layer's diets must be formulated to ensure that proper growth of birds with good health for sustainable good egg production (Bain *et al*., 2016). As such it vital to ensure that pullets are given appropriate diets throughout the entire rearing period. This is because is nutritionally adequate diets enable the birs to attain correct body weight and composition to sustain egg production throughout the laying period. Any deviation from this, compromises growth and mean egg weight (Bouvarel *et al*., 2011). Particular attention and emphasis must be given to protein/energy ration of pullet diet in the 14-16 week, in that consuming feeds that are in excess of protein/ energy requirements enhances fattening score which may lead to negative implications on the laying hen. To minimize the fat deposition, a diet lower in energy should be provided as this partially allows the bird to compensate by increasing feed intake. Work done by Gebrehawariat *et al*.(2016) on use of rumen contents as feed ingredient in White leghorn layers revealed that growth was not compromised at 10% rumen content inclusion levels. More so, dried rumen content (DRC) lead to increased dry matter (DM) intake with increasing rumen contents in the diet. These results however disagreed with that of Esonu *et al*. (2006) who observed increase in growth with increasing levels of rumen contents in the diets.

### 2.6.2 Effects of dietary inclusion of rumen contents on point of lay, eggs characteristics and composition

Diets are known to influence egg characteristics and composition depending on the ingredients used. Reports on use of agro-based products revealed that egg production, egg mass and egg size were reduced when high levels of fiber were included in the diets (Rezaei, 2006). Similarly, feed conversion ratio was poor with increasing concentration of agro-based by-products in the diet. However, the point at which this occurs changes with variation in the fiber, protein, oil content and rancidity of the ingredients in question. Egg nutrients may sometimes negatively affect general egg quality as undesirable fishy flavors has been detected in laid eggs especially, where flax seed meal, rapeseed meal, fish meal has been incorporated in laying hen diets at high levels (Gonzalez-Esquerra & Leeson, 2000). Thus, before diets are commercialized, safety evaluations need to be carried out so that societal and consumer concerns are addressed. Therefore is important to reduce egg defects as the first line of concern inorder to improve egg quality (appearance or flavor/taste). Macro-minerals calcium and phosphorous act as egg shell structure components and thus play essential roles in egg shell formation (Mabe *et al*., 2003). Dietary manipulations should therefore ensure optimal supply of essential nutrients to growing layer hens. Uniformity in the laying pattern was observed following dietary inclusion of rumen contents in the diets (Gebrehawariat *et al*., 2016) indicating better nutrient intake and growth. Similarly, increasing egg weight was observed with increasing levels of rumen contents in the diet signifying nutrient intake and absorption leading to better egg weight. In relation to egg shell thickness, no adverse effect was observed with inclusion of rumen contents in layer diets, implying no dietary calcium and phosphorus metabolism hindrance (Gebrehawariat *et al*., 2016).

### 2.6.3 Effects dietary inclusion of rumen contents on egg yolk pigmentation

Egg quality is well known to be influenced by certain nutrients and dietary feed formulation. Lack of critical nutrients or excesses of nutrients in feeds are responsible for poor quality feeds (Wang *et al*., 2017). Nutrition plays a big role in determining the quality and color of the egg both internally and externally (Cho *et al*., 2012). York color is an important egg quality parameter for consumers (Englmaierová *et al*., 2014) and since laying hens cannot synthesize egg yolk pigments (Karásková *et al*., 2016), feed additives for instance phytogenic, dried carrot meal, dietary corticosterone (Kim *et al*., 2015), have been continuously used to enrich the egg yolk color. However, there has been varying effects on the yolk color in relation to the type and quantity of feed additive used. In most cases, the color of the yolk has been reported to become darker with increasing incorporation of forage crops and byproducts in layer diets, rumen contents too are a result of partial forage digestion with potential of imparting yellow colour to egg yolk (Gebrehawariat *et al*., 2016). The colour change is attributed to the quantity of xanthophyll contained in feed additive (Horsted *et al*., 2006). The use of carrot meal and dietary corticosterone for yolk color enhancement could inevitably impose added costs to the farmer and more so, they may be subject to human competition. Rumen contents too from slaughter houses could serve the same purpose at a cheaper cost as they contain xanthophyll for egg yolk pigmentation. However, rumen contents must be subjected to proper processing and incorporated in feeds at the right proportions.

### 2.6.4 Effect of dietary inclusion of rumen contents on egg, albumen, and yolk weights

Egg weight, albumen and yolk weights are of significant importance in that, they influence egg quality, grading and reproductive fitness of the chicken. The weight of eggs is mainly influenced by dietary metabolizable energy and the size of the yolk and consequently the body weight of the laying birds (Al-Wazeer, 2016). However, despite diets being formulated to same energy and protein levels for laying birds, work done by Gebrehawariat *et al*. (2016) revealed improved egg weights as result of inclusion of rumen contents in layer diets. As the levels of dried rumen contents in diets increased to 15%, there was a concomitant reduction in egg weight with no adverse effects on egg shell thickness, albumen height, albumen and yolk weight.

### 2.6.5 Effects of diets on egg shell quality

Egg shell quality is of great importance as regards to the safety of eggs for human consumption in that a shell with no deformailities provides good strength and resistance to breaking that is is necessary for protection of the egg against invasion by pathogen (Otiang *et al*., 2021). However, in most cases egg shell quality gets compromised as the laying bird ages, as a result of increase in the egg weight with no concomitant increase in calcium bicarbonate deposition in the egg shell. This increases the amount of cracked shells and therefore loss to the farmer. Feed should be formulated in such a way that they provide appropriate mineral and vitamin requirements majorly, calcium, phosphorous and vitamin D3 for proper eggshell formation to safe guard against losses due to eggshell malformation (Jiang *et al*., 2013; Sobczak & Kozłowski, 2015).

### 2.6.6 Effects of diets on growth, egg production curve

Growth is generally defined as the irreversible increase in body weight with time brought about by increase in cell numbers and size. The way an animal responds to particular diets subjected to it is of significant importance due to its practical implications on feeding and management (Anang *et al*., 2017; Narushin & Takma, 2003). The growth curve describe increase in body weight against time, body weight and egg production in poultry usually follows a sigmoid trend with inflection points where the rate of growth is maximum with an upper asymptote (Vitezica *et al*., 2010). Egg production curve is an important indicator of how good or bad management of birds has been conducted over time. Through this curve, a farmer is able to know the pattern of egg produced over time (Savegnago *et al*., 2011). This helps the farmer to make appropriate decisions aimed at improving egg production on a timely basis (Morales *et al*., 2016). However, for this to be effective, there is need for proper record keeping in relation to number of eggs from a poultry house (hen-housed) or the total number of eggs produced to live hens (hen day) at a specific time frame (Narinc *et al*., 2014). As the production increases, the curve also increase and stagnates at peak, thereafter a steady decline occurs which progresses to the end of egg production. The nature of the curve is similar to the lactation curves of dairy cattle and growth curves, however, different models of the egg yield curves can be used depending on the prevailing conditions. Which ever model used, it should represent the individual or herd-based chicken production cycle.

**2.7 Conceptual framework**

The study problem was conceptualized in figure 1 by looking at how livestock farmers utilize rumen contents from slaughter houses in poultry feeding system and how varying levels of goat rumen content in diets affects growth, digestibility, carcass characteristics, quality and sensory attributes in broiler chickens. In layers, dietary goat rumen content inclusion levels was assessed on point of layer, laying percentage, egg characteristics and sensory attributes. The profit arising from use of rumen contents in broiler and layers was compared in order to arrive at appropriate recommendations for effective guidance of poultry farmers.

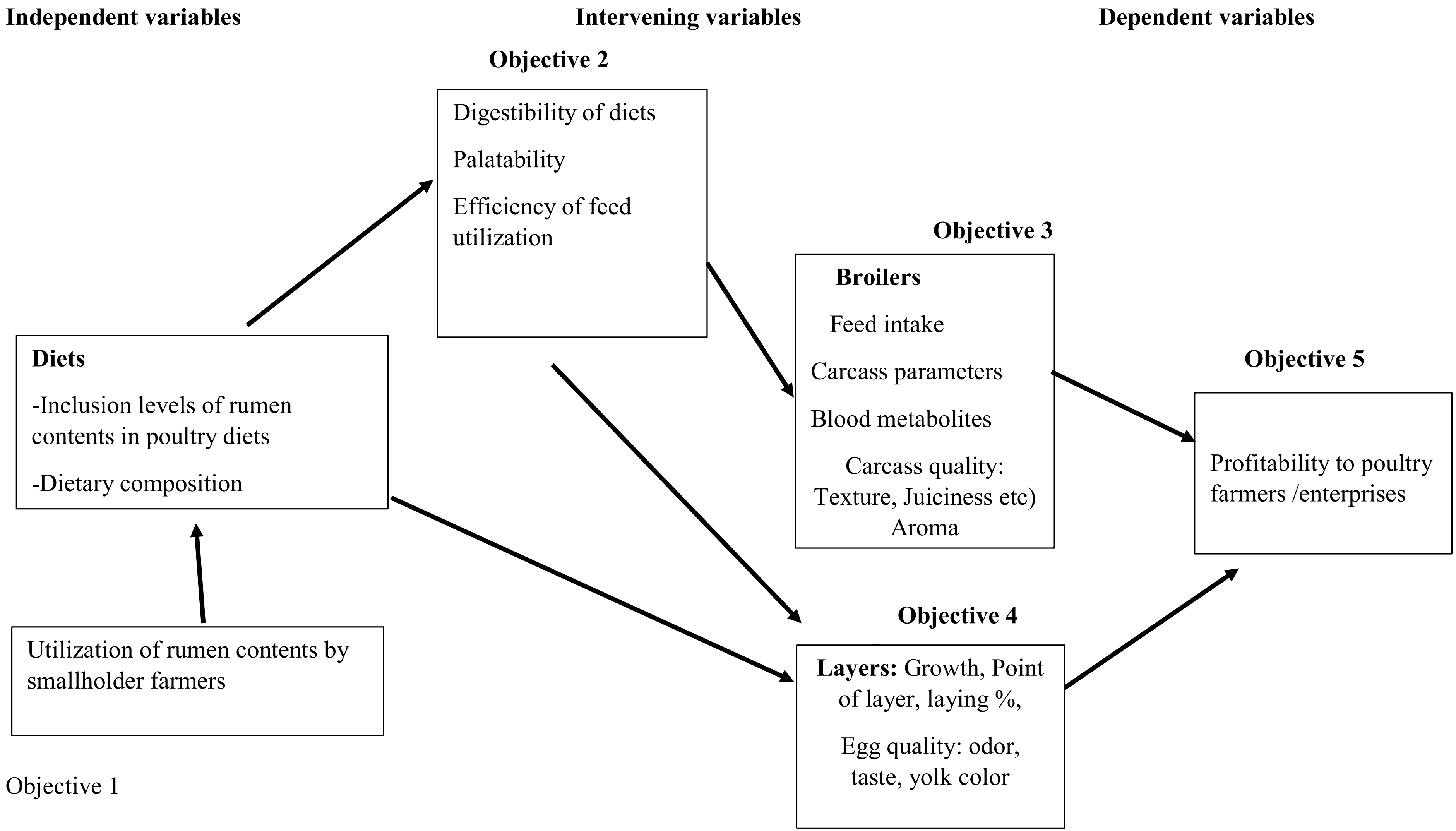



**Figure 1.** Conceptual frame work showing the use rumen contents and implication on poultry production (Own concept).

CHAPTER THREE

MATERIALS AND METHODS

## 3.1 Rumen content utilization in livestock diets

### 3.1.1 Study site

The study was conducted in three Districts (Kampala, Mukono and Wakiso) in central Uganda. Kampala city is located 45 Km north of the Equator at 0°19’6”N and 32°34’60”E (Figure 2). Wakiso District lies approximately 20 kilometers Northwest of Kampala, at 00 24N, 32 29E coordinates, while Mukono district is located 27 Kilometers from Kampla at 00°20′N, 32°45′E. The districts were chosen for the study because of their close proximity to the city center and being the fastest growing peri-urban areas in Uganda.

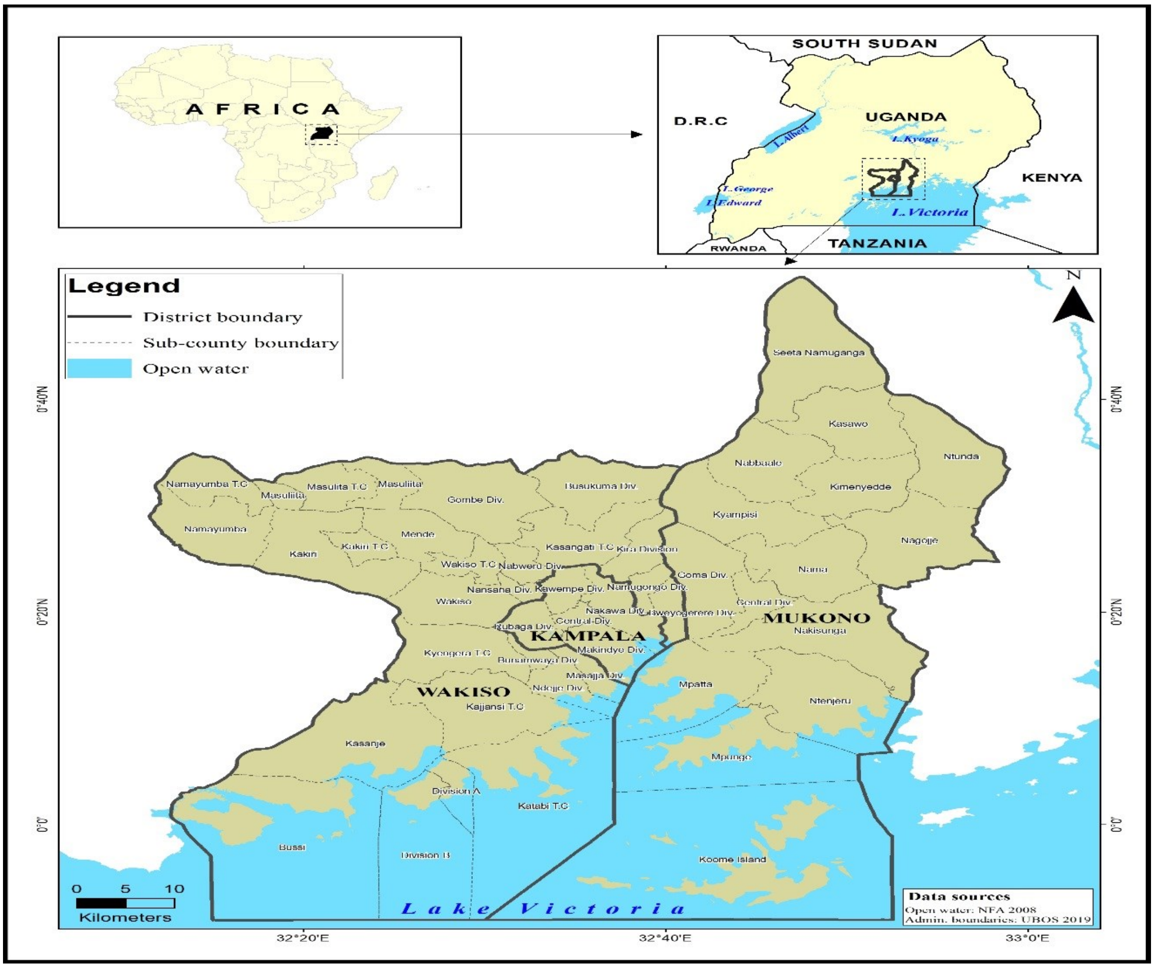



**Figure 2.** Map showing the location of study area, source of the map **(**Ruguma *et al*., 2018**)**.

### 3.1.2 Data collection

Date was collected through interviews targeting respondents who were well informed in relation to farming activities being practiced in the study area (key informants). These included veterinary doctors, health inspectors, abattoir chair persons and elders. The sample size was determined according to formula by (Bixley, 1965).

N= $N/(1+N*(e)2$……………………………………………………………… (i)

Where, n is the sample size, N is the population and e, is the acceptable standard error; e=0.05

The sample size was calculated based on 95% confidence level. Considering a population of about 130 livestock farmers who utilized rumen contents in livestock diets around the Central Districts in Uganda, a total of 100 participants were interviewed.

Data were collected using a structured questionnaire with both open and closed end questions (Questionnaire is attaches in Appendix 1). Qualitative data collected included, sex, marital, education status, feeding and feed resource utilization, potential constraints, use of animal wastes in livestock feeds and other alternative feeding strategies. On the other hand, quantitative data included family size, flock size and proportion of rumen content use in the livestock diets. Focus group discussions were also carried out with key informants in order to get deep understanding of people's feeling about the subject matter.

### 3.1.3 Data analysis

The filled questionnaires were coded and entered in the SPSS version 22 computer software (IBM, 2011). Data on social demographic characteristics of the farmers, challenges faced by the farmers, alternative feeding strategies employed by farmers as a result of higher feed prices, proportion of rumen contents used in livestock diets, contaminants found in rumen contents and kind of advised need by farmers for efficient utilization of rumen contents in livestock diets were analyzed using descriptive statistics. While Chi Square ($X^2$) was used to test the association between use of rumen contents in livestock diets and the type of livestock. If any of the chi square cells was less than 5 then fisher exact test statistics would be performed.

### 3.2 Effects of feeding dried goat rumen content based diets on growth rate, digestibility and carcass characteristics of broilers

#### 3.2.1 Experimental site

The study was conducted at Tatton Agriculture Park, Egerton University, Njoro, Kenya. Tatton Agricultural Park lies on a latitude of 0° 23' South, longitude 35° 35' East and an altitude of 2238 m above sea level and receives a bimodal mean annual rainfall of 1000-1200 mm. Long rains are received between April and August and short rains between October and December. According to Egerton weather station, mean annual temperatures range between 10 and 22°C (Egerton University, Civil and Environmental Engineering Department).

#### 3.2.2 Rumen content collection and processing

Goat rumen contents were collected from Kampala city abattoirs immediately following slaughter. The slaughtered goats were mostly from the Ugandan rangeland areas and therefore on fulltime grazing. Even though, there could be goats brought to the abattoir from peri-urban areas, this was quite a small number with insignificant effect on the targeted quality of rumen contents from rangeland grazed goats. The goats came to the abattoir on trucks along with cattle and sheep. To ensure that only healthy and physiologically normal animals are slaughtered, goats were subjected to ante mortem inspection was subjected to the goats 24 hours prior to slaughter by the abattoir veterinary inspector. Both sides of the goats were observed at rest and in motion for signs of bruises, fractures, cleanliness, nutritional status, disease and abnormalities (swelling, bloated abdomen, hernia). Only goats that passed ante mortem inspection as deemed by the abattoir veterinary inspector were considered for slaughter and rumen content collection. The rumen contents were collected in 200 litre plastic drums during the wet season of September 2018 to January 2019 and March to April 2019, when the pastures were lush and highly nutritious. To avoid mix up of goat rumen content with rumen contents from other livestock slaughtered at the abattoir, drums for collecting rumen contents were placed in a section that handled goat carcass processing and were fully labeled for easy identification. Efforts were also taken not to mix rumen content with other intestinal contents by collecting only contents from the reticulo-rumen chambers. The collected rumen contents were continually checked thoroughly to remove contaminants, this process continued during drying so as to ensure that dried rumen contents were safe and free from foreign materials such as pieces of metals, plastic bags and stones. The rumen contents were sun dried on black polythene bags to ensure maximum absorption of solar heat good enough to expedite not only the drying process but also to destroy pathogens and worms in case they occurred in rumen contents. The drying process took up to 5 days per batch and was characterized by frequent stirring and turning to ensure uniform drying to a moisture content of about 12%. The sun dried material was stored in a clean room. Finally, the sun dried rumen contents were then milled in a hammer mill through a 1.5mm screen to produce a finely ground meal.

### 3.2.3 Proximate analysis

The ground rumen content samples were analyzed for Dry matter (DM), Crude protein (CP), Gross energy (GE), Ether extract (EE), Crude fiber (CF), Organic matter (OM), Calcium (Ca) and Phosphorus (P), (Feldsine *et al*., 2002). Dry matter determination was carried out according to standard procedures (Feldsine *et al*., 2002). Nitrogen was determined by Kjedhal's method (AOAC, 2005, method 968.06) using a CNS-2000 carbon, nitrogen, and sulfur analyzer (Leco Corporation, St. Joseph, MI). The Kjedhal's CP values were determined by multiplying the assayed N values by 6.25. Gross Energy was determined using an adiabatic bomb calorimeter (Gallenkamp, London, UK), standardized with Benzoic acid. Fibertec System M (Tecator, Hoganas, Sweden) was used for NDF and ADF determination. Ether extract (EE) content was determined following the Soxhlet extraction procedure. Calcium (Ca) and phosphorus (P) were determined using an atomic absorption spectrophotometer. Nitrogen free extract (NFE) was calculated by subtracting the sum of % ash, %crude ether extract (EE), % crude fiber (CF) and % crude protein (CP) from 100.

%NFE= $100-(\%Ash+\%CF+\%EE+\%CP)$

### 3.2.4 Amino acid (AA) analysis

Approximately 0.01g of the feed samples were weighed and put in ampoule bottles followed by 10 ml of 6 M HCl. Nitrogen was then pumped into the bottles containing the samples and the bottles corked. Amino acids were released from the protein molecules by acid hydrolysis with 6 M HCl in the oven at 110˚C for 24 h. After hydrolysis, 1ml of the sample was extracted after stirring and put in 1.5 ml eppendoff tubes. The HCl was then evaporated by running the solution through nitrogen till the brownish crystal-like color remained at the bottom of the ependoff tubes. This was followed by adding 1ml of pure sterilized water to the tubes and the samples were stored over night at 4˚C. Pre-column derivatization was carried out using o-phthalaldeyde (OPA) for primary amino acids and 9-fluorenylmethyl chloroformate (FMOC-Cl) for secondary amino acids. The amino acids were separated and quantified using HPLC (1220 Infinity, Agilent Technologies, Santa Clara, CA, USA). Separation was obtained on a

Zorbax Eclipse-AAA (4.6 × 150 mm, 3.5 µm) operating at 40˚C and a flow rate of 2 mL/min. The mobile phase consisted of 40 mM $NaH_2PO_4$ pH 7.8 (A) and acetonitrile: methanol: water (45:45:10, v/v) with gradient elution. A diode-array detector (DAD) and a fluorescence detector were used to detect amino acids with the following parameters: UV: 338 nm for OPA amino acids and 262 nm for the 9-fluorenylmethyloxycarbonyl (FMOC) amino acids; FLD: excitation wavelength/emission wavelength 266/305 nm. Amino acids were quantified following calibration using four standards ranging from 10 nmol/µL to 1 nmol/µL.

### 3.2.5 Dietary formulations

The ingredients used in formulating diets included; broken maize (BM), wheat pollard (WP), soybean meal (SBM), lake shells, Dicalcium phosphate (DCP), fish meal (FSM), common salt, vitamin premix and dried rumen content (Table 1). Dietary treatments were formulated basing on partial fish meal at levels of 0, 5 and 10% as indicated in Table 1. The treatment with 0% dried goat rumen contents was the control.  The experimental diets were iso-caloric (3100 Kcal/Kg) and iso-proteinous (21% CP) and contained equal levels of calcium (Ca), available phosphorus (P), sulphur amino acids, lysine and sodium in line with the dietary nutritional requirement for growing broiler birds (NRC, 2001).

### 3.2.6. Experimental design

The birds were balanced for weight per experimental unit and allotted to dietary treatments following a complete randomized design (CRD) with three replications. Ten (10) birds within a cage formed an experimental unit. The cage size was 150cmx170cm.

Table 1 Dietary composition by proportion

| Ingredients (kg) | Broiler starter | Broiler finisher DT1 | DT2 | DT3 |
|---|---|---|---|---|
| DGRC | 0.00 | 0.00 | 5.00 | 10.00 |
| BM | 60.00 | 59.00 | 67.00 | 68.20 |
| WP | 8.00 | 17.10 | 7.10 | 2.00 |
| FM | 10.00 | 10.00 | 8.00 | 6.00 |
| SBM | 19.80 | 12.00 | 11.00 | 11.90 |
| DCP | 1.20 | 0.90 | 0.90 | 0.90 |
| Lime stone | 0.20 | 0.20 | 0.20 | 0.20 |
| Salt | 0.30 | 0.30 | 0.30 | 0.30 |
| *Vitamin premix | 0.50 | 0.50 | 0.50 | 0.50 |
| **Total/ Kg** | **100** | **100** | **100** | **100** |
| **Calculated (%)** | | | | |
| DM | 87.2 | 89.6 | 89.8 | 90.90 |
| CP | 22.4 | 20.6 | 20.8 | 20.20 |
| Ca | 0.54 | 0.50 | 0.50 | 0.50 |
| P | 0.69 | 0.60 | 0.60 | 0.60 |
| CF | 3.75 | 4.20 | 4.90 | 5.30 |
| ME MJ/Kg | 13.31 | 13.15 | 13.03 | 12.98 |

*To supply Vitamins.A 12000000iu; D3 2500000iu; E 20000mg; K3 2000mg; B1 2000mg; B2 5000mg; B6 4000mg; B12 15mg; Niacin 30000mg; Pantothenic acid 11000mg; Folic acid 1500mg; Biotin 60mg; Choline chloride 220000mg; Antioxidant 1250mg; Mn 50000mg; Zn 40000mg; Fe 20000mg; Cu 3000mg; I 1000mg; Se 200mg; Co 200mg. Note1 DGRC: dried goat rumen contents; BM: broken maize; WP: wheat pollard; SBM: soybean meal; FM: Fish meal; DCP:Dicalcium phosphate; DM: dry matter; CP: crude protein; CF: crude fiber; Ca: calcium; P: phosphorous; ME: metabolisable energy; DT1:0% DGRC; DT2: 5%DGRC DT3: 10%DGRC

### 3.2.7 Management of birds, feeding and performance measurements

Day old broiler chicks (Cobb type) were purchased from Kenchick, a Kenyan company that specializes in poultry related business. The birds were placed in a brooder and the temperature was adjusted up to facilitate adequate warming of the birds. Birds in the brooder were given an adequate space of 530 $cm^2$ that allowed free movement and exercising. The brooding pen was floored and covered with wood shaving to a depth of 6 inches. The wood shavings were kept dry by constant turning with a spade. The brooding temperature in the cages was maintained at 31°C during the first week and then reduced to 24°C by the end of third week. The birds also received 20 hour fluorescent illumination, feed and clean water were given on *ad libitum* basis throughout the experimental period. To prevent occurrence of major diseases, birds were vaccination against Gumboro, Fowl pox and Newcastle on a routine basis in line with veterinary vaccination schedule. In the first week, Newcastle 1 was given by eye drop while in the second and third week gumboro 1 and 2 were administered by eye drop respectively. In the fourth week the birds were given Newcastle 2 La sofa in drinking water. Feeding birds followed a two phase program, starter and finisher diets offered from day 1 to 21 and day 22 to 42 respectively. A common formulated starter diet was given to brooding birds from day 1 to 21 day comprised of 22% CP and 13.3MJ/kg ME. Thereafter, experimental diets were offered to the birds in the finisher stage starting from the 22$^{nd}$ day, this was done so in order to allow time for the birds' caeca to develop to full size capable of handling fiber in the experimental diets The chicks were individually weighed and allocated to nine (9) brooder cages (10 chicks per cage) such that the average bird weight per cage was similar (0.52 ±0.01Kg). Body weight (BW) and feed intake (FI) were taken weekly throughout the experimental period. Mortalities were also recorded whenever they occurred. Average daily gain (ADG) was calculated as the difference between final body weight at the end of the experiment and initial body weight recorded at the start of the experiment/ length of the experimental period in days. Feed conversion ratio (FCR) was calculated by dividing daily feed intake (AFI) by average daily gain (ADG).

### 3.2.8 Digestibility of experimental diets

From the 25$^{th}$ to 29$^{th}$ day, two birds per treatment were removed from the cages and taken to metabolic cages. Water and feed troughs were installed in the cages. Feed offered and refusals were recorded on daily basis. A black polythene bag was placed at the bottom of the cages to enable total collection of feacal collected as voided by the birds. Amount of feed intake and total excreta output were measured per cage over a period of 4 consecutive days. This allowed determination of nutrient retention and apparent metabolisable energy (AME). On the $42^{nd}$ day, 4 birds per treatment per replicate were euthanized by intracardial injection of sodium pentobarbitone and contents of the lower half of the ileum were expressed by gentle flushing with distilled water. Digesta from birds within a cage was piled together resulting in a total of three samples per dietary treatment; the samples were frozen immediately after collection.

### 3.2.9 Sample chemical analysis

The excreta and ileal contents samples were freeze dried. Samples of diets, ileal contents and excreta were ground to pass through a 0.5 mm sieve and stored in airtight plastic containers at −4°C until the time of chemical analyses.

All samples were analyzed for Dry matter (DM), Nitrogen (N), Gross Energy (GE), fat, and Acid Insoluble Ash (AIA). AIA in both feed and fecal samples acted as an internal indicator. Samples of diets and excreta were analyzed for calcium, phosphorus, neutral detergent fiber (NDF), and acid detergent fiber (ADF). Dry matter determination was carried out according to standard procedures (AOAC International, 2005, method 930.15). Nitrogen was determined by the Kjeldah's (AOAC International, 2005) using a CNS-2000 carbon, nitrogen, and sulfur analyzer (Leco Corporation, St. Joseph, MI). The Kjeldah's N (CP) values were determined by multiplying the assayed N values by 6.25. Gross energy was determined using an adiabatic bomb calorimeter (Gallenkamp, London, UK), standardized with benzoic acid. Fibertec System M (Tecator, Hoganas, Sweden) was used for determination of NDF and ADF. Fat content was determined following the Soxhlet extraction procedure. Calcium (Ca) and phosphorus (P) were determined using atomic absorption spectrophotometer.

### 3.2.10 Determination of apparent metabolisable energy and ileal digestibility

Apparent metabolizable energy (AME) values of the diets was calculated from equation;

$$AME\,\frac{MJ}{Kg}feed = \frac{(Feed\ DM\ intake\ x\ GE\ diet) - (Excreta\ DM\ out\ put\ x\ GE\ excreta)}{Feed\ intake\ (DM)xGE\ diet}$$

........................................................................................................ (ii)

Where GE is given in kilocalories per Kilogram, and feed intake and excreta output in kilograms per day. Nitrogen-corrected AME was determined by correction for zero nitrogen retention by multiplication with 8.22 kcal per gram nitrogen retained in the body as described by Hill & Anderson (1958).

The apparent ileal digestibility of DM, nutrients (CP and fat), and GE were calculated following the formula below, acid insoluble ash (AIA) was used as an internal marker and was determined both in the feed and ileal digesta:

$$\text{Apparent ileal digestibility } \% = \frac{\left(\frac{NT}{indicator}\right) diet - \left(\frac{NT}{Indicator}\right) ileal\ digesta}{\left(\frac{NT}{Indicator}\right) diet} x\ 100$$

……………………………………………………………………………………… (iii)

Where, (NT/Indicator) diet = ratio of component and indicator in the diet, and (NT/Indicator) ileal content = ratio of component and indicator in ileal contents. Component can be DM, CP, fat, or GE.

Apparent total tract retention of DM, EE, CP, Calcium, phosphorus, CF were calculated as follows:

$$\text{Retention } \% = \frac{(Feed\ IntakexComponent\ \_diet) - (\text{Excreta out put xComponent\_ excreta})}{(Feed\ IntakexComponent\ \_diet)} x100$$

……………………………………………………………………………………… (iv)

Components are DM, EE, CP, calcium, phosphorus, CF. Feed intake and excreta output are given in kilograms per day and components as a percentage (Adeola *et al*., 2008).

### 3.1.11 Data analysis

The data collected was analyzed using the GLM procedures of SAS Institute (2010) as a completely randomized design (CRD). Treatment effects were determined with orthogonal contrasts arrangement (Stern, 1986). The cage was the experimental unit for all the response criteria. Differences were considered significant at $P \leq 0.05$. Where significant differences between treatments were noted Tukey's test was applied at $P < 0.05$.

### 3.2.12 Carcass characteristics determination

At the 42$^{th}$ day, 4 birds per replicate in a treatment were numbered randomly, selected, weighed, and slaughtered in accordance with the animal welfare law (Anderson, 2005). Prior to slaughter, feed was withdrawn for 12 hr but water provided *ad libitum* in order to empty the digestive tracts. The birds were slaughtered following the cervical dislocation method, then plucked and eviscerated. The organ (liver, spleen, proventriculus, gizzard, duodenum, ileum and jejunum, cecum, large intestines, heart, bursa fabricus, and pancreas) weights were recorded. The warm carcass weight was recorded after bleeding, plucking, removing the head, neck, shanks, abdominal fat, and intestines. Then, the breast, leg (thigh+drumstick), and abdominal fat weights were also recorded. Carcass yield were determined by the weight of the main commercial parts of breast meat (including pectoralis major and pectoralis minor muscles) and the leg (including thigh and drumstick meat) expressed as a percentage of carcass weight.

## 3.4 Determine the effect of inclusion of dried goat rumen content in broiler chicken diets on blood metabolites, carcass composition and acceptability

### 3.4.1 Blood parameters and carcass composition

Prior to slaughter, blood samples were collected from the jugular vein puncture for determination of blood cholesterol (BC), triglyceride and lipoproteins. The blood samples were placed in a tube containing EDTA and properly shaken to prevent coagulation. The blood samples were then taken to the laboratory for analysis. The blood samples were then centrifuged following coagulation at 2,000 rpm, serum was collected and stored −20°C for later analysis. Blood parameters, including red blood cells (RBC) and white blood cells (WBC), haemoglobin (Hb), packed cell volume (PCV), mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH), and mean corpuscular haemoglobin concentrations (MCHC) were measured within 2h post blood collection using a haematology analyser (ABC Vet , ABX Diagnostics, Montpellier, France). While serum concentrations of triglyceride, total cholesterol (TC) and high density lipoprotein (HDL), were measured using analytical kits (Asan Pharm. Co., Ltd. Seoul, Korea). Serum concentration of low density lipoprotein (LDL) cholesterol was determined as described by Lewis (1973). All samples were analyzed simultaneously to eliminate variances due to the storage and handling of samples prepared at different times. To determine MCV, MCH and MCHC the formulars shown below were used;

MCV = (PCVx10)/ (RBC count (in $10^6/mm^3$))

MCH = (Hb g/dl) x 10/ (RBC count (in $10^6/mm^3$))

MCHC= (Hb g/dl) x 100/ (PCV %)

For carcass composition studies, samples with attached skin from breast meat and thigh muscles were dissected, homogenized using a blender and stored in a freezer at −20°C until further analyses. Moisture, dry matter, protein, and ash were analyzed on all meat samples. Ether extract was determined using a soxhlet apparatus with ethyl ether.

### 3.4.2 Carcass composition determination

Samples with attached skin from breast meat, thigh muscles were dissected, homogenized using a blender and stored in a freezer at −20°C until further analyses. Dry matter, CP, ash and EE were analyzed on all meat samples were determined according to procedures described by Feldsine *et al*. (2002).

For water holding capacity (WHC) determination, the breast and leg meat samples were excised and placed in plastic bags; then freely suspended using a steel wire hook and stored at 4°C. Care was taken to minimize the contact between the muscle and the inside surface of the bag. Twenty four hours later, WHC of samples (breast and thigh) was estimated by determining the amount of expressible juice using a modified filter paper press method. A raw meat sample of breast and thigh weighing approximately 1.0 g was placed between 18 pieces of 11-cm-diameter filter paper, which was then pressed at 35 Kg for 6 min. The amount of expressed juice was determined as the weight loss after pressing and presented as a percentage of the initial sample weight.

### 3.4.3 Acceptability of broiler meat to sensory panelists

Broiler meat carcasses were cut into breast and leg quarters, packaged, and stored in a refrigerator at 4ºC until further evaluation (Damaziak *et al*., 2019; Lawlor *et al*., 2003). Twelve broiler carcasses were randomly picked from each treatment for sensory characteristics evaluation.

### 3.4.4 Sensory evaluation

#### 3.4.4.1 Broiler meat sample preparation and determination of sensory quality

Chilled carcasses were aged on ice for 2.5 hr prior to deboning. The chilling of carcasses enabled easy skin removal and also for ease of the deboning process. The cooked samples of the left drum sticks were presented to screened and trained panel of judges for descriptive sensory evaluation. The left drum sticks were chosen for their uniformity and more so, the left tends to be more tender, and juicier due to less activity from the chicken. Descriptive sensory analysis was conducted on the breast and thigh meats.

#### 3.4.4.2 Sample preparation

Chicken meat was deboned, cut in small pieces measuring approximately of 2 x 2 cm, immersed in water in a pot and boiled for 45-60 minutes. Meat from each carcass was cooked separately according to the treatments. The cooked meat pieces were then presented for descriptive sensory analysis. Samples were randomized according to the diet subjected to chicken and then by meat type (breast meat or thigh). Each panelist was presented with 6 pieces on a white sensory evaluation plate labeled with 3-digit blinding codes.

#### 3.4.4.3 Screening of panelists and training

A trained descriptive panel of chicken meat judges comprised of 13-15 members as recommended by sensory spectrum Inc, Chatham, NJ conducted quantitative descriptive analysis (QDA) as described by Stone & Sidel (2004). The panels of judges were trained according to the procedures provided by ISO (1993). In the prescreening testing, judges were trained in areas of developing sensory descriptors and the definition of the sensory attributes in order to distinguish or differentiate the sensations (Boughter & Bachmanov, 2008; Wise *et al*., 2008). All panelists that participated in the sensory study were students of Egerton University. The panelists were trained for three days and the training sessions lasted for 2 hours. In the trainings, panelists discussed the sensory characteristics which enabled them to identify, define and familiarize with the sensory attributes. The panelists identified the sensory attributes for describing appearance, odour, flavor, and texture**.** The trained panels were also familiarised to descriptive textural attributes to evaluate tenderness characteristics of breast and thigh meat. These included, initial hardness, cohesiveness, and moisture release. The moisture release was evaluated in the first bite stage, whereas hardness of mass, cohesiveness of mass, fibrousness, and number of chews to swallow were evaluated in the chew down stage.

On the final day of training, 30 minutes of the 2-hour session were devoted for revisions and development of the final list of sensory attributes. At the end of the last training session, panelists selected the sensory attributes to be used in the study. The definitions of sensory terms as discussed and agreed upon by the panelists is shown in Table 2. The hedonic scale to be used in the study was also discussed during the training sessions and comprehensive vocabulary was selected for the chicken sensory assessment (Carbonell *et al*., 2008; Lawlor *et al*., 2003).

A nine point hedonic scale was used to assess the appropriateness of color 1=none, 9= extremely intense the appropriateness of tenderness (1 = much too tough, 5 = much too tender), the appropriateness of juiciness (1 = much too dry, 9 = much too juicy), and the appropriateness of flavor (1 = much too weak, 9 = much too strong). Off flavor (1= not detected and 9= extremely detected). Panelists were requested to "identify any off-flavors detected, such as rancid, bitter, metallic, or other unique off-flavors."

Table 2 Description of sensory attributes developed by the panelists to evaluate broiler meat

| Attribute | Definitions [1] | Scale |
|---|---|---|
| Color | Surface color of cooked meat | 1=None, 9= Extremely intense |
| Color intensity | Color evenness throughout the meat sample | 1=Light, 9= Dark |
| Flavor | Flavors and aromatics associated with boiled meat | 1=Extremely bland, 9= Extremely intense |
| Fishy smell | Intensity of the fishy smell | 1=None, 9=Extremely intensity |
| Umami | The intensity of Umami test | 1=Low, 9= Extremely intense |
| Bitterness | The intensity of bitterness | 1=None, 9=Extremely intense |
| Sweetness | The intensity of sweetness | 1=None, 9= Extremely sweet |
| Oiliness | The intensity of test of fat or oil | 1=Not oily, 9= Extremely oily |
| Wetness | Amount of moisture on the sample of a meat sample | 1=Not wet, 9=Extremely wet |
| Springiness | Degree to which sample returns to original shape after a certain time period | 1=Not springy, 9=Extremely springy |
| Hardness | Force required to bite through the sample | 1=Tough, 9=Extremely tender |
| Juiciness | Amount of fluid released during the first three chews | 1=Not juicy, 9= Extremely juicy |
| Fibrousness | Degree of visible fibers on the cut side of the sample | 1=Extremely abundant 9= None |
| Chew count | The amount of chewing required to prepare the sample for swallowing | 1=Low count, 9=High count |
| Sustained juiciness | Degree a meat sample maintains the released fluid during chewing | 1=Low 9=High |
| Easy of swallow | How ease it takes to swallow the sample | 1=Not easy, 9= Extremely easy |
| Fatty feel | Intensity of physical greasy sensation in the mouth | 1=None, 9= Extremely fatty |
| Tooth pack | Degree to which meat particles stick on surface of molars | 1=None, 9= Extremely much |

[1]Definitions were suggested and accepted by the panelist.

### 3.4.5 Data Analysis

Data was compiled and computed to determine statistical significance based on the number of correct responses. The effects of DGRC on sensory data was analyzed using analysis of variance (ANOVA) at 5% level of significance. Where the means were significant, mean separation was done using turkey's honest significant difference (HSD). Calculation were done following the statistical analysis system (SAS) version 9.3. Correlations were tested with spearman's rank correlation and coefficient of correlation (k) was computed. Correlation coefficients were ranked as, $k<0.4$; $0.4<k<0.6$ and $k>0.6$ signifying low, medium and high correlations respectively.

### 3.5 Effect of diets based on dried goat rumen contents on point of lay, laying percentage, egg characteristics and acceptability

#### 3.5.1 Study site

The study was conducted at Mukono Zonal Agricultural Research and Development Institute (MUZARDI). MUZARDI is located in the former DFI village, Ntawo parish, Mukono Municipality in Mukono district about 27 Kilometers from Kampala on the northern shores of Lake Victoria at 00°20′N, 32°45′E. The area lies at 1161m above sea level and has a tropical type of climate. The amount of rain falls and temperature received in the area are 1390 mm | 54.7 inch and 21.5 °C | 70.7 °F respectively.

#### 3.5.2 Layer chickens and their management

Three month layer chickens (H&N Brown Nick) were purchased from Biyinzika poultry internal Ltd an established poultry breeding company in Uganda. Prior to purchase of experimental birds, pens, water and feeding troughs, and laying nests in the experimental house were properly cleaned and disinfected using Virkon S disinfectant. The floor of the pens was concrete was covered with coffee husks litter material to a depth of 3inch. A total of 90 hens were used for the study and were identified using numbered wing bands. The experimental hens were weighed and randomly allotted to three treatments in a completely randomized design (CRD). Prior to offering experimental dietary treatments, the birds were fed a common commercial diet and clean drinking provided *ad libitum* to acclimatize them to the new environmental set up. Health precautions and disease control measures were undertaken throughout the study period. Feed was weighed and provided to the birds on a daily basis. Daily feed ration was offered in two equal parts in the morning and afternoon at 08:30 and 14:30 hours respectively. The initial body weight for each replicate was recorded at the beginning of the experiment, and on a weekly basis to determine changes in body weight throughout the entire eight months experimental period.

#### 3.5.3 Experimental diets

The three experimental diets were formulated where fish meal was partially substituted with dried goat rumen content (DGRC) at inclusion levels of 0, 5 and 10% as illustrated in Table 3. The diet (DT1) with 0% substitution was the control. Each treatment consisted of 10 birds with three replicates in a completely randomized design (CRD).

Table 3 Layers dietary composition by proportion

| | Grower's mash | | | Layer's mash | | |
|---|---|---|---|---|---|---|
| **Ingredients** | **DT1** | **DT2** | **DT3** | **DT1** | **DT2** | **DT3** |
| DGRC | 0 | 5 | 10 | 0 | 5 | 10 |
| Broken maize | 27 | 32 | 43 | 49 | 53 | 51 |
| Wheat pollard | 54 | 42 | 26 | 18.5 | 13 | 12 |
| Fish meal | 10 | 8 | 6 | 10 | 8 | 6 |
| Soybean meal | 3 | 7 | 9 | 7.5 | 6 | 6 |
| Lake shells | 3 | 3 | 3 | 12 | 12 | 12 |
| DCP | 2 | 2 | 2 | 2 | 2 | 2 |
| Salt | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| *Vitamin premix | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| **Total/ Kg** | **100** | **100** | **100** | **100** | **100** | **100** |
| **Calculated (%)** | | | | | | |
| Dry matter | 82.44 | 83.13 | 83.95 | 73.73 | 76.85 | 79.76 |
| Crude protein | 18.63 | 18.65 | 17.78 | 16.43 | 16.37 | 16.44 |
| Calcium | 1.441 | 1.47 | 1.50 | 3.51 | 3.54 | 3.50 |
| Phosphorus | 0.74 | 0.91 | 1.07 | 0.78 | 0.93 | 1.08 |
| Crude fiber | 5.814 | 5.956 | 5.846 | 3.773 | 4.328 | 5.06 |
| ME MJ/Kg | 11.92 | 11.83 | 11.67 | 11.52 | 11.31 | 11.13 |
| Cost/kg feed (USD) | 0.37 | 0.36 | 0.35 | 0.36 | 0.35 | 0.34 |

DT1=0% DGRC; DT2=5% DGRC; DT3=10% DGRC;*Premix in the diet provided per kilogram; Vitamins.A 12000000iu; D3 2500000iu; E 20000 mg; K3 2000 mg; B1 2000mg; B2 5000 mg; B6 4000 mg; B12 15mg; Niacin 30000 mg; Pantothenic acid 11000 mg; Folic acid 1500 mg; Biotin 60 mg; Choline chloride 220000 mg; Antioxidant 1250 mg; Mn 50000 mg; Zn 40000 mg; Fe 20000 mg; Cu 3000 mg; I 1000 mg; Se 200 mg; Co 200 mg. Note[1] **DGRC:** dried goat rumen contents; **DCP:** Dicalcium phosphate; **ME:** metabolisable energy; 1USD=3700UGX.

The diets were formulated to meet the requirements for the growing and laying birds as described by NRC (2001). Further, care was exercised to optimize the levels of most essential minerals and Ca:P ratio in the diets.

Samples of DGRC meal were analyzed for the proximate composition according to Feldsine *et al*. (2002). Amino acid (AA) analysis of DGRC was conducted high performance liquid chromatography (HPLC) as described by Rozan *et al*. (2000). The AA analytical procedure is described in detail in section 3.2.4.

**3.5.4 Egg production parameters**

Eggs were collected three times daily for a period of four months and the sum of the daily collections recorded in relation to diets and number of replicates. The hen day egg production (HDEP) and hen house egg production (HHEP) was calculated using the formula given by NRC (2001).

$$\text{HDEP} = \frac{Number\ of\ eggs\ produced\ on\ daily\ basis}{Number\ of\ birds\ available\ in\ the\ flock\ on\ that\ day} x100$$

………………………………………………………………………………………… (v)

$$\text{HHEP} = \frac{Total\ number\ of\ eggs\ produced\ by\ the\ flock}{Total\ number\ of\ hens\ originally\ housed} x100$$

………………………………………………………………………………………… (vi)

**3.5.5 Egg characteristic parameters**

Fifteen eggs laid per treatment were randomly selected from the second and fourth months of lay, weighed daily using an electronic weighing scale, and the average weight recorded. All eggs were stored in a refrigerator (5°C) for 24hours before determining egg quality characteristics. The yolk was separated from the albumen using a table spoon, the remaining albumen on egg yolk were removed by rolling the egg yolk on a blotting paper towel. Weights of egg yolk and albumen were taken using sensitive electronic weighing scale.

#### 3.5.5.1 Egg weight and egg mass

Eggs collected in a day were weighed immediately after collection for each treatment. The average weight of eggs collected per day from each treatment was calculated as weight of all eggs divided by the number of eggs laid. After mean weight had been determined, the formula below was used to calculate the egg mass on daily basis (Bell & Weaver, 2002).

Average egg mass = % Hen-day egg production * Average Egg weight in grams

#### 3.5.5.2 Feed conversion ratio

Feed conversion ratio (FCR) per treatment was determined as a ratio of the total weight of feed consumed on DM basis and egg mass according to the following formula.

FCR= dry matter intake (grams/hen/day)/ average daily gain (grams/hen/day)

#### 3.5.5.3 Yolk color

The color of yolk from every egg of different groups was determined at 28-day interval by first removing the yolk membrane, followed by stirring the yolk thoroughly to mix all parts. Then samples were taken on a piece of white paper and yolk color was determined by by a scale of 1-10 where 1=extremely pale colour and 10= extremely deep intense yellow colour.

#### 3.5.5.4 Egg shell thickness

After placing the entire contents of an egg on the glass slab, the shell pieces were made devoid of shell membranes and measurements were taken from three sites; the top (pointed part), bottom (round part) and the middle of the egg using a vernier caliper. The average of the three measurements was taken as shell thickness of each egg.

#### 3.5.5.5 Yolk index (YI)

It was calculated for five eggs produced in different groups at every 28-day interval. The yolk height was measured using Ames Haugh Unit Spherometer and diameter by Vernier Calipers. The YI was calculated as:

$$\text{YI} = (Yolk\ height\ in\ mm)/(Yolk\ diameter\ in\ mm)\ x100 \ldots\ldots\ldots\ldots \text{(vii)}$$

#### 3.5.5.6 Albumen weight (AW)

This was calculated as the difference between the weight of the whole egg and the weight of the yolk and egg shell. The proportion of the albumen to egg weight was calculated using the formula below;

$Albumen\ \% = (Albumen\ weight\ (g))/(Weight\ of\ the\ whole\ egg\ (g)$x100.... (viii)

### 3.5.6 Egg sensory evaluation

The egg sensory evaluation was carried out by a trained panelist (8-12) aged between 20 and 35 years. A total of 15 eggs per treatment were got for the panel sensory evaluation. Eggs were boiled, cooked and cooled by placing eggs in water. The cooking of the eggs lasted for 8 minutes from the start of boiling. Then, the sauce pan was removed from the stove, and the hot water was discarded and immediately replaced with cold water at room temperature. The eggs stayed in the cold water for about 3 minutes. The eggs were then peeled, cut into quarters and placed on plastic disposable plates. The disposable plates were labelled in relation treatments from which the eggs came from. Prior to the sensory analysis, panelists were asked to not consume any form of food within 3 hrs to the actual testing. Sensory evaluation parameters evaluated were appearance, yolk color, white color, general aroma, general flavor, and texture (Hayat *et al*., 2010). The panelists were instructed on the process of evaluating the parameters like appearance, odor, texture, taste, and acceptance of the sensory quality of eggs (Hayat *et al*., 2010). The parameters were quantified by a nine-point hedonic scale (1 = dislike extremely; 9 = like extremely). The panelists were placed in a room, alone, so as not to influence with the outcome of the others.

### 3.5.7 Data analysis

Growth rate in layers was analyzed by nonlinear regression logistic model (Aggrey, 2002) described below;

$Wt = a/[(1 + bexp - cx)]$.......................................................... (viii)

Where Wt is body weight (BW) at time t, a, is the asymptotic BW, b is the shape parameter, c, is the exponential growth rate, and x is the age at the inflection point. Feed intake, feed conversion ratio and egg characteristic data was subjected to orthogonal contrast analysis using SAS Institute (2010). Sensory data was analyzed using analysis of variance (ANOVA) at 5% level of significance. Where the means were significant, mean separation was done using turkey’s honest significant difference (HSD). Calculation were done following the statistical analysis system (SAS) version 9.3. Correlation between sensory attributes were analysed as explained in section 3.4.5

### 3.6 Partial budget analysis of using dried goat rumen content in broiler and layer diets

The relative cost benefit describes the percentage gain or loss realized by feeding dried goat rumen content (DGRC) based diets to poultry in comparison to the control diet. To evaluate the economic benefit of incorporating DGRC in poultry diets, partial budget analysis was employed according to Upton (1973). The partial budget was calculated as the difference between the feed costs incurred during the experimental periods for broiler and layer with respect to sale of broilers and eggs. The net return (NR) was calculated by subtracting total variable cost (TVC) from total return (TR). The change in net return (ΔNR) was computed by subtracting change in variable cost (ΔTVC) from change in total return (ΔTR). The marginal rate of return (MRR) quantifies the increase in net return associated with each additional unit of expenditure. This was expressed by percentage as:

$$MRR\% = (\Delta TR/\Delta TVC) \times 100$$

The feed costs were calculated based on the market price of each ingredient and percent of inclusion. Feed consumed by the birds per treatment was multiplied by the cost /kilogram feed to obtain total feed costs. The cost of dried goat rumen contents (DGRC) included cost of collection, drying, transportation and milling costs. The current market prices of broilers, layers and eggs were considered during the experimental period as total return.

# CHAPTER FOUR
# RESULTS

## 4.1 Extent of use of rumen contents in livestock diets among farmers

### 4.1.1 Demographic characteristics of the respondents

The results of demographic characteristics of the respondents are shown in Table 4.

The results show that majority of the work force involved in livestock farming are aged between 31-45 and 20-30 years contributing 37 and 26 % of total work force respectively. The young (10-20yrs) and old people (61-90 yrs) contributed 2 and 6% of the labor force respectively.

In this study, 89% of the people working in livestock farming operations were married. The single (not married), the divorced and widowed contributed 5, 1 and 3% respectively in the livestock farming operations.

In relation to family structure, 51% of the work force in livestock farming operations was contributed by the fathers while mothers contributed 46%.

House hold (HH) size was grouped into three categories, small (1-4) people, medium (5-10) and large (>10) people. The small, medium and large size HH categories accounted for 68, 23 and 8% respectively. In relation to education level about 68% of the respondents had attained secondary education and above. People who did not go to school and those who attained primary level education were 5 and 24 % respectively.

Table 4 Distribution of respondent's demographic characteristics

| | Livestock farmers (n=100) | |
|---|---|---|
| | Frequency | Percentage |
| **Age (years)*** | | |
| 10-20 | 2.0 | 2.0 |
| 21-30 | 26.0 | 26.0 |
| 31-45 | 37.0 | 37.0 |
| 46-60 | 25.0 | 25.0 |
| 61-90 | 6.0 | 6.0 |
| **Position in family*** | | |
| Head | 51.0 | 51.0 |
| Mother | 46.0 | 46.0 |
| Son | 2.0 | 2.0 |
| Daughter | 1.0 | 1 |
| **Marital status*** | | |
| Single | 5.0 | 5.0 |
| Married | 89.0 | 89.0 |
| Divorced | 1.0 | 1.0 |
| Widowed | 3.0 | 3.0 |
| **House hold size*** | | |
| 1-4 | 68.0 | 68.0 |
| 5-10 | 23.0 | 23.0 |
| >10 | 8.0 | 8.0 |
| **Education level*** | | |
| None | 5.0 | 5.0 |
| Primary | 24.0 | 24.0 |
| Secondary | 48.0 | 48.0 |
| Advanced level | 10.0 | 10.0 |
| University | 10.0 | 10.0 |

*The percentages don't sum up to 100% because other respondents left some questions blank

### 4.1.2 Animal types kept by the farmers

Table 5 shows animals kept by the farmers. Indigenous chicken was predominantly available and most practiced type of chicken farming among households. Dairy farming was the second practiced enterprise by the respondents.

Table 5 Animals kept among livestock farmers

| Animal Type | n | Minimum | Maximum | Mean | SEM |
|---|---|---|---|---|---|
| Dairy | 43 | 1 | 20 | 3.28 | 0.48 |
| Sheep and goats | 36 | 1 | 10 | 4.25 | 0.41 |
| Layers | 33 | 300 | 10000 | 1780.30 | 496.88 |
| Broilers | 25 | 100 | 5000 | 724.00 | 190.18 |
| Pigs | 33 | 1 | 100 | 9.70 | 2.98 |
| Indigenous chicken | 46 | 1 | 100 | 17.46 | 2.64 |

SEM: Standard error of the mean; n: number of animals kept

### 4.1.3 Challenges faced by farmers

Farmers were faced with numerous challenges that hindered their smooth operations at the farm level (Table 6). High input prices (feeds, veterinary drugs) was the major problem faced by the farmers, this was followed by feeed adulteration, feed scarcity low and limited land.

Table 6 Problems faced by the farmers

| Parameters | Frequency | Percentage* |
|---|---|---|
| Limited land | 10 | 10.0 |
| Scarcity of feeds | 34 | 34.0 |
| High prices of inputs | 67 | 67.0 |
| Adulteration | 44 | 44.0 |
| Drought | 32 | 32.0 |
| Limited water supply | 8 | 8.0 |

*Percentage more than 100 because farmers stated more than one problem

### 4.1.4 Alternative feeding strategies used by farmers

Farmers employed various copping strategies that enabled them to remain viable in their farmig operations as revealed in Table 7.

Table 7 Alternative feeding strategies employed in livestock feeding

| Strategy | Frequency | Percentage* |
| --- | --- | --- |
| Peels | 44 | 44.0 |
| Forages | 21 | 21.0 |
| Concentrates | 21 | 21.0 |
| Industrial by products | 34 | 34.0 |
| Food left overs | 23 | 23.0 |
| Others | 28 | 28.0 |

*Percentage more than 100 because farmers stated more than one feeding strategy used

Use of peelings (banana, sweet potato and cassava), industrial by products, others, food left overs, forages and concentrates were used by 44, 34, 28, 23 and 21% of the farmers respectively.

### 4.1.5 Use of rumen content in livestock diets

The percentage of farmers who utilized rumen contents as a feed ingredient in livestock production is shown in Table 8. There was a statistically significant association between type of livestock and use of rumen contents in livestock diets ($X^2$=75.67, $P<0.05$). Rumen contents (RC) were mostly utized in pig production than in poultry production by 29 and 20% of the farmers respectively. Use of rumen contents in indigenous chickens was not a common practice among respondents. No farmer used RC in broiler production.

Table 8 Use of rumen contents in livestock diets

| Livestock | Use (%) | Don't use (%) | Chi Square ($X^2$) | P-value |
|---|---|---|---|---|
| Pigs | $29^a$ | $71^c$ | 75.67 | <0.0001* |
| Layers | $20^b$ | $80^b$ | | |
| Broilers | $0^c$ | $100^a$ | | |
| Indigenous chicken | $1^c$ | $99^a$ | | |
| Others | $2^c$ | $98^a$ | | |

*abcd superscripts indicate significant differences (P<0.05).

### 4.1.6 Degree of use of rumen contents in the study area

Farmers used rumen contents in varying proportions among the study areas as shown in Table 9. The percentage of farmers who used rumen contents in livestock diets in Kampala, Wakiso and Mukono districts was 47.4, 42.1 and 10.5 % respectively.

Table 9 Use of rumen contents in the study area

| Kampala | Mukono | Wakiso | P-value |
|---|---|---|---|
| n (%) | n (%) | n (%) | 0.0001 |
| 18(47.4) | 4(10.5) | 16(42.1) | |

### 4.1.7 Proportion of rumen contents use in different livestock

Figure 3 illustrates the degree of rumen content use in livestock diets. Overall, rumen contents were mostly used in pig dietary formulations than in layers diets. In layers diets, most of the respondents (85.8%) used rumen contents at 20% inclusion level. In pig diets, a big percentage of respondnts (77.4%) were incapable of quantify the amount of rumen contents used.

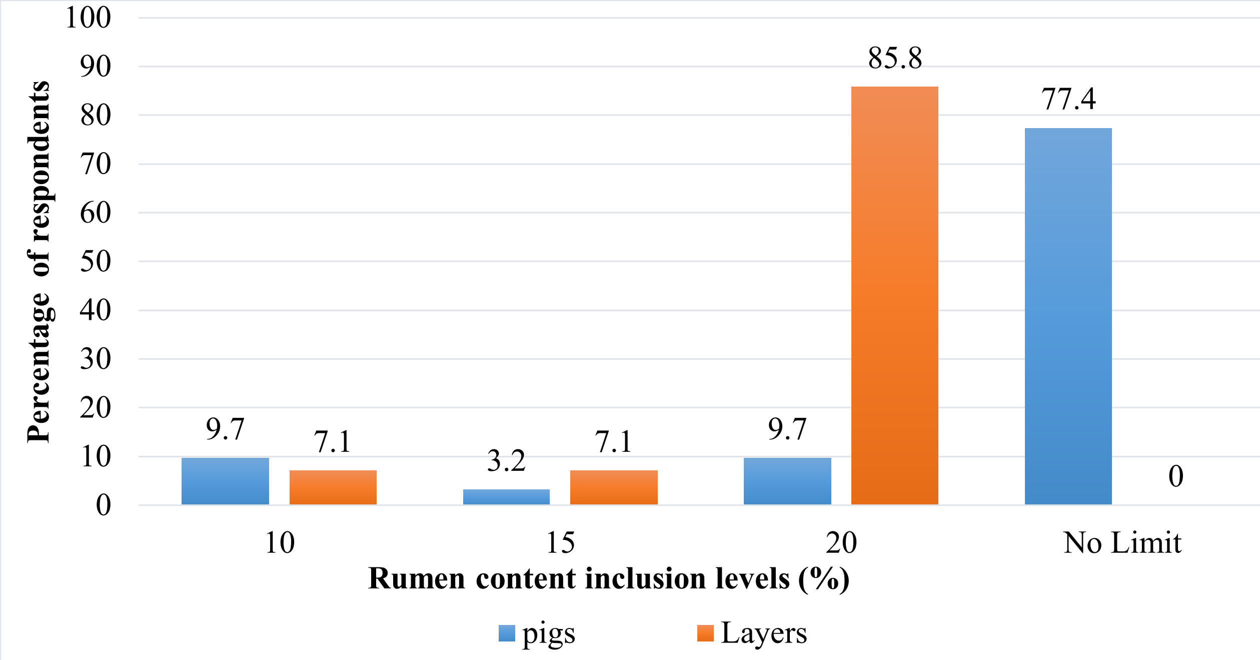



**Figure 3.** Extent of rumen content use pig and layer rations

### 4.1.8 Benefits realized by the farmers with use of rumen content in livestock diets

Use of rumen contents elicited several beneifits to the farmers in pigs and layers as shown in Table 10.

Table 10 Benefits realized by the farmers with use of rumen contents in livestock diets

| Pigs | Layers |
|---|---|
| Increased pig growth | Good chicken growth |
| Reduced feed costs | Yellow yolk |
| | Reduced feed costs |

### 4.1.9 Problems encountered with use of rumen contents

Challenges faced by farmers with use of rumen contents in livestock feeding are shown in Figure 4. Inadequate knowledge on appropriate inclusion levels of rumen contents in the diets for livestock was the major challenge faced by the farmers, this was accompanied by drying challenges and bad smell while rumen content contaminants was the least among the challenge encountered.

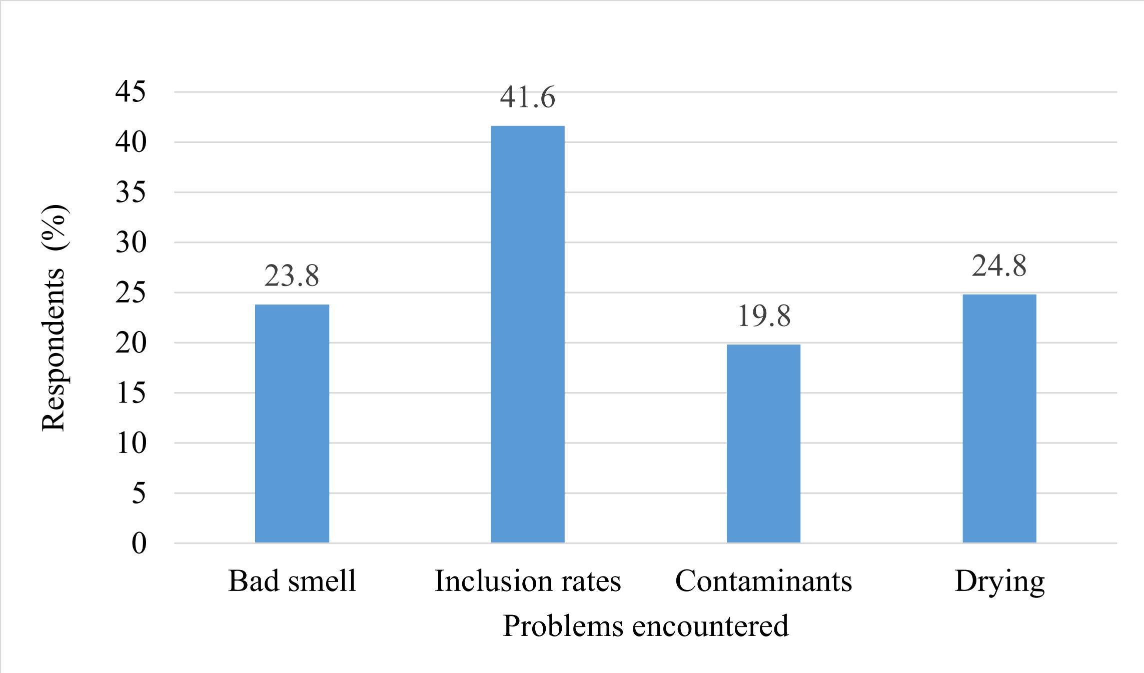



**Figure 4.** Problems encountered with use of rumen contents

### 4.1.10 Contaminants found in rumen contents

Respondents stated a number of contaminants found in rumen contents while processing it into animal feeds as shown in Table 11. Polythene bags were reported the biggest contaminants found in slaughter wastes. However, polythene bags were more pronounced in cattle rumen contents than in goat and sheep. Prevalence of metals and rags was more reported in goat rumen contents in sheep rumen and cattle.

Table 11 Contaminants found in rumen contents

| Contaminants (%) * | Cattle | Goats | Sheep |
|---|---|---|---|
| Polythene bags | 51 | 30 | 11 |
| Metals | 26 | 34 | 5 |
| Rags | 3 | 15 | 13 |
| Other | 10 | 2 | 23 |

*Percentage not equal 100 because some respondents left questions unanswered

### 4.1.11 Advice farmers needed for efficient utilization of rumen contents in livestock diets

In order to promote efffecient use of rumen content diets for livestock, farmers needed advice in several areas as shown in Figure 5. Over all, most farmers needed advice on pig ration formulation, followed by advice on poultry feed formulation.

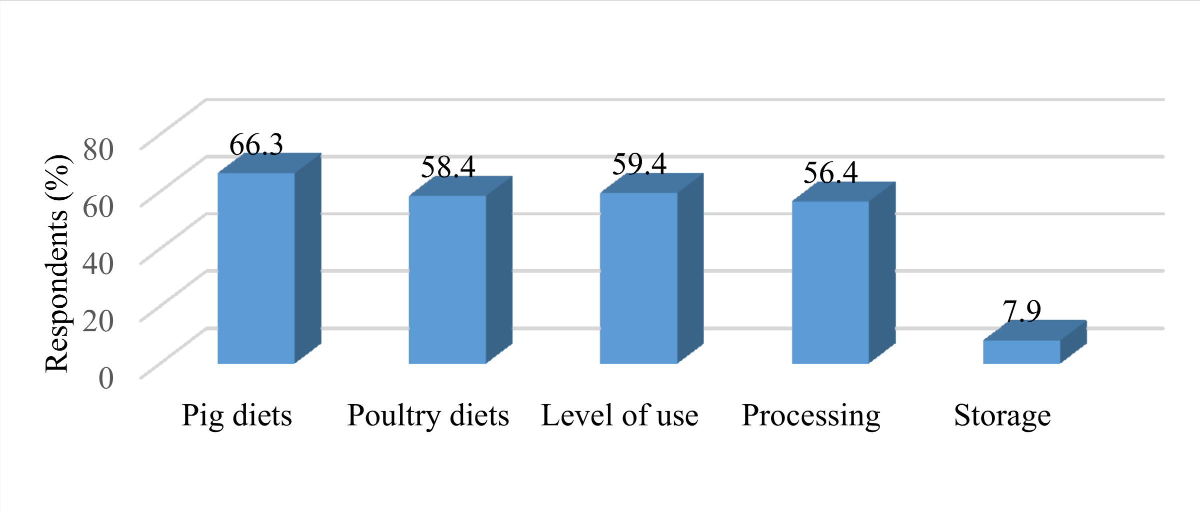



**Figure 5.** Kind of advice needed by the farmers

The kind of advice needed included, level of rumen content inclusion in the rations, rumen content processing methods and its storage in their order of importance

## 4.2. Effects of inclusion of dried goat rumen contents in broiler chicken diets on growth, blood metabolites, carcass parameters and consumer acceptability

### 4.2.1 Chemical analysis of feed ingredients and experimental diets

Table 12 and 13 show the results of the laboratory analyses of the feed ingredients and experimental diets respectively.

Table 12 Chemical composition of feed ingredients used in experimental dietary formulations

| (%) | BM | WP | SBM | FM | DGRC |
|---|---|---|---|---|---|
| Dry matter | 89.51 | 86.00 | 89.23 | 93.10 | 97.3 |
| Crude protein | 10.64 | 16.61 | 44.41 | 58.21 | 16.2 |
| Crude fiber | 1.95 | 7.43 | 3.51 | 12.01 | 20.7 |
| Calcium | 0.01 | 0.001 | 0.20 | 2.97 | 1.70 |
| Phosphorus | 0.23 | 0.06 | 0.65 | 2.62 | 3.80 |
| ME MJ/Kg* | 14.24 | 12.15 | 11.73 | 13.78 | 4.98 |
| **Amino acid profile (m mol/L)** | | | | | |
| Ala | 0.13 | 0.10 | 0.12 | 0.18 | 0.09 |
| Arg | 0.11 | 0.07 | 0.07 | 0.10 | 0.09 |
| Asn | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Asp | 0.16 | 0.14 | 0.18 | 0.18 | 0.18 |
| Gln | 0.01 | 0.00 | 0.00 | 0.01 | 0.00 |
| Glu | 0.27 | 0.08 | 0.15 | 0.27 | 0.06 |
| Gly | 0.12 | 0.07 | 0.04 | 0.12 | 0.05 |
| His | 0.00 | 0.02 | 0.02 | 0.00 | 0.02 |
| Ile | 1.98 | 1.81 | 1.86 | 2.01 | 1.76 |
| Leu | 0.09 | 0.03 | 0.07 | 0.12 | 0.00 |
| Lys | 0.11 | 0.06 | 0.09 | 0.15 | 0.07 |
| Met | 0.09 | 0.07 | 0.04 | 0.15 | 0.06 |
| Phe | 0.03 | 0.03 | 0.03 | 0.05 | 0.03 |
| Ser | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Thr | 0.11 | 0.07 | 0.00 | 0.14 | 0.03 |
| Trp | 0.05 | 0.05 | 0.03 | 0.05 | 0.05 |
| Tyr | 0.09 | 0.09 | 0.09 | 0.09 | 0.09 |
| Val | 0.12 | 0.09 | 0.11 | 0.15 | 0.09 |
| Total AA | 3.47 | 2.77 | 2.90 | 3.79 | 2.66 |

Note[1] BM: broken maize; WP: wheat pollard; SB: soybean meal; FM: Fish meal; DGRC: dried goat rumen contents; ME: metabolisable energy; AA: Amino acids Ala: Alanine; Arg: Arginine; Asn: Asparagine; Asp: Aspartic acid; Gln: Glutamine; Glu:Glutamic acid; Gly:Glycine; His:Histidine ; Ile: Isoleucine; Leu: Leucine; Lys: Lysine; Met: Methionine; Phe:

Phenylalanine; Ser: Serine; Thr: Threonine; Trp: Tryptophan; Tyr: Tyrosine; Val: Valine ; *ME is based on calculated values.

Lower crude protein (CP) and Metabolisable energy (ME) was recorded withn dried goat rumen contents (DGRC) in comparison to the rest of the ingredients. Despite this, DGRC registered higher in crude fiber (CF) and Phosphorus (P) content. In relation to amino acid (AA) profile, DGRC amino acid content was comparable to wheat pollard (WP). Over all, total amino acids (TAA) were higher for fish meal (FM) followed by broken maize (BM).

### 4.2.2 Chemical composition of experimental diets

Laboratory analysis of dietary treatments is shown in Table 13

Table 13 Analyzed chemical composition of the experimental diets

| | Dietary composition | | |
|---|---|---|---|
| **Parameters** | **DT1** | **DT2** | **DT3** |
| DM% | 89.73 ±0.26 | 87.11± 0.26 | 87.99 ±0.26 |
| CP% | 21.01 ±3.14 | 21.99± 3.14 | 21.11 ±3.14 |
| EE% | 7.00 ±0.01 | 8.00±0.01 | 8.00± 0.01 |
| CF% | 2.9 ±0.02 | 3.50 ±0.02 | 4.50 ±0.02 |
| Ash% | 5.25 ±0.22 | 5.05 ±0.22 | 4.77± 0.22 |
| Ca% | 1.98 ±0.07 | 1.90±0.07 | 1.80±0.07 |
| P% | 0.45 ±0.04 | 0.47 ±0.04 | 0.49± 0.04 |
| NFE% | 64.74 ±1.74 | 61.20 ± 1.74 | 66.56 ± 1.74 |
| ME MJ/Kg | 13.71±0.03 | 13.57 ± 0.03 | 13.55 ± 0.03 |

DM: dry matter; CP: crude protein; CF: crude fiber; NDF: EE: ether extract; Ca: calcium; P: phosphorous; NFE Neutral free extract; ME: metabolisable energy. DT1=0%DGRC; DT2=5%DGRC; DT3=10%DGRC; Values presented in means and standard error of means (Means ±SE)

In this study, dry matter (DM), crude protein (CP) and ether extract (EE) were similar across diets. However, there was a little variation in dietary crude fiber (CF) across treatments with increase in DGRC inclusion levels. Despite the slight disparities in the CF content of the diets, CF of the diets was within the range (2-5%) for optimum broiler performance as reported by

NRC, (2001). Metabolizable Energy (ME) of the dietary treatments ranged between 13.19-13.40 MJ/Kg feed.

### 4.2.3 Apparent and ileal nutrient digestibility of broiler diets

Table 14 shows results of apparent and ileal nutrient digestibility in broilers across dietary treatments. From the results it is shown that, inclusion of dried goat rumen contents (DGRC) levels in broiler diets had significant ($P<0.05$) effects on apparent and ileal digestibility in broiler chickens. Birds fed on dietary treatment that contained 5% DGRC levels had highest apparent digestibility coefficients (Linear, Quadratic $P<0.05$) for DM, CP, CF, EE, Ca, Ash and NFE. This was followed by birds fed diets with 10% DGRC levels, however, with the exception P and ME digestibility which were comparable. The diet where no DGRC was added, registered the lowest apparent digestibility in those parameters in comparison with the experimental diets with DGRC. In general, there was an increasing trend in apparent digestibility coefficients of nutrients for all studied at 5% DGRC dietary inclusion level. However, at 10% DGRC level in the diet, led to decrease in digestibility of nutrients with expection of P and ME. Aditionally, the results revealed that, birds on 5% DGRC diets had the highest ileal digestibility whereas those on diets with 10% DGRC inclusion level had lowest ileal digestibility for DM, CP, CF, EE, Ca and NFE.

Table 14 Apparent Nutrient and ileal digestibility of diets containing DGRC in broilers

| Parameters | Diet 1 | Diet 2 | Diet 3 | SEM | P-value | |
|---|---|---|---|---|---|---|
| | | | | | Linear | Quadratic |
| Apparent nutrient digestibility | | | | | | |
| DM | 71.27$^{a}$ | 93.92$^{c}$ | 85.12$^{b}$ | 0.93 | 0.0018 | 0.0008 |
| CP | 60.31$^{b}$ | 89.67$^{a}$ | 85.29$^{a}$ | 3.97 | 0.0213 | 0.0406 |
| CF | 59.14$^{a}$ | 71.80$^{c}$ | 67.82$^{b}$ | 0.76 | 0.0039 | 0.0029 |
| EE | 64.34$^{a}$ | 87.42$^{c}$ | 77.60$^{b}$ | 0.86 | 0.0017 | 0.0006 |
| Ca | 74.04$^{a}$ | 86.72$^{c}$ | 80.12$^{b}$ | 0.82 | 0.0137 | 0.0024 |
| P | 69.44$^{a}$ | 75.53$^{b}$ | 74.92$^{b}$ | 0.77 | 0.0154 | 0.0388 |
| Ash | 60.35$^{a}$ | 82.35$^{b}$ | 78.61$^{b}$ | 0.92 | 0.0008 | 0.0014 |
| NFE | 82.24$^{a}$ | 89.97$^{c}$ | 86.06$^{b}$ | 0.42 | 0.0075 | 0.0015 |
| ME | 78.89$^{a}$ | 92.22$^{b}$ | 81.31$^{b}$ | 1.33 | 0.2894 | 0.0051 |
| Apparent ileal digestibility | | | | | | |
| DM | 79.94$^{b}$ | 91.22$^{b}$ | 68.22$^{a}$ | 3.86 | 0.1215 | 0.0362 |
| CP | 79.17$^{b}$ | 91.85$^{c}$ | 68.26$^{a}$ | 1.53 | 0.0152 | 0.0024 |
| CF | 65.23$^{a}$ | 90.37$^{c}$ | 76.48$^{b}$ | 0.87 | 0.0028 | 0.0004 |
| EE | 70.02$^{b}$ | 79.42$^{b}$ | 67.60$^{a}$ | 1.19 | 0.2461 | 0.0054 |
| Ca | 76.69$^{b}$ | 92.56$^{c}$ | 61.25$^{a}$ | 1.13 | 0.0023 | 0.0004 |
| P | 77.68$^{b}$ | 77.83$^{b}$ | 62.06$^{a}$ | 1.38 | 0.0041 | 0.0183 |
| Ash | 71.05$^{a}$ | 83.57$^{b}$ | 72.47$^{a}$ | 2.94 | 0.7555 | 0.0466 |
| NFE | 76.41$^{b}$ | 78.22$^{b}$ | 69.86$^{a}$ | 1.19 | 0.0304 | 0.0404 |
| ME | 81.13$^{b}$ | 83.35$^{b}$ | 72.00$^{a}$ | 4.08 | 0.2124 | 0.2683 |

$^{abc}$ Means with different superscript within row differ significantly ($P<0.05$). DT1=0%DGRC; DT2=5%DGRC; DT3=10%DGRC; DM: dry matter; CP: crude protein; CF: crude fiber; EE: ether extract; NFE: Nitrogen free extract; Ca: calcium; P: phosphorous; ME: metabolisable energy; SEM: Standard error of the mean

### 4.2.4 Performance of broiler chicken fed dried goat rumen content based diets

Performance of broiler chickens fed diets incorporated with dried goat rumen contents is show in Table 15. Incorporation of dried goat rumen contents in broiler diets resulted in improved growth performance of birds. Birds fed on diets with 5% dried goat rumen content (DGRC) had a significantly higher average final body weight (Linear, Quadratic P<0.05) and average daily gain (ADG) (Quadratic, P<0.05) at relatively lower average daily feed intake (ADFI) than the diet with 0% DGRC.

Table 15 Performance of broiler chickens fed diets with dried goat rumen contents

| | Level of DGRC | | | | P-value | |
|---|---|---|---|---|---|---|
| Parameters (n=90) | DT1 | DT2 | DT3 | SEM | Linear | Quadratic |
| AIBW (Kg/bird/day) | 0.52 | 0.52 | 0.52 | 0.01 | 0.9601 | 0.9080 |
| AFBW (Kg/bird/day) | $1.59^{a}$ | $1.84^{c}$ | $1.64^{b}$ | 0.02 | 0.0031 | <0.0001 |
| ADFI (g/bird/day) | $115.81^{c}$ | $88.94^{b}$ | $87.40^{b}$ | 0.45 | <.0001 | <0.0001 |
| ADG (g/bird/day) | $52.76^{b}$ | $60.08^{c}$ | $52.29^{a}$ | 0.23 | 0.1636 | <0.0001 |
| FCR | $2.19^{c}$ | $1.49^{a}$ | $1.67^{b}$ | 0.05 | <.0001 | <0.0001 |
| Mortalities (%) | 0 | 0 | 0 | 0 | | |

[abc]Means with different supper scripts within row differ significantly (P>0.05); DGRC dried goat rumen content;DT1=0% DGRC; DT2=5% DGRC; DT3=10% DGRC; AIBW average initial body weight; AFBW average final body weight; ADFI average daily feed intake; ADG average daily gain; FCR feed conversion ratio SEM standard error of the mean

The feed conversion ratio (FCR) was significantly lower (Linear, Quadratic, P<0.05) for the birds fed on diets containing 5% DGRC diets than birds on 0 and 10% DGRC diets. Average daily feed intake (ADFI) was significantly higher (Linear, Quadratic P<0.05) for birds fed on diet with 0% dried goat rumen content (DGRC) than birds on 5% and 10% DGRC diets. However, as the level of DGRC increased in the diet, average daily feed intake (ADFI) of birds decreased. Despite the higher average daily feed intake (ADFI) exhibited by the birds fed on diet containing 0% dried goat rumen content (DGRC) inclusion level, the birds had lower average daily gains (ADG). DGRC incorporation in the experimental diets was accepted with varying degrees by the birds across the two treatments (5% and 10%) inclusion levels. No mortality was recorded among birds across the three dietary treatments.

### 4.2.5 Effects of diets based on dried goat rumen content on carcass and organ characteristics of broiler chickens

Carcass and organ characteristics of broiler chicken as affected by inclusion of dried goat rumen contents (DGRC) in the diets is shown in Table 16.

Hot carcass weight and carcass yield were significantly higher for the birds fed on diets with 5% DGRC inclusion levels (Linear, Quadratic $P<0.05$). Wings, legs, breast and abdominal fat weights were significantly ($P<0.05$) higher for birds fed on 5% level of DGRC diet than birds on 0 and 10% % DGRC diets. In relation to internal organ characteristics, liver, proventiculus weight and length were significantly (Quadratic $P<0.05$) higher for the birds fed on 5% DGRC diet than birds on 10% and 0% DGRC diets. Average weight of gizzard, ceacum, heart, spleen and duodenum increased significantly (Quadratic $P<0.05$) in response to increased levels of DGRC in the diets.

In general, as the level of dried goat rumen contents (DGRC) incorporation in the diet increased, there was an increase in organ weights of the birds.

Table 16 Carcass and organ characteristics of broiler chickens fed on diets with graded levels of dried goat rumen contents (DGRC)

| | Level of DGRC | | | | P-value | |
|---|---|---|---|---|---|---|
| Parameters (n=36) | DT1 | DT2 | DT3 | SEM | Linear | Quadratic |
| Carcass (Kg) | 1.12$^{a}$ | 1.27$^{c}$ | 1.07$^{a}$ | 0.02 | 0.0497 | <0.0001 |
| Carcass yield* (%) | 63.63$^{a}$ | 65.17$^{c}$ | 64.39$^{b}$ | 0.14 | 0.0005 | <0.0001 |
| Wing (g) | 215.15$^{a}$ | 235.92$^{b}$ | 215.75$^{a}$ | 0.59 | 0.4843 | <0.0001 |
| Shank (cm) | 8.11$^{b}$ | 8.04$^{b}$ | 7.93$^{a}$ | 0.03 | 0.0001 | 0.6416 |
| Leg (g)* | 345.26$^{b}$ | 372.50$^{c}$ | 333.42$^{a}$ | 14.12 | 0.0234 | <0.0001 |
| Leg (cm)* | 14.65$^{a}$ | 15.62$^{b}$ | 14.82$^{a}$ | 0.12 | 0.3349 | <0.0001 |
| Breast (g) | 283.25$^{a}$ | 341.66$^{b}$ | 284.58$^{a}$ | 6.38 | 0.8834 | <0.0001 |
| Breast (cm) | 14.29$^{a}$ | 15.23$^{c}$ | 14.74$^{b}$ | 0.101 | 0.0036 | <0.0001 |
| Abdo. fat *(g) | 22.8$^{a}$ | 36.25$^{c}$ | 27.46$^{b}$ | 0.29 | <0.0001 | <0.0001 |
| Trunk (cm) | 18.31$^{b}$ | 19.69$^{c}$ | 18.81$^{b}$ | 0.14 | 0.0203 | <0.0001 |
| Internal organs | | | | | | |
| Liver (g) | 28.40$^{a}$ | 31.91$^{b}$ | 29.14$^{a}$ | 0.32 | 0.1076 | <0.0001 |
| Proventric* (g) | 9.37$^{a}$ | 10.53$^{c}$ | 10.04$^{b}$ | 0.11 | 0.0002 | <0.0001 |
| Proventriculus** | 4.36$^{a}$ | 4.86$^{b}$ | 4.54$^{a}$ | 0.06 | 0.0567 | <0.0001 |
| Gizzard(g) | 54.41$^{a}$ | 54.58$^{a}$ | 56.91$^{b}$ | 0.22 | <0.0001 | <0.0001 |
| Duodenum (cm) | 30.51$^{a}$ | 30.17$^{a}$ | 33.62$^{b}$ | 0.27 | <0.0001 | <0.0001 |
| Ileum (cm) | 69.67$^{c}$ | 65.15$^{a}$ | 66.36$^{b}$ | 0.36 | <0.0001 | <0.0001 |
| Jejenum (cm) | 74.05$^{c}$ | 71.15$^{b}$ | 68.47$^{a}$ | 0.56 | <0.0001 | 0.8775 |
| Ceacum (cm) | 17.24$^{a}$ | 18.027$^{b}$ | 17.41$^{a}$ | 0.09 | 0.1670 | <0.0001 |
| Ceacum (g) | 13.72$^{c}$ | 12.82$^{b}$ | 11.38$^{a}$ | 0.10 | <0.0001 | 0.0420 |
| Heart (g) | 10.13$^{a}$ | 11.46$^{b}$ | 10.23$^{a}$ | 0.16 | 0.6395 | <0.0001 |
| Spleen (g) | 1.66$^{a}$ | 1.72$^{b}$ | 1.86$^{c}$ | 0.01 | <0.0001 | 0.0194 |
| L. intestines* (g) | 10.30$^{a}$ | 12.28$^{b}$ | 10.53$^{a}$ | 0.07 | 0.2537 | <0.0001 |
| Pancreas (g) | 4.77$^{b}$ | 4.67$^{b}$ | 3.85$^{a}$ | 0.07 | <0.0001 | 0.0002 |

$^{abc}$Means with different superscripts in the same row differ significantly (P<0.05); DT1=0% DGRC; DT2=5% DGRC; DT3=10% DGRC DGRC dried goat rumen content, * Leg (Thigh+drum stick), CarcaYield*: carcass yield; Abdo. fat *: Abdominal fat; Proventric*: Proventriculus; Proventriculus**: Proventriculus (cm); L. intestines*: Large intestines.

### 4.2.6 Effect of dried goat rumen contents (DGRC) based diets on broiler bird hematological parameters

Results of blood sample analysis as affected by dietary inclusion of dried goat rumen contents (DGRC) in broiler diets is shown in Table 17. Treatment had no significant effect ($P > 0.05$) on red blood cells (RBC), lymphocytes, hemoglobin (HGB), mean corpuscular volume (MCV), and mean corpuscular hemoglobin (MCH). Glucose, total blood cholesterol (TC), low density lipoprotein (LDL) and high density lipoprotein (HDL) were significantly ($P<0.05$) higher for the 0% dried goat rumen content diet (DGRC) than for the 5% and 10% DGRC diets.

The triglycerides, were significantly (Quadratic, $P<0.05$) higher in broilers fed on 5% dried goat rumen content (DGRC) and decreased as the level of DGRC in the diet increased to 10%.

Table 17 Blood parameters of broilers fed diets containing graded levels of dried goat rumen contents (DGRC)

| | Diets | | | | P-value | |
|---|---|---|---|---|---|---|
| Parameters (n=18) | DT1 | DT2 | DT3 | SEM | Linear | Quadratic |
| RBC $x10^9/l$ | 3.34 | 3.05 | 3.40 | 0.12 | 0.7495 | 0.1201 |
| GRAN $x10^9/l$ | 162.95 | 175.05 | 176.15 | 2.55 | 0.5054 | 0.1766 |
| MCV (fl) | 147.95 | 151.15 | 151.45 | 0.97 | 0.0847 | 0.3112 |
| MCH (pg) | 50.30 | 52.50 | 50.15 | 0.72 | 0.8928 | 0.0828 |
| MCHC (%) | $34.00^a$ | $43.45^b$ | $33.10^a$ | 0.40 | 0.2107 | 0.0003 |
| Glucose mmol/l | $1.82^c$ | $1.22^a$ | $1.59^b$ | 0.02 | 0.0042 | 0.0003 |
| Hemoglobin g/dl | 17.65 | 17.45 | 18.44 | 0.36 | 0.2220 | 0.2738 |
| Total Cholesterol mmol/l | $4.30^c$ | $3.10^b$ | $2.85^a$ | 0.21 | 0.0008 | 0.0962 |
| High density LP mmol/l | $1.80^c$ | $1.40^b$ | $0.75^a$ | 0.12 | 0.0002 | 0.4382 |
| Low density LP mmol/l | $1.84^c$ | $1.65^a$ | $1.77^b$ | 0.016 | 0.0140 | <0.0001 |
| Triglycerides mmol/l | $1.05^a$ | $1.80^c$ | $1.30^b$ | 0.15 | 0.2796 | 0.0089 |

[abc]Means in the same row with different superscripts differ significantly ($P<0.05$); DT1=0% DGRC; DT2=5% DGRC; DT3=10% DGRC; RBC=Red blood cell. GRAN=Granulocytes; HGB=Hemoglobin. MCV= Mean corpuscular volume. MCH= Mean corpuscular hemoglobin. MCHC=Mean corpuscular hemoglobin concentration; TC=Total Cholesterol; HDL=High density lipoproteins; LDL= Low density lipoproteins

### 4.2.7 Effect of diets based on dried goat rumen content on broiler meat nutritional composition

Chemical composition of broiler meat as affected by incorporation of dried goat rumen contents (DGRC) in the diets is shown in Table 18. Diet significantly affected moisture content (MC) of the meat samples (Quadratic P<0.05), however, the interactions between diet and carcass parts (breast and thigh meat) was not significant (P>0.05). Moisture content (MC) for breast meat of broiler birds fed diets with 5% and 10% dried goat rumen content (DGRC) was higher compared with birds fed on 10% level of dried goat rumen contents (P<0.05). Overall, moisture content was higher in breast than thigh meat across the diets.

Mineral composition (Ash) for the breast and thigh meat increased with incorporation of dried goat rumen contents (DGRC) in broiler diets (P<0.05). Diet significantly affected the crude protein (CP), ether extract (EE) and crude fiber (CF) composition of the meat samples (P<0.05). The interactions between diet and carcass part (breast and thigh) for both EE and CP were also significant (P<0.05).

Table 18 Effect of diets based on dried goat rumen content on broiler meat nutritional composition

| Diet | Carcass part | MC | CP | Ash | EE | CF |
|---|---|---|---|---|---|---|
| DT1 | Breast | $68.11^{c}$ | $19.08^{b}$ | $0.76^{c}$ | $5.19^{a}$ | $0.03^{c}$ |
| DT1 | Thigh | $67.41^{c}$ | 18.83c | $0.69^{c}$ | $4.67^{b}$ | $0.03^{c}$ |
| DT2 | Breast | $72.91^{a}$ | $22.39^{a}$ | $0.97^{a}$ | $4.96^{a}$ | $0.05^{a}$ |
| DT2 | Thigh | $69.55^{ab}$ | $19.95^{b}$ | $0.81^{b}$ | $5.11^{a}$ | $0.04^{b}$ |
| DT3 | Breast | $70.78^{b}$ | $20.52^{b}$ | $0.83^{b}$ | $4.45^{b}$ | $0.05^{a}$ |
| DT3 | Thigh | $68.79^{c}$ | $20.15^{b}$ | $0.73^{c}$ | $4.59^{b}$ | $0.05^{a}$ |
| **SEM** | | 0.92 | 0.51 | 0.06 | 0.07 | 0.00 |
| **P-Value** | | | | | | |
| Linear | | 0.3097 | 0.5571 | 0.0026 | 0.0001 | <.0001 |
| Quadratic | | 0.0009 | <0.0001 | <.0001 | 0.0004 | <.0001 |
| Diet*carcass part | | NS | S | NS | S | NS |

$^{abc}$Means within a column with different superscripts are significantly different (P<0.05). DT1=0% DGRC; DT2=5% DGRC; DT3=10% DGRC; MC: moisture content; CP: crude protein; EE: ether extract; CF: crude fiber; NS: not significant; S: Significant

### 4.2.8 Effect of dried goat rumen contents (DGRC) based diets on broiler meat water holding capacity

Effect of dried goat rumen contents on water holding capacity in broiler meat is shown in Table 19.

Table 19 Water holding capacity of broiler meat as affected by diets

| | Diets | | | | P-Value | |
|---|---|---|---|---|---|---|
| Carcass part | DT1 | DT2 | DT3 | SEM | Linear | Quadratic |
| Breast | $26.62^{b}$ | $29.04^{a}$ | $28.31^{a}$ | 0.22 | 0.0134 | 0.1549 |
| Thigh | 29.48 | 29.09 | 28.62 | 0.32 | 0.1549 | 0.9297 |

$^{ab}$Means in the same row bearing different superscripts differ significantly (P<0.05); DT1=0% DGRC; DT2=5% DGRC; DT3=10% DGRC; SEM: standard error of the mean

Incorporation of dried goat rumen contents (DGRC) in broiler diets led to improvements in water holding capacity (WHC) of breast meat in relation to diets with no dried goat rumen contents (Linear, Quadratic P<0.05). However, use of DGRC in broiler diets did not influence thigh meat water holding capacity by diet (P>0.05).

### 4.2.9 Effect of dried goat rumen contents (DGRC) based diets on sensory characteristics of broiler meat

Table 20 shows the effect of incorporating dried goat rumen contents (DGRC) in broiler diets on broiler meat sensory characteristics. Chicken meat samples were evaluated under three attributes; Appearance (Color, oiliness); Aroma (chicken flavor, fishy flavor); Texture (springiness, hardiness, fibrousness, chew counts); Juiciness (Juice release, wetness, ease of swallow). The results showed that among appearance attributes, oiliness was significantly different (P<0.05) across diets. Inclusion of dried goat rumen contents diets resulted in production of more oily meat than the diet with no DGRC. Wetness and juiciness of the meat samples followed the same trend as Oiliness. Diet did not affect (P>0.05) color, bitterness, sweetness, fishy flavor, springiness, hardness, fatty mouth feel, easy of swallow, tooth pack and fibrousness of broiler chicken meat.

Table 20 Effect of dried goat rumen contents (DGRC) based diets on sensory characteristics of broiler meat as evaluated by descriptive sensory panel

| Attribute (n=11) | Mean score values (Mean±SD) | | | P-value |
|---|---|---|---|---|
| | DT 1 | DT 2 | DT3 | |
| Color | 7.36±1.74 | 7.72±1.10 | 7.72±1.67 | 0.8157 |
| Color uniformity | 9.09±1.44 | 8.45±1.12 | 9.00±1.26 | 0.4641 |
| Flavor | 7.63±2.11 | 8.90±1.81 | 8.54±1.43 | 0.2518 |
| Fishy smell | 3.54±2.16 | 3.09±2.11 | 2.63±1.20 | 0.5333 |
| Umami | 6.81±2.5 | 7.09±2.77 | 7.72±2.90 | 0.7289 |
| Bitterness | 2.27±1.61 | 2.00±1.54 | 2.18±1.47 | 0.9154 |
| Sweetness | 4.00±2.36 | 5.00±2.40 | 4.36±2.46 | 0.6208 |
| Oiliness | $5.18^{a}$±1.83 | $7.00^{b}$±1.61 | $6.90^{b}$±1.92 | 0.0401 |
| Wetness | $5.09^{a}$±1.75 | $7.00^{b}$±1.41 | $6.91^{b}$±2.07 | 0.0271 |
| Springiness | 6.72±2.45 | 6.63±2.33 | 6.63±2.29 | 0.9946 |
| Hardness | 6.72±2.32 | 5.27±1.79 | 5.18±2.04 | 0.1615 |
| Juiciness | $5.45^{a}$±1.43 | $6.72^{b}$±1.79 | $6.18^{b}$±1.40 | 0.0350 |
| Fibrousness | 7.36±1.74 | 6.18±1.25 | 6.45±1.36 | 0.1603 |
| Chew count | 7.54±1.86 | 6.54±1.21 | 6.81±1.47 | 0.3037 |
| Sustained Juiciness | 6.63±1.74 | 7.18±1.53 | 6.91±1.70 | 0.7464 |
| Easy of swallow | 7.74±1.75 | 8.63±1.28 | 8.18±1.66 | 0.2815 |
| Fatty feel | 5.27±1.95 | 6.18±2.63 | 6.18±2.40 | 0.5830 |
| Tooth pack | 6.09±1.92 | 5.45±1.63 | 5.54±1.36 | 0.6267 |

[ab]Mean values within row followed by different superscripts are significantly different (P<0.05); DT1= 0% dried goat rumen contents (DGRC); DT2=5% dried goat rumen contents (DGRC); DT3= dried goat rumen contents (DGRC): Scale: 1-9; 1=low 9=extremely high

### 4.3.0 Correlation between broiler meat sensory attributes

Table 21 illustrates the correlation between broiler meat sensory attributes. The results showed oiliness was highly significantly correlated with juiciness and wetness at $r = 0.69$ and $r = 749$ respectively. There was also a significant positive correlation between meat sweetness and flavor ($r = 0.516$, $P<0.05$). Meat fatty feel (FF) was also significantly correlated with oiliness of meat ($r = 0.67$; $P<0.01$).

Table 21 Correlation between broiler meat sensory attributes

| | C | Unif | Flav | FS | U | BT | SW | Oil | WT | SP | H | J | F | CC | SJ | SE | FF | TP |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| C | 1.000 | | | | | | | | | | | | | | | | | |
| Unif | .211 | 1.000 | | | | | | | | | | | | | | | | |
| Flav | .543** | .331 | 1.000 | | | | | | | | | | | | | | | |
| FS | .131 | -.426* | -.027 | 1.000 | | | | | | | | | | | | | | |
| U | .108 | .044 | .454** | .314 | 1.000 | | | | | | | | | | | | | |
| BT | .336 | .028 | .219 | .570** | .145 | 1.000 | | | | | | | | | | | | |
| ST | .344 | .273 | .516** | .124 | .271 | .445** | 1.000 | | | | | | | | | | | |
| Oil | .649** | .105 | .472** | .067 | .129 | .196 | .478** | 1.000 | | | | | | | | | | |
| WT | .484** | -.003 | .381* | .266 | .194 | .206 | .460** | .814** | 1.000 | | | | | | | | | |
| SP | .292 | .193 | .472** | .230 | .636** | .252 | .063 | .249 | .255 | 1.000 | | | | | | | | |
| H | .192 | .063 | -.012 | .216 | -.165 | .277 | -.001 | -.022 | .153 | .152 | 1.000 | | | | | | | |
| J | .493** | .121 | .457** | .256 | .265 | .180 | .378* | .695** | .749** | .414* | -.100 | 1.000 | | | | | | |
| F | .020 | .172 | .339 | .394* | .233 | .424* | .150 | -.087 | .141 | .495** | .512** | .165 | 1.000 | | | | | |
| CC | .233 | .272 | -.120 | .055 | -.440* | .146 | .116 | -.026 | .095 | -.207 | .607** | -.088 | .289 | 1.000 | | | | |
| SJ | .327 | .080 | .410* | .043 | .046 | -.041 | .193 | .583** | .704** | .327 | .086 | .718** | .355* | .046 | 1.000 | | | |
| SE | .615** | .183 | 1 | -.104 | .299 | .118 | .469** | .551** | .466** | .369* | -.097 | .567** | .076 | -.240 | .482** | 1.000 | | |
| FF | .423* | .122 | .225 | .202 | .208 | .097 | .154 | .670** | .652** | .384* | .142 | .736** | .196 | .098 | .628** | .311 | 1.000 | |
| TP | -.089 | .017 | .054 | .160 | .016 | .062 | -.297 | -.253 | -.131 | .235 | .449** | -.140 | .548** | .288 | .054 | -.251 | .040 | 1.000 |

*. Correlation is significant at the 0.05 level; **. Correlation is significant at the 0.01 level. C: Colour of meat; Unif: Color uniformity; Flav: Flavor; FS: Fishy smell; U: Umami; BT: Bitterness; ST: Sweetiness; Oil: Oiliness; WT: Wetness; SP: Springiness; H: Hardness; J: Juiceness; F: Fibrousness; CC: Chew count; SJ: Sustained Juiciness; SE: Swallow easiness; FF: Fatty feel; TP: Tooth pack

### 4.3.1 Economics of inclusion of dried goat rumen contents (DGRC) in broiler diets

Economic analysis of inclusion of dried goat rumen contents (DGRC) in broiler diets is shown in Table 22. Marginal rate of return (MRR) was higher (151.65) for the 5% DGRC diet, however, as the level of DGRC increased to 10%, MRR also decreased to 64.4. It was generally observed that incorporation of DGRC in broiler diets resulted in reduction in feed cost/ kilogram feed. In comparison to the 0% DGRC diet, the 5% and 10% DGRC diets resulted in 7.29% and 12.44% reduction in feed costs respectively. Chicken sale/feed cost was higher for 5% DGRC followed by 10% DGRC diet and lowest for the 0% DGRC diet.

Table 22 Economics of inclusion of dried goat rumen contents (DGRC) in broiler diets

| Parameters | DT1 | DT2 | DT3 |
|---|---|---|---|
| Total feed intake (Kg) | 72.85 | 56.03 | 55.06 |
| Total feed cost/treatment UGX | 167434.79 | 119391.53 | 110807.30 |
| [a]Labour cost (for processing DGRC UGX) | 0.00 | 1000.00 | 2000.00 |
| TVC (UGX) | 167434.79 | 120391.53 | 112807.30 |
| Feed cost/Kg (UGX) | 2298.35 | 2130.85 | 2012.30 |
| *Gross income (TR) (Birds sold) (UGX) | 403380 | 427680 | 383940 |
| Net Return (NR) (UGX) | 235945.21 | 307288.47 | 271132.70 |
| Change in TR | 0.00 | 71343.26 | 35187.49 |
| change in TVC | 0.00 | 47043.26 | 54627.49 |
| Change in NR | 0.00 | 71343.26 | 35187.49 |
| MRR (%) | 0.00 | 151.65 | 64.41 |
| ADG (g)/bird/day (g) | 54.60 | 59.18 | 50.81 |
| Feed cost/gain | 42094.32 | 36006.25 | 39604.41 |
| Chicken sale/Feed cost | 2.41 | 3.58 | 3.46 |

UGX=Uganda Shillings, Broiler sale =14400/Broiler; DGRC= dried goat rumen content; DT1= contains 0% DGRC inclusion; DT2 = contains 5%; DGRC inclusion; DT3= contains 10% DGRC inclusion; [a]Labor cost/Kg DGR=816.67 UGX *each treatment contained a total of 30 birds; 1$=3700 UGX; TVC=Total Variable Costs; TR=Total Revenue; NR=Net Revenue; MRR=Marginal Rate of Return; ADG; Average Daily Gain.

### 4.4. Effect of dried goat rumen content based diets on point of lay, laying percentage, egg quality and consumer acceptability

#### 4.4.1 Chemical composition of experimental diets

Chemical composition of nutrients in the diets for laying hens as revealed laboratory analysis is shown in Table 23. There was similarilties in the composition of Dry matter (DM), Crude protein (CP) and ether extract (EE) across diets. However, slight differences were registered in crude fiber (CF) composition in the diets. The 10% dried goat rumen content inclusion levels (DGRC) treatments had higher CF %. Despite the slight differences in the CF content, dietary CF was within the recommended range (2-5%) to enable optimum broiler performance as reported by NRC (2001). Dietary energy /Metabolizable Energy (ME) ranged between 2750-3000 Kcal/kg feed.

Table 23 Analyzed (laboratory analysis) chemical composition of layer diets

| | Grower's mash | | | | Layer's mash | | | |
|---|---|---|---|---|---|---|---|---|
| Parameters | DT1 | DT2 | DT3 | SEM | DT1 | DT2 | DT3 | SEM |
| DM% | 90.04 | 90.52 | 90.78 | 0.21 | 88.74 | 88.03 | 88.12 | 0.12 |
| CP% | 17.60 | 17.99 | 17.76 | 0.13 | 17.31 | 17.2 | 17.07 | 0.08 |
| EE% | 2.91 | 2.68 | 3.45 | 0.12 | 2.50 | 2.59 | 3.44 | 0.01 |
| CF% | 4.62 | 4.76 | 4.93 | 0.13 | 4.43 | 4.46 | 4.61 | 0.03 |
| Ash% | 21.15 | 27.64 | 27.35 | 1.07 | 17.51 | 17.15 | 16.66 | 0.29 |
| Ca% | 3.62 | 3.72 | 3.92 | 0.09 | 4.12 | 3.95 | 4.06 | 0.05 |
| P% | 1.04 | 0.98 | 1.06 | 0.01 | 0.93 | 0.89 | 0.93 | 0.01 |
| NFE% | 53.53 | 45.83 | 45.34 | 1.12 | 58.23 | 60.59 | 58.22 | 0.30 |
| ME MJ/Kg | 11.80 | 11.32 | 10.98 | 0.19 | 12.46 | 12.07 | 12.01 | 0.04 |

DT1= contains 0% DGRC inclusion; DT2 = contains 5% DGRC inclusion; DT3= contains 10% DGRC inclusion; DM: dry matter; CP: crude protein; CF: crude fiber; NDF: EE: ether extract; Ca: calcium; P: phosphorous; NFE Neutral free extract; ME: metabolizable energy. SEM: standard error of mean

#### 4.4.2 Effect of use of dried goat rumen contents (DGRC) based diets on nutrient digestibility in layers

Digestibility of nutrients in layer diets as affected by incorporation of dried goat rumen contents is shown in Table 24. Crude protein (CP) and crude fiber (CF) in growers' mash were significantly ($P<0.05$) improved with incorporation of dried goat rumen contents (DGRC) in layers at 5% level. Inclusion of DGRC in grower’s mash at 10% led to significant ($P<0.05$) improvement in digestibility of calcium (Ca) and metabolizable energy. No significant effect ($P>0.05$) was observed in digestibility of ether extract (EE) and nitrogen free extract (NFE) with incorporation of DGRC in layers at growing stage.

In the laying stage, incorporation of dried goat rumen contents (DGRC) in the diets at 5% resulted in significant ($P<0.05$) improvement in digestibility of dry matter (DM) and crude fiber (CF). Diet had no significant effect ($P>0.05$) on digestibility of phosphorus (P), crude protein (CP), and metabolizable energy (ME). There was a significant ($P<0.05$) decrease in calcium digestibility with increasing incorporation of dried goat rumen content (DGRC) in the diets.

Table 24 Digestibility of DGRC based diets in layers

| | Diets | | | | |
|---|---|---|---|---|---|
| | DT1 | DT2 | DT3 | SEM | P-Value |
| Grower's mash | | | | | |
| DM% | 78.41$^{b}$ | 74.11$^{b}$ | 61.31$^{a}$ | 1.61 | 0.0101 |
| CP% | 75.57$^{a}$ | 83.82$^{b}$ | 72.00$^{a}$ | 1.39 | 0.0198 |
| EE% | 73.31 | 63.70 | 70.62 | 6.07 | 0.1887 |
| CF% | 56.41$^{a}$ | 64.02$^{b}$ | 67.27$^{c}$ | 1.074 | 0.0121 |
| Ca% | 66.14$^{a}$ | 64.52$^{b}$ | 73.59$^{c}$ | 1.36 | 0.0346 |
| P% | 58.06$^{a}$ | 58.73$^{b}$ | 69.91$^{c}$ | 2.62 | 0.0823 |
| NFE% | 96.71 | 88.66 | 89.84 | 0.64 | 0.1887 |
| ME % | 72.19$^{b}$ | 64.04$^{a}$ | 61.96$^{a}$ | 1.01 | 0.0111 |
| Layer's mash | | | | | |
| DM% | 77.41$^{a}$ | 75.23$^{a}$ | 65.12$^{b}$ | 1.65 | 0.0254 |
| CP% | 68.52 | 66.89 | 66.91 | 0.50 | 0.0677 |
| CF% | 68.10$^{c}$ | 72.29$^{a}$ | 70.69$^{b}$ | 0.79 | 0.0021 |
| Ca% | 80.66$^{c}$ | 67.47$^{b}$ | 52.41$^{a}$ | 1.84 | 0.0039 |
| P% | 74.29 | 69.66 | 69.98 | 0.95 | 0.0688 |
| EE% | 87.27$^{b}$ | 69.34$^{a}$ | 92.95$^{a}$ | 0.14 | <.0001 |
| NFE% | 97.79$^{b}$ | 96.65$^{a}$ | 96.70$^{a}$ | 0.94 | 0.0173 |
| ME % | 75.79 | 73.06 | 72.66 | 1.65 | 0.1741 |

$^{abc}$Means within arrow with different superscripts differ significantly (P<0.05); DM: dry matter; CP: crude protein; CF: crude fiber; EE: ether extract; Ca: calcium; P: phosphorous; NFE Neutral free extract; ME: metabolizable energy. SEM: standard error of mean; DT1; diet containing 0%DGRC; DT2: diet containing 5%DGRC; DT3: diet containing 10%DGRC

### 4.4.3 Effect of DGRC based diets on daily feed intake, feed conversion ratio and mortality rate in layers

The results on average daily feed intake (ADFI), feed conversion ratio (FCR) and mortality rate (MR) as affected by incorporation of dried goat rumen contents (DGRC) in layer diets are shown in Table 25.

Table 25 Average daily feed intake, feed conversion ratio and mortality rate of layers fed DGRC rations

| | **Dietary treatments** | | | | **P-value** | |
|---|---|---|---|---|---|---|
| | DT1 | DT2 | DT3 | SEM | Linear | Quadratic |
| **Grower's phase** | | | | | | |
| ADFI (g/bird/day) | 50.97$^{a}$ | 58.44$^{b}$ | 62.28$^{c}$ | 0.53 | <.0001 | 0.0098 |
| ADG (g/bird/day) | 16.12$^{b}$ | 15.92$^{a}$ | 15.98$^{a}$ | 0.04 | 0.0022 | 0.4166 |
| FCR (feed/gain) | 3.17$^{a}$ | 3.58$^{b}$ | 3.87$^{c}$ | 0.01 | <.0001 | 0.0038 |
| Mortality (%) | 26.66 | 32.66 | 31.33 | 5.77 | 0.4454 | 0.3822 |
| **Laying phase** | | | | | | |
| ADFI (g/bird/day) | 159.46$^{a}$ | 166.02$^{c}$ | 169.35$^{b}$ | 0.30 | <.0001 | <.0001 |
| ADG (g/bird/day) | 59.73$^{c}$ | 51.69$^{b}$ | 49.69$^{a}$ | 0.28 | <.0001 | 0.0001 |
| FCR (feed/hen) | 2.66$^{a}$ | 3.20$^{b}$ | 3.40$^{c}$ | 0.07 | <.0001 | 0.0517 |
| Mortality (%) | 9.54$^{a}$ | 16.71$^{b}$ | 26.22$^{c}$ | 0.20 | <.0001 | 0.0031 |

$^{bc}$Means within arow with different superscripts differ significantly (P<0.05); DT1; diet containing 0%DGRC DT2: diet containing 5%DGRC; DT3: diet containing 10%DGRC; SEM: Standard error of the mean ADFI; Average daily feed intake FCR: Feed conversion ratio

In both grower and laying stages, diet significantly (Linear: Quadratic P<0.05) affected ADFI and FCR. There was an increase in average daily feed intake (ADFI) and FCR with increasing levels of DGRC in the diets. In the grower's phase, birds had higher mortality rate in comparison to during the laying phase. Despite low mortality rate recorded in the laying stage, the trend showed that mortality significantly (Linear: Quadratic P<0.05) increased with increasing levels of DGRC in the diets.

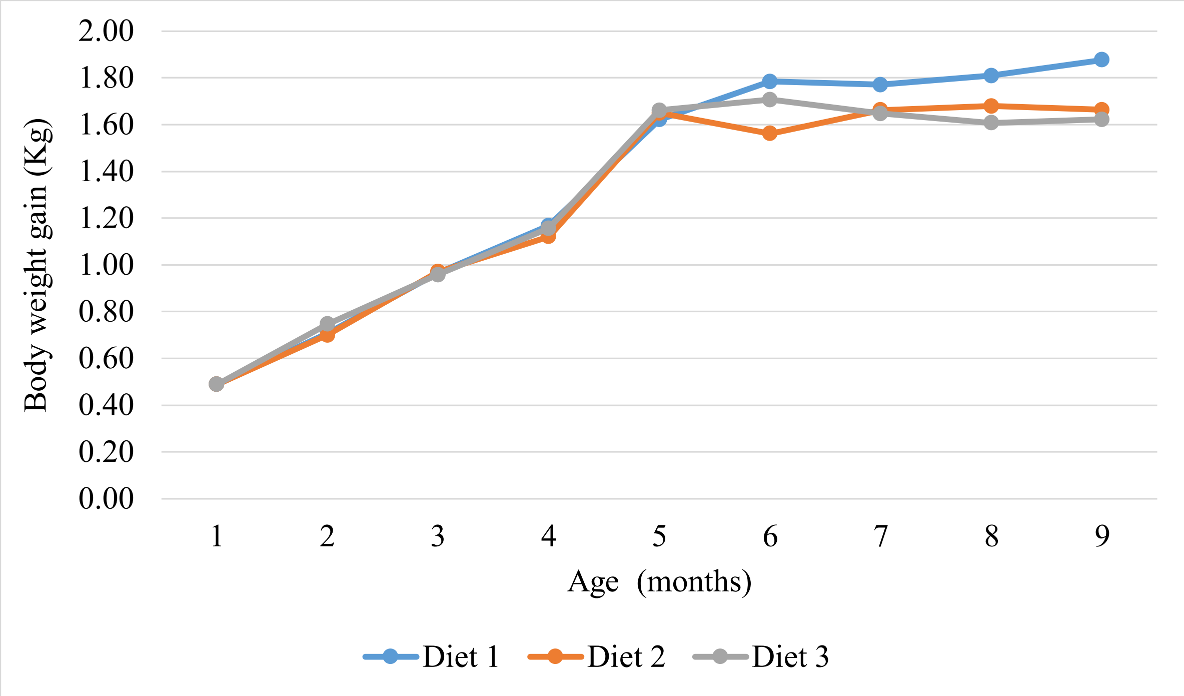
### 4.4.4 Effect of DGRC based diets on body weight gain in layers

The effect of incorporating dried goat rumen contents (DGRC) in layer diets on body weight gain in layers is illustrated in Figure 6a and 6b. The growing stage of birds (month 3-5) was characterized by slow growth to the extent that, at five months most birds had not attained the minimum laying weight of 1.6 Kg (Figure 6a). Despite this, birds on diet 1 (0%DGRC) and 3 (10% DGRC) had similar body weight, signifying no treatment differences among the two diets but different from birds fed on treatment two (5%DGRC). As the age progressed to the 5$^{th}$ month, inflection points of growth became visible with diet 2 showing lower body weight gains as compared to birds on treatment 1 and 3. From the 5$^{th}$ to 6$^{th}$ month, diet showed no differences in body weight gain among the birds. However, at this stage all the birds had attained maturity body weight (>1.6 Kg) to sustain egg production. Treatment differences on body weight gain became visibly clear and intermittent from month 6 to 10$^{th}$ month. Despite the intermittent growth pattern exhibited by the birds on different dietary treatments, bird on diet 1 (0% DGRC) gained relatively more weight than those on diet 2 and 3. At the 6$^{th}$ - 7$^{th}$ month as the birds on treatment 1 and 3 were gaining more weight, the reverse was true for birds on treatment 3. However, birds on treatment 2 were able to compensate for growth from the 7th - 10$^{th}$ month and by passed body weight of birds on dietary treatment 3.

Figure 6b is the fitted curve for live weight of birds fed dietary treatments using logistic model. Estimated asymptotic weight parameter (a=2.08) was found higher for the laying birds fed diets with 0% DGRC (diet 1) compared to layers fed on 5 and 10% DGRC diets. Laying birds on the 10% DGRC had the least asymptotic weight parameter (a=1.79).

The logistic model has a symmetric structure at the point of inflection (Figure 6b). The growth rate at point of inflection was higher for the birds fed on 10% DGRC diet (Figure 6b and Table 26) in relation to birds fed on 0% and 5% diets.

The proportion of variation in live weight of laying birds explained by the model was higher ($R^2$=0.95) in laying birds fed diets with 0% DGRC diets. However, the average $R^2$ for the model across treatments was above 0.9. Maximum relative growth at inflection was higher for the laying hens fed on 0% DGC diet across diets (Figure 6b and Table 26).




Grower's stage (3-5 Months), Laying (6-10 Months)

**Figure 6a**. Effect of DGRC diets on layer body weight

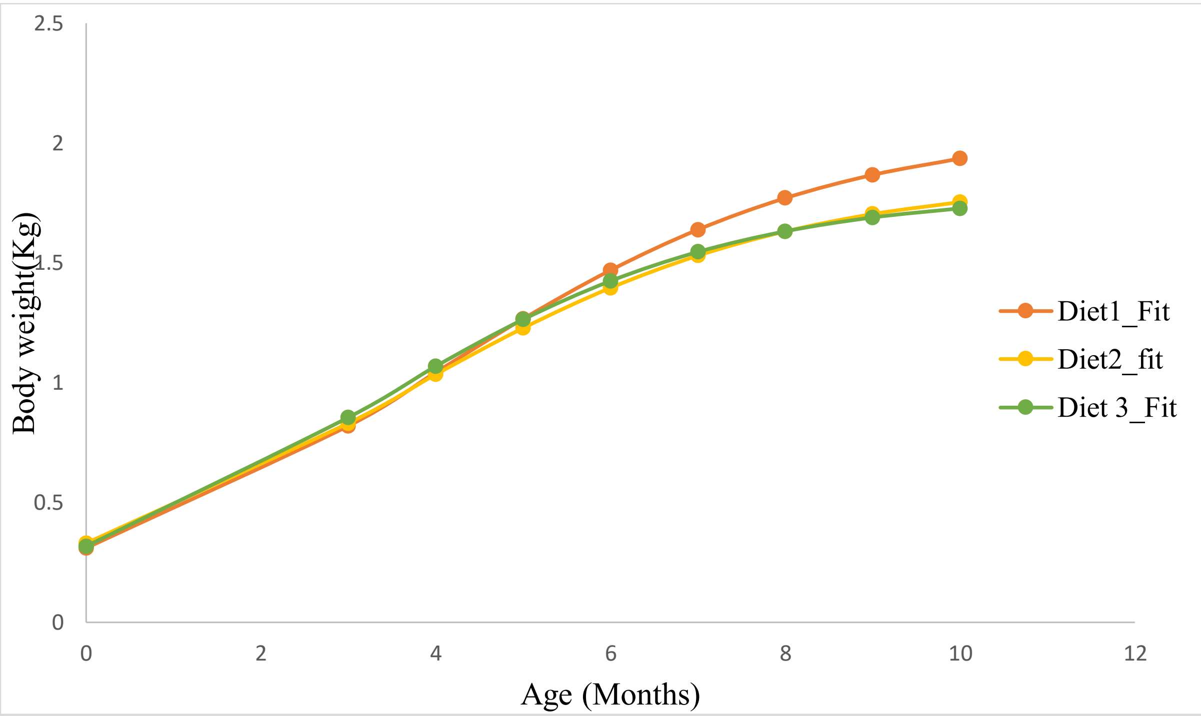



**Figure 6b.** Logistic curve fit for body weight in layers as affected feeding on DGRC diets

Table 26 Estimated logistic regression model parameters for laying hen live weight as affected by inclusion of DGRC in layer diets

| **Parameter** | | **DT1** | **DT2** | **DT3** |
|---|---|---|---|---|
| BWG (Kg) | Parameters | | | |
| | a | 2.08±0.20 | 1.85±0.19 | 1.79±0.17 |
| | b | 5.66±1.89 | 4.59±1.82 | 4.62±2.20 |
| | c | 0.43±0.11 | 0.44±0.13 | 0.48±0.15 |
| | $R^2$ | 0.95 | 0.92 | 0.91 |

DT1: diet containing 0%DGRC DT2: diet containing 5%DGRC; DT3: diet containing 10%DGRC; BWG: body weight gain.

### 4.4.5 Effects of DGRC on total egg production

The effect of dried goat rumen contents on total egg production is shown in Figure 7. At the commencement of egg production, the number of eggs produced was low however as the laying period progressed from 6$^{th}$ to the 7$^{th}$ month, the number of eggs produced drastically increased linearly with birds on diet 1 (0% DGRC) producing more eggs as compared to the birds on 5 and 10% dietary treatments. Further progress in the laying period (7-8 month), despite birds on diet 1(0% DGRC) maintaining higher egg production, the trend was relatively flat. From the 7$^{th}$-9$^{th}$ month, despite egg production showing a down ward trend for birds on diet 2 (5% DGRC) and 3 (10% DGRC), the decrease in egg production was higher for birds on diet 2. Overall, total egg production was higher for birds on diet 1 in relation to egg production of birds on other two diets.

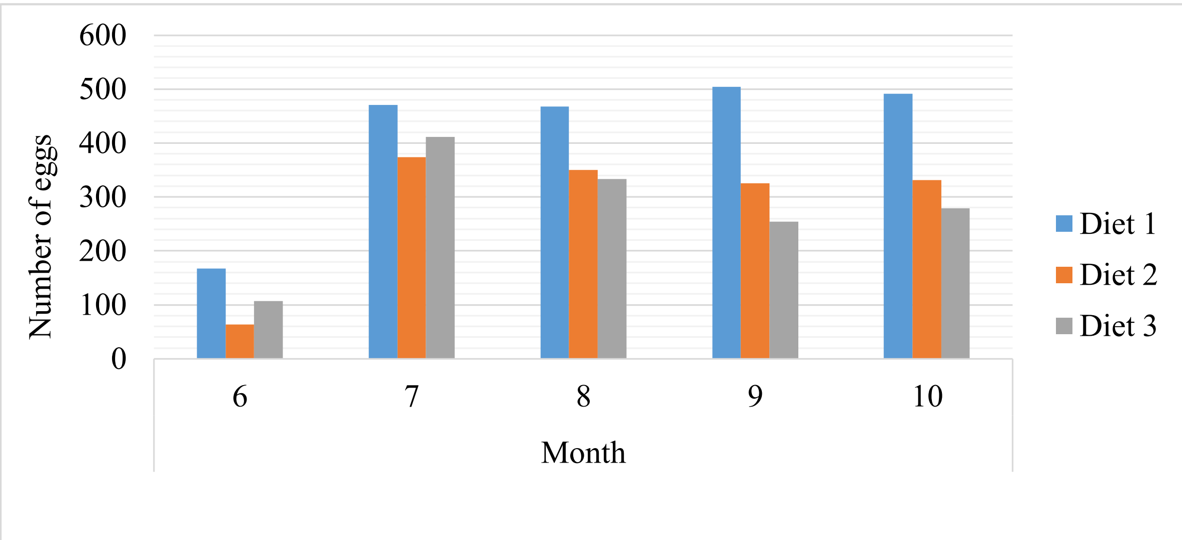


**Figure 7.** Effect of DGRC on egg production

### 4.4.6 Effect of dried goat rumen contents diet on percentage egg production

The effect of DGRC based diets on percentage egg production is shown in figure 8. There was a linear decrease laying percentage as the levels of DGRC increased in the diet, however, no significant differences were observed on laying percentage between Diet 1 (0% DGRC) and Diet 2 (5% DGRC).

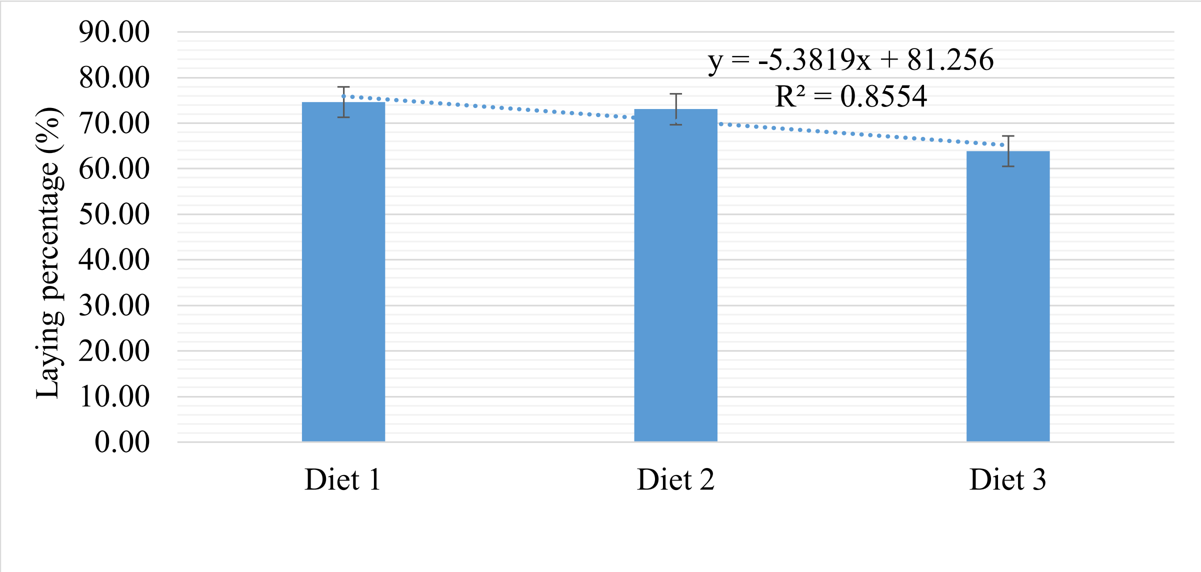



**Figure 8.** Effect of DGRC in layer diets on laying percentage

### 4.4.7 Effect of dried goat rumen contents diet on percentage Hen day egg production

Figure 8 shows the percentage hen day egg production (HDEP) as affected by inclusion of DGRC in the diets for laying hens.

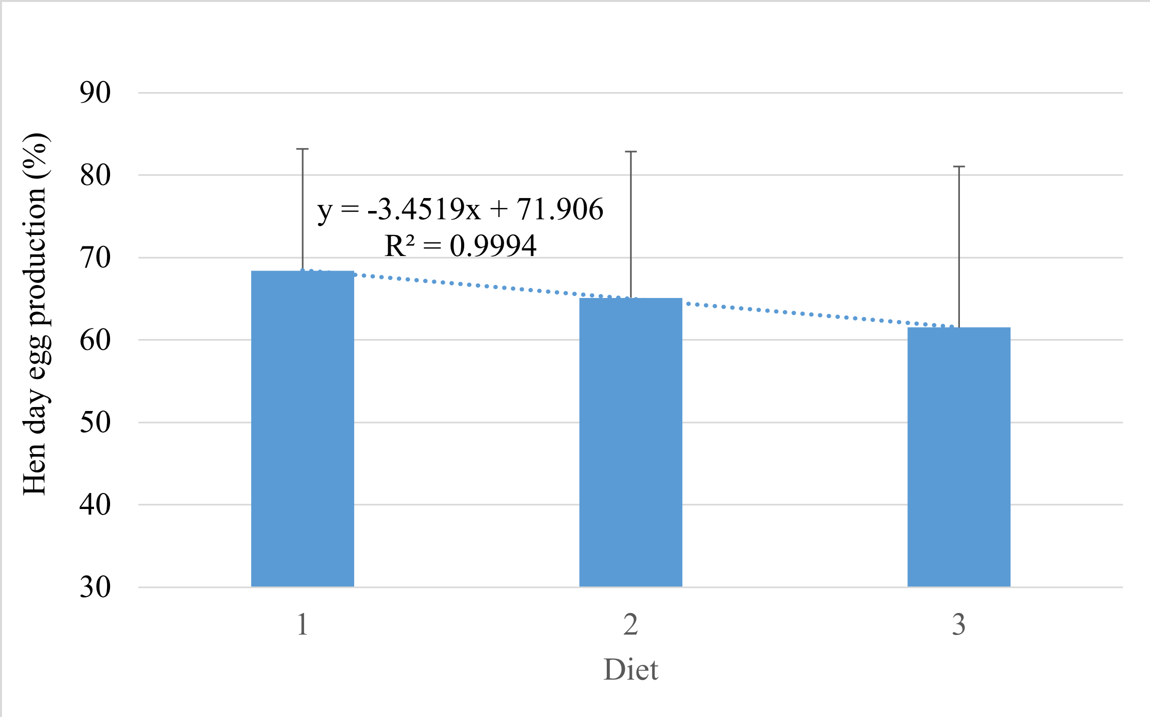



**Figure 9**. Effect of DGRC diets on percentage hen day egg production (HDEP)

The results showed that the percentage HDEP for diet1 (0% DGRC), diet 2 (5% DGRC) and diet 3 (10% DGRC) had a slight downward trend with increasing level of DGRC in the diets. However, there were no significance differences in HDEP across the diets ($P>0.05$).

### 4.4.8 Effect of dried goat rumen contents on percentage Hen house egg production

The effect of incorporating dried goat rumen contents in layer diets on hen house egg (HHEP) production percentage is shown in Figure 10 below.

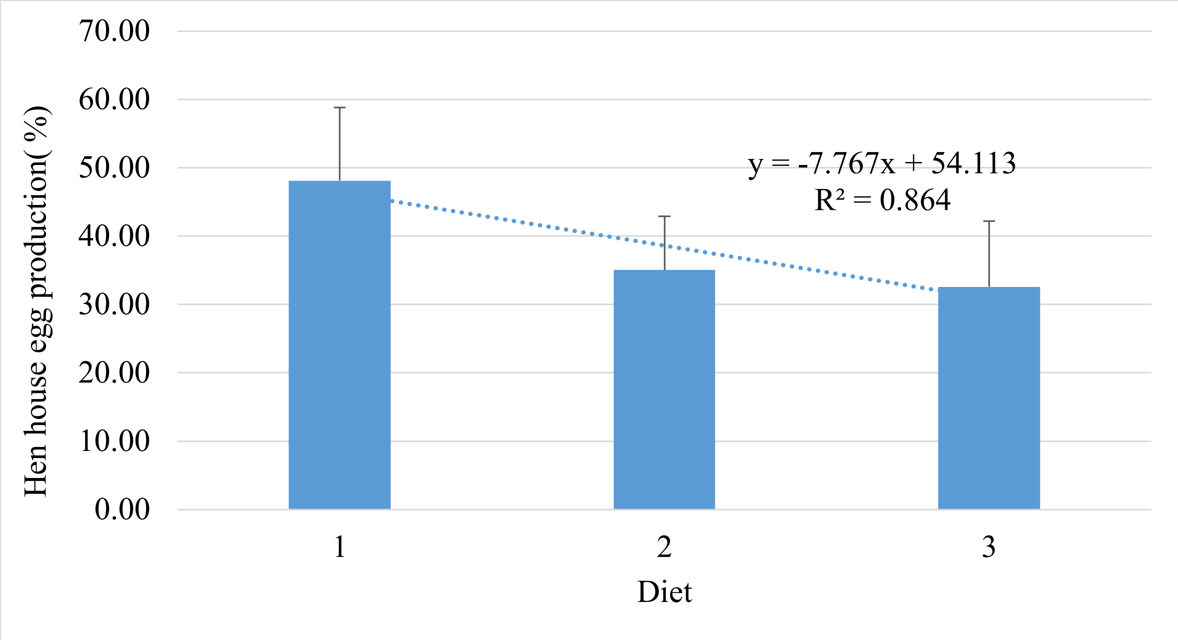



**Figure 10.** Effect of DGRC on percentage hen house egg production

Layers on 0% DGRC (diet 1) diets had a significantly higher ($P<0.05$) HHEP percentage compared to those fed 5% DGRC (diet 2) and 10% DGRC (diet 3) diets. As the level of DGRC increased in the diets this was followed by a linear reduction in HHEP percentage.

**4.4.9 Effect of dried goat rumen contents on egg characteristics**

The effect of incorporation of dried goat rumen contents in layer diets on egg characteristics is shown in Table 27. At the start of laying, egg weight was lower but it kept increasing as the laying period progressed. In the second month of laying, egg weight was the similar between the control treatment T1 (0% DGRC) and T2 (5% DGRC). However, this was statistically different (Linear, Quadratic $P<0.05$) from treatment T3 (10% DGRC). Egg shell weight increased with increase in DGRC in the diet in the second month with a similar trend observed in the fourth month.

Egg shell weight and albumen percentage were similar, had linear relationship in the second month for treatment (T1) and (T2) and statistically significant ($P<0.05$) from treatment (T3). Use of dried goat rumen content (DGRC) in layer diets improved albumen weight, yolk weight, and egg shell percentage in the second month of lay. However, in the $4^{th}$ month, there was a decline in these parameters with increasing dried goat rumen content (DGRC) incorporation in layer diets.

Egg shell and yolk percentage in the second month of laying decreased with increasing levels of DGRC in the diet in the 2nd month of laying. However as laying progressed to the 4th month, both egg shell and yolk percentage showed significant (Linear, Quadratic $P<0.05$) improvement in performance with increasing levels of DGRC in the diets.

Egg shell thickness increased significantly (Linear, $P<0.05$) for hens fed on 10% DGRC diets across diets as the laying period progressed to the 4th month. However, despite this, egg shell thickness was not significantly different ($P>0.05$) among diets.

Over all, the use of dried goat rumen contents (DGRC) in layer diets significantly (Linear, $P<0.05$), (Quadratic $P<0.05$), (Linear, Quadratic $P<0.05$) increased egg mass, shell weight, yolk weight and shell percentage respectively. However, albumen weight and percentage were significantly (Linear, Quadratic $P<0.05$) decreased with increasing levels of DGRC in layer diets. No significant effects were observed on yolk percentage, shell thickness and yolk index as a result of incorporation of dried goat rumen contents (DGRC) in layer diets.

Table 27 Effect of dried goat rumen content diets on egg characteristics

| Variable | Month 2 | | | | p-value | | Month 4 | | | | p-value | | Over all | | | | p-value | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | TI | T2 | T3 | SE | L | Q | TI | T2 | T3 | SE | L | Q | TI | T2 | T3 | SE | L | Q |
| Egg weight (g) | $60.15^{b}$ | $59.69^{b}$ | $55.96^{a}$ | 0.37 | ** | ** | $61.57^{c}$ | $60.06^{b}$ | $59.02^{a}$ | 0.10 | ** | NS | $60.86^{b}$ | $59.88^{b}$ | $57.49^{a}$ | 0.29 | ** | **NS** |
| Shell W (g) | $6.80^{b}$ | $6.71^{b}$ | $6.47^{a}$ | 0.04 | ** | **NS** | $6.82^{a}$ | $7.55^{c}$ | $7.19^{b}$ | 0.02 | ** | ** | $6.81^{a}$ | $7.13^{b}$ | $6.84^{a}$ | 0.08 | **NS** | ** |
| Yolk weight(g) | $13.67^{a}$ | $14.55^{b}$ | $14.89^{b}$ | 0.17 | ** | **NS** | $14.38^{a}$ | $15.16^{b}$ | $13.38^{a}$ | 0.09 | NS | ** | $13.52^{a}$ | $14.85^{c}$ | $14.14^{b}$ | 0.14 | ** | ** |
| Shell (%) | $11.13^{a}$ | $11.46^{b}$ | $11.45^{b}$ | 0.03 | ** | **NS** | $11.08^{a}$ | $12.56^{c}$ | $12.19^{b}$ | 0.03 | ** | ** | $11.11^{a}$ | $12.02^{b}$ | $11.82^{c}$ | 0.09 | ** | ** |
| Yolk (%) | $26.65^{b}$ | $24.70^{a}$ | $27.22^{b}$ | 0.31 | **NS** | ** | $21.73^{a}$ | $25.24^{c}$ | $22.67^{b}$ | 0.15 | ** | ** | 24.19 | 24.97 | 24.95 | 0.47 | **NS** | **NS** |
| Albumen weight (g) | $33.49^{b}$ | $32.69^{a}$ | $32.89^{a}$ | 0.15 | **NS** | ** | $39.01^{b}$ | $33.29^{a}$ | $35.33^{a}$ | 0.59 | ** | ** | $35.76^{b}$ | $33.49^{a}$ | $34.11^{a}$ | 0.55 | ** | ** |
| Albumen (%) | $60.76^{b}$ | $60.65^{b}$ | $59.41^{a}$ | 0.14 | ** | **NS** | $63.37^{c}$ | $55.43^{a}$ | $59.86^{b}$ | 0.99 | ** | ** | $62.07^{b}$ | $58.04^{a}$ | $59.64^{a}$ | 0.62 | ** | ** |
| Shell (T)(mm) | $0.403^{b}$ | $0.378^{a}$ | $0.423^{c}$ | 0.01 | ** | **NS** | $0.36^{c}$ | $0.35^{b}$ | $0.33^{a}$ | 0.01 | ** | ** | 0.38 | 0.36 | 0.37 | 0.00 | **NS** | **NS** |
| Yolk index | $0.41^{b}$ | $0.40^{a}$ | $0.41^{b}$ | 0.00 | ** | ** | $0.38^{b}$ | $0.39^{c}$ | $0.37^{a}$ | 0.00 | ** | ** | 0.39 | 0.39 | 0.391 | 0.00 | **NS** | **NS** |

$^{abc}$Means within a row with different superscripts differ significantly ($P<0.05$); T1; diet containing 0%DGRC T2: diet containing 5%DGRC; T3: diet containing 10%DGRC; SE: Standard error; L: Linear relationship; Q: Quadratic relationship; Shell W: egg shell weight; Shell (T): Egg Shell thickness; ** Significant; NS: Not significant

### 4.5.0 Effect of dried goat rumen contents (DGRC) on egg sensory characteristics

Egg sensory attributes as affected by incorporation of dried goat rumen contents (DGRC) in layer diets is shown in Table 28.

Table 28 Effect of dried goat rumen contents on egg sensory characteristics as evaluated by descriptive sensory panel

| | Mean score* | | | |
|---|---|---|---|---|
| **Attribute (n=36)** | **DT1** | **DT2** | **DT3** | **P-value** |
| Appearance | 6.80±1.95 | 7.63±2.05 | 7.44±2.10 | 0.1980 |
| Odor | 6.11±2.53 | 6.22±1.48 | 6.69±2.18 | 0.0784 |
| Texture | $6.22^a$±2.55 | $7.30^b$±1.78 | $7.36^b$±1.86 | 0.0381 |
| Color of yolk* | $2.52^a$±1.95 | $7.25^b$±2.04 | $7.77^b$±1.77 | <.0001 |

$^{ab}$Mean values within row followed by different superscripts are significantly different (P<0.05) *Mean±SD; DT1; diet containing 0%DGRC DT2: diet containing 5%DGRC; DT3: diet containing 10%DGRC: Scale 1-10: *extremely pale-extremely yellow.

The level of incorporation of (DGRC) in layer diets did not affect (P>0.05) egg appearance and odor. However, texture and yolk color were significantly (P<0.05) affected by level of inclusion of DGRC in laying hens. A significant effect (P<0.05) of treatments on yolk color was observed with use of DGRC in the diets. Diets with DGRC had more dark yellow yolks than eggs from layers fed on diets with no DGRC.

### 4.5.1 Correlation coefficients between egg sensory parameter measurements

The correlations between egg sensory parameters is indicated in Table 29. There was a significant positive correlation between texture and appearance of the egg (r = 0.29, P<0.01).

Table 29 Spearman correlation coefficients between egg sensory parameter measurements

| | Appearance | Odour | Texture | Acceptance | Yolk color |
|---|---|---|---|---|---|
| Appearance | 1.000 | | | | |
| Odour | $.29^{*}$ | 1.000 | | | |
| Texture | $.386^{**}$ | $.527^{**}$ | 1.000 | | |
| Acceptance | $.304^{**}$ | $.566^{**}$ | $.615^{**}$ | 1.000 | |
| Yolk color | $.237^{*}$ | $.331^{**}$ | $.351^{**}$ | $.614^{**}$ | 1.000 |

*. Correlation is significant at the 0.05 level; **. Correlation is significant at the 0.01 level

Acceptance of the egg was also positively significantly related to appearance, odour, texture and egg yolk colour.

### 4.5.2 Costs and benefit effect of inclusion of DGRC in layer diets

Table 30 shows the costs and benefit effect of inclusion of DGRC in layer diets. Total feed intake and total feed costs were lower for laying hens fed diets with DGRC. Incorporation of DGRC in the diets resulted in negative marginal rate of return (MRR). Proportion of gross income to feed cost was lower with the use of DGRC in layer diets.

Table 30 Economics of inclusion DGRC in layer diets

| **Parameters** | **DT1** | **DT2** | **DT3** |
|---|---|---|---|
| Total feed intake (Kg) | 583.89 | 449.97 | 447.94 |
| Total feed cost/treatment (Ug.sh) * | 767228.70 | 575060.90 | 556343.60 |
| Labour cost (for processing DGRC UGX) | 0.00 | 4499.70 | 8999.40 |
| TVC (UGX) | 767228.70 | 579560.60 | 565343.00 |
| Feed cost/Kg(UGX) | 1314.00 | 1278.00 | 1242.00 |
| Gross income (TR) (Eggs+chicken sales)(UGX) | 1100333.00 | 741333.30 | 721333.30 |
| Net Return (NR) (Ug.sh) * | 333104.30 | 161772.70 | 155990.30 |
| Change in TR | 0.00 | -171331.60 | -177114.00 |
| change in TVC | 0.00 | 187668.10 | 201885.70 |
| Change in NR | 0.00 | -171331.60 | -177114.00 |
| MRR (%) | 0.00 | -91.30 | -87.73 |
| ADG (g)/bird/day (g) | 37.93 | 33.81 | 32.84 |
| Feed cost/gain | 34642.64 | 37799.42 | 37825.64 |
| (Eggs +chicken) sale/Feed cost | 1.43 | 1.29 | 1.30 |

UGX=Uganda Shillings, chicken sale =20000/layer; DGRC= dried goat rumen content; DT1= contains 0% DGRC inclusion; DT2 = contains 5%; DGRC inclusion; DT3= contains 10% DGRC inclusion; [a]Labor cost/Kg DGR=816.67 UGX *each treatment contained a total of 30 birds; *1$=3700 UGX; TVC=Total Variable Costs; TR=Total Revenue; NR=Net Revenue; MRR=Marginal Rate of Return; ADG; Average Daily Gain.

# CHAPTER FIVE
# DISCUSSION

## 5.1 Extent of use of rumen contents in livestock diets among farmers

### 5.1.1 Demographic characteristics of the respondents

The study showed that livestock farming in the area of study (Table 4) was dominated by the young age group (30-45yrs), this implied that people within this age bracket are strong and energetically fit to execute the required duties as opposed to older people. More so, the youth constitute the highest portion of job seekers. As such, they do any income generating jobs available in order to support their daily living requirements (Bon *et al*., 2010; ILO, 2013) A study by the World Bank (2014) also revealed that, the youth will remain Africa's abundant asset due to change in the demographic structure.

In relation to household size, small household size category (1-5 people) was the highest which is in line with the findings of UBOS (2018) which revealed an average of 4.5 persons per house hold. Household size is mostly dictated by the resources available to support families and increasing urbanization (Tripathi & Mahey, 2017). In peri urban areas where the survey was conducted from, is mostly characterized by smallholder farming communities with limited land holdings and this further limits household size to the numbers that can be supported by family (GOU & UNICEF, 2017; UBOS, 2018). Also, the high cost of food, water, education and electricity associated with most peri-urban areas may be forcing families to opt for a smaller family size. In this study, 68% of the respondents had attained at least secondary education which also has an influence on household (HH) size. As the level of education increases, family size decreases due to increased awareness of the cost of living and the need to provide for a decent life. These results though slightly lower, agree with the findings of Katongole *et al*. (2012), who reported more than 74% of respondents to have attained at least senior secondary education while investigating strategies for coping with feed scarcity among urban and peri-urban livestock farmers in Kampala, Uganda. Similar findings were also reported elsewhere by Mohakud *et al*. (2020) while assessing the extent and structure of pig rearing system in urban and peri-urban areas of Guwahati. Education level also reflects by the rate of adoption of technologies by the farmers (Castle *et al*., 2016; Miller *et al*., 2017).

### 5.1.2 Animal types kept by the farmers

Farmers in the study area mostly engaged in poultry business (layers, broilers and indigenous chicken). This could be probably because chicken being a small livestock, farmers found it easier to rear compared to large livestock like cattle. Additionally poultry especially indegenoius birds can survive under minimal input at household level (Kperegbeyi *et al*., 2009). According to FAOSTAT (2015), poultry products (meat and eggs) are among the predominantly consumed animal food source as it is not discriminated among cultures and religions thus making it a key component in food security and nutrition of most households in the study area. Poultry farming is more especially crucial among smallholder farmers that are resource constrained in both urban and rural areas. As such, this makes it one of the fastest growing subsectors globally. Chickens are also considered as a form of petty cash in that they can be sold off very quickly to settle a particular problem at a household level (Lotesiro *et al*., 2017). Incomes from sale of chicken and eggs for instance have been used for meeting cost of education related materials like school uniforms, school materials (books, pens) paying school fees, hospital bills, cultural uses ( offering a chicken to a traditional healer, biological clocks), and buying household items (sugar, salt, oil, tea leaves and soap) (Lotesiro *et al*., 2017). Azzarri *et al*. (2015) reported that chickens are also extremely important in exchanging for goods and services, or even for consumption when there is a guest, or for rituals and ceremonies.

Chickens have a small body size, highly proliferate, have a short production cycle and are available in most households. This makes them more likely to be consumed, exchanged, or sold in times of need, compared with larger livestock (Dumas *et al*., 2016). Poultry especially indigenous chickens (IC) are mostly kept by the youth and women, the majority and resource poor category of the population (Lotesiro *et al*., 2017). Chicken selling prices are in most cases affordable, hence chickens can be sold off quickly in case of a need. Poultry convert household wastes into edible products like meat and eggs, this is one of the reasons they are found in almost every house- hold (FAOSTAT, 2015).

Most respondents kept indigenous chicken followed by cattle, sheep and goats. This finding differed from that of Katongole *et al*. (2012) who reported dairy cattle as the most reared livestock specie. The reason for this could be as a result of change in land tenure system and increasing urbanization of what used to be peri-urban districts surrounding Kampala. This change in land use has reduced available agricultural land (Maheshwari *et al*., 2016), as a consequence, most urban dwellers have been left with small pieces of land which has forced some of them to keep birds that require small area of land as opposed to large ruminants. More so, people who had cattle either kept them under zero grazing or would leave them roam around other people's undeveloped places in search of pasture which also led to waste disposal challenges. However, restrictions by urban authorities through by-laws led to some farmers abandon such practice of leaving animals to loiter around and many were forced to sell their animals. This is also emphasized by the United Nations report that urbanization presents unprecedented environmental, social, economic and political challenges. Globally, expansion of cities not only leads to loss of agricultural land but also changes in hydrology and natural habitat (Fotso *et al*., 2008).

Poultry contributes to food security through supplying nutrient rich and culturally acceptable products for consumption (meat, eggs), income generation through the sale of chickens and eggs to buy food, creation of employment in the value chain and through the provision of manure and insect pest control in association with vegetable and livestock production (Wong *et al*., 2017).

### 5.1.3 Challenges faced by livestock farmers

Livestock farmers are faced with several challenges, however, in the current study, high prices of livestock inputs (feeds and veterinary supplies) was the biggest problem encountered by livestock farmers, followed by poor quality animal feeds, feed scarcity and limited land. High feed prices are not unique to Uganda only but a major problem facing most farmers in developing countries (Abro *et al*., 2020; Jain *et al*., 2018; Kouadio & Kouadja, 2020). In Uganda, fishmeal and maize are the predominant protein and energy feed ingredients used in livestock feed formulation. These feed ingredients are also subject to competition from humans, thus aggravating the situation during periods of scarcity. Under such situations, feed dealers subject most feed ingredients to adulteration. This not only subjects livestock farmers to a double loss but also exposes them to substantial livelihood risk. The competition for inputs drastically affects farmers' profit margins which consequently hinders their expansion programs (Lubandi *et al*., 2019; Natukunda *et al*., 2011).

### 5.1.4 Alternative feeding strategies used by farmers

To curb the problem of the ever increasing feed prices, farmers resorted to use mostly peelings from bananas, sweet potatoes and cassava. The peelings are got from nearby restaurants, schools and home steads. Promotion and use of peelings as a way to reduce feed prices and human competition had also been reported in other studies (Katongole *et al.*, 2012; Kouadio & Kouadja, 2020). The peels were subjected to welting and sometimes boiling so as to reduce inherent ant-nutritional factors and also to increase digestibility by the animals. Other farmers indicated that banana peelings were chopped into small pieces, dried and given to the birds, this slowed excessive weight loss in the birds during periods of feed scarcity. However, these needed scientific backing so as to give more informed guidance to farmers. Industrial agro by-products used by the farmers included; wheat bran, wheat pollard, brewer's waste and by-products from slaughter houses. Other farmers bought and stocked feed ingredients like maize and dried cassava in large quantities during the harvest season when the prices were lower in preparation for periods of scarcity which was in line with the findings of (Katongole *et al.* (2012). Few of the farmers interviewed reported formulating their own feeds, a practice that reduced feed costs because commercially available formulated feeds are considered expensive (Maheshwari *et al.*, 2016; Singh *et al.*, 2019). Commercial concentrates used by the farmers included; Hendrix, Intercol and Kafica, which were mostly imported into the country and their use was justified by the need to curb rampant feed adulteration by the local feed manufactures.

### 5.1.5 Use of rumen contents in livestock diets

Rumen content was used in pig and layers diets by 29 and 20% of the respondents respectively. The inclusion of rumen contents in pig diets was reported to be easier than in layer diets because it did not involve milling and sorting which reduced the cost on feed preparation. This is because most farmers perceive pigs as animals that can eat almost everything offered to them. Despite this notion, pigs too need well formulated and balanced feeds for better performance (Mwesigwa *et al.*, 2013; Pomar & Remus, 2019). A few of the respondents reported giving fresh rumen contents to pigs without subjecting it to any form of processing. The fresh rumen content was given solely or mixed with a little maize bran and fed to the pigs. Despite this being an innovative survival strategy, the nutritional adequacy of this approach to pig feeding remained questionable (Kasule *et al.*, 2014; Muthui *et al.*, 2019). This is because, the fresh rumen contents could be infested with worms and other disease causing agents which could eventually compromise production efficiency of the pigs. The feeding of rumen contents to livestock without any supplementation is also a bad practice and therefore cannot support optimum animal growth (Alao *et al.*, 2017; Osman *et al.*, 2015). Rumen content was not used in broiler diets because farmers did not envisage its usefulness to broilers as a feed resource.

### 5.1.6 Degree of use of rumen content in the study area

Rumen contents were mostly used in Kampala district compared to Mukono and Wakiso. According to discussion with key informants, the idea of rumen content use in livestock diets started at Nalukolongo abattoir, one of fast growing suburbs of Kampala as a pilot project over five years ago by a person who saw this technology being used in China. This idea was then picked up by people in other nearby locations. However, adoption rate has been gradually slow slow due to lack of knowledge in efficient utilization of rumen content in livestock diets.

### 5.1.7 Proportion of rumen content use in different livestock

In relation to proportion of rumen content in livestock, it was found that, rumen contents were mostly used in pigs and layer diets with varying inclusion levels. Despite rumen contents being reported as having no ant-nutritional factors (Agbabiaka *et al*., 2012), there is an optimum inclusion level in livestock diets that must not be surpassed, beyond which animal performance becomes compromised. In this study, 85.8% of the respondents incorporated rumen contents in layer diets at 20% inclusion level. Despite achieving their objective of improving egg yolk color, the 20% rumen content inclusion level was quite high for proper layer growth performance (Odunsi, 2003). Available literature shows a reduction in average daily feed intake (AFI), hen day egg production (HDEP), egg weight and shell thickness with increasing levels of rumen contents in layer diets (Gebrehawariat *et al*., 2016; Odunsi, 2003) due to high rumen content fiber levels.

In pig diets, 77.4% of the respondents could not quantify the amount of rumen contents they used. Despite the fact that numerous feed ingredients provide nutrients that pigs require to grow, pigs too require a balanced feed ration that provide optimum energy, proteins, and vitamins for better growth performances (Adesehinwa, 2008; Mwesigwa *et al*., 2013). More so, rumen contents are high in crude fiber which can limit feed intake (FI) and lead to poor growth due to inefficient feed utilization. Thus, the notion by most farmers that pigs can eat anything offered to them without catering for optimum nutritional needs requires mind set change for improved pig performance. No respondent indicated use of rumen contents in broiler diets as they envisaged no beneficial effects to broiler chickens. However, there seems to be a knowledge gap by this assertion, since use of rumen content has been reported to improve broiler performance (Fathalla *et al*., 2015; Inci *et al*., 2013).

### 5.1.8 Problems encountered with use of rumen contents

Optimum inclusion rates of rumen contents in livestock rations was the most encountered challenge by the respondents, this was followed by difficulties in drying rumen contents and bad smell. Insufficient knowledge with regard to proper use of rumen contents in animal diets was the major hinderance to rumen content utilization. Lack of knowledge by the farmers affects rate of technology adoption (Kasule *et al*., 2014; Mwesigwa *et al*., 2020), and this probably explains why use of rumen contents was not a common practice among respondents.

While drying rumen content, some farmers reported being burnt by the heat that is generated from the decomposition of rumen contents which resulted in skin lashes. Other respondents also reported injury infliction by the sharp objects found in rumen contents. Such injuries led to a lot of pain and other health related problems (Mann *et al*., 1983). Bad smell from rumen content was also encountered by several farmers as a hindrance to rumen content use as feed ingredients in livestock diets.

Contaminants found in rumen contents included; polythene bags, metallic objects and tree thorns. The sharp objects usually pierced hands during sun drying of rumen contents. Contaminats in the rumen contents result from animals grazing on diverse feed sources (Lange *et al*., 2018). Plastic bags are more pronounced in livestock reared in urban setttings compared to those reared in rural seetings with vast grazing lands (rangelands). In the urban settings, there is enormous use of plastic packaging materials which are then disposed along with food left overs. Though bill restricting the use of polythene bags was enacted years back, Uganda is still yet to implement full banning of plastic bag usage. Unrestricted disposal of plastic bags leads to environmental pollution and also limits the sustainability of life support systems, social harmony and human health (Aurah, 2013). It is therefore, important to limit the exposure of livestock to contaminants as this can lead to depression, reduced milk production/yield, bloat, gastro intestinal tract (GIT) obstruction and eventually economic loss (Okunola A *et al*., 2019) and in extreme cases death of livestock.

### 5.1.9 Advice farmers needed for efficient utilization of rumen contents in livestock diets

Farmers stated several areas where they needed advice in relation to efficient utilization of rumen contents for improved livestock production. Overall, most farmers indicated that, they needed advice in pig and poultry feed formulation. The kind of advice needed included; levels of inclusion of rumen content in the diets, rumen content processing methods and its storage in order of importance. This revelation is in line with the findings of Kasule *et al*. (2014) who reported farmer's own feed rations being nutritionally lacking while investigating the nutritional properties of own mixed chicken rations in urban and peri-urban areas of Kampala. As such, farmers needed advice on how to formulate nutritional quality feed so as to ensure profitable and sustainable livestock production. A study by Mwesigwa *et al*. (2015) also revealed that, most farmers are not aware of the nutritional composition of the diets they give to their animals. This implies that, extension services to the farmers still seems a daunting challenge that calls for collective efforts and political will in terms of allocation of research funds and hiring adequate extension staff.

### 5.2 Effects of inclusion of dried goat rumen contents in broiler chicken diets on growth, blood metabolites, carcass parameters and consumer acceptability

#### 5.2.1 Chemical analysis of feed ingredients and experimental diets

The crude fiber (CF) and Phosphorus (P) exhibited by dried goat rumen content (DGRC) is in line with the findings of other researchers (Djordjevic *et al*., 2006; Gebrehawariat *et al*., 2016). Dry matter (DM), crude protein (CP), calcium (Ca) and phosphorus (P) values of DGRC were higher than those reported by Gebrehawariat *et al*. (2016). This may be due to nutritional differences with respect to season and the type of animal from which the rumen contents were gotten from. The goat rumen contents used in the study experiments were collected from the abattoir during the wet season, therefore, the forages eaten by the goats prior to slaughter must have been young and tender with high concentration of minerals (Agbabiaka *et al*., 2012). Goats are browsers (concentrate selectors) and therefore tend to go for tender leaves and grasses that are more nutritious (Tsega & Tamir, 2009), resulting in their rumen content being finer, less fibrous and more nutritious than that of large ruminants (bulky feeders) such as cattle, camel and buffalo. This may further explain why goat rumen content had lower crude fiber (CF) in comparison to CF of sun dried bovine rumen contents (SDBRC) reported by Gebrehawariat *et al*. (2016). The composition of rumen contents is also influenced by pre-slaughter conditions exposed to the animals such as type of feed characteristics, selectivity of pastures in different locations and holding period prior to slaughter (Abouhief *et al*., 1999; Agbabiaka, *et al*., 2012).

#### 5.2.2 Chemical composition of experimental diets

Despite the experimental diets being formulated to meet the nutritional requirements for growing birds (isocaloric and isoproteinous), there were differences in crude fiber (CF) contents of the diets as a result of incorporation of dried goat rumen content (DGRC). Even though the fiber content of the diet with 10% dried goat rumen content (DGRC) inclusion level was higher, it was within the recommended limit (2-5%) for normal growth responses of the birds (NRC, 2001). Several authors have reported rumen contents to contain high fiber content which tend to increase the total fiber content of the diets (Esonu *et al*., 2004; Khan *et al*., 2014) which eventually limits rumen contents incorporation in poultry feeds. Although high fiber leads to low energy in poultry diets (Jha *et al*., 2019), levels of 50g/Kg (5%) feed are actually beneficial for gastro intestinal development, function and health (Shakouri *et al*., 2006; Sklan *et al*., 2003). As the fiber in the gastro intestinal tract (GIT) is fermented by lactobacillus and fibidobacterial species, production of lactic acids and short chain fatty acids which results in lower pH thereby creating a suitable environment for maintaining normal microbial population, thus preventing pathogen establishment in the GIT (Jha & Berrocoso, 2016).

### 5.2.3 Nutrient digestibility

Improvements in nutrient digestibility leads to increased nutrient availability which eventually improves the performance of the birds. In this study, incorporation of dried goat rumen contents (DGRC) at 5% improved the digestibility of dry matter (DM), crude protein (CP), crude fiber (CF), calcium (Ca) and phosphorous (P) which was in line with works of A Cherdthong (2020). This implied that, there is a limit to which dried goat rumen contents (DGRC) can be incorporated in diets for growing birds beyond which digestibility of nutrients becomes compromised (Oguri *et al*., 2013). More so, rumen contents contain bacterial cells and minerals, that are of high biological value (Okpanachi *et al*., 2011), which could have enhanced nutrient digestion in diets where rumen contents were incorporated.

The apparent ileal digestibility coefficients (Table 14) revealed the same trend, birds on 5% dried goat rumen content (DGRC) diet had better digestibility coefficients in relation to dry matter (DM), crude protein (CP) and phosphorus than those on 0% DGRC and 10% DGRC diets. However, despite the differences in apparent ileal digestibilities (AID), the coefficients seemed to have been over estimated by the model. The results concurred with the findings of Garcia *et al*. (2007).

### 5.2.4 Performance of broiler chickens fed dried goat rumen contents

The improved performance of birds on diets with DGRC as compared to those with no DGRC in the diets (Table 15) is in agreement with the report of Esonu *et al*. (2006) who observed a general increase in growth rates of birds as the level of rumen content was increased in the diets as a result of improve nutrient digestibility. However, the significant decrease in average daily feed intake (ADFI) of birds with increase in dried goat rumen contents (DGRC) at 5 and 10% levels in the diets may be attributed to increase in fiber content as a result of increasing levels of dried goat rumen (DGRC) contents in the diets (Jiménez-Moreno *et al*., 2009; Makinde *et al*., 2017; Oscar & Woo, 2021; Ubua *et al*., 2019) and more so to the choking effect of rumen contents as visually seen by some birds being choked while feeding. Fibrousness of diets limits feed intake (FI) especially in young birds because the gastro intestinal tract (GIT) cannot digest fiber easily (Gebrehawariat *et al*., 2016; Ubua *et al*., 2019). Additionally, as the level of DGRC increased in the diets, there was an increased greenish color in the diets which could have led to a commensurate increase of abnoxious odor. This, with the accompanying choking effect in the diets could have eventually translated into reduced feed intake by the birds (Adeniji & Balogun, 2005; Dongmo *et al*., 2000; Fathalla *et al*., 2015; Odunsi, 2003; Yitbarek *et al*., 2016). Despite the reduced average daily feed intake (ADFI) exhibited by the birds fed diets with DGRC, their growth performance was not compromised in relation to body weights (BWs) which signifies that nutrient digestibility was un interrupted. Birds on the 5% DGRC diet had better body weight gains as compared to birds on 0 and 10% DGRC diets (Table 15). The better weight gain exhibited by the birds may partly be attributed to better feed digestibility by the birds (Table 13). Digestibility of DM, CP, CF, EE and ME were improved at 5% DGRC in broiler diets in comparison with the 0% and 10% DGRC diets. Rumen contents are largely comprised of partially digested forages with appreciable quantities of microbial protein, amino acids (AA), tannins, volatile fatty acids (VFAs) and a vast array of minerals which are not only responsible for promoting good chick growth but also of valuable significance in protecting chicks from infectious diseases thereby improving the gut health and immunity (Alagbe, 2017; Hidanah *et al*., 2018; Rodríguez *et al*., 2012; Sebola *et al*., 2019; Sugiharto *et al*., 2019). Even though the diets with dried goat rumen contents (DGRC) were high in fiber, growth of the birds was not affected, this was due to the fact CF was within the acceptable limits and therefore did not compromise nutrient availability and retention by the birds. Dietary fiber (DF) affects gastro intestinal tract (GIT) development and is pertinent in modifying microbial intestinal characteristics thereby enhancing balanced growth (Hetland *et al*., 2004; Mateos *et al*., 2012).

Several studies have reported a decline in performance of birds as the levels of rumen content (RC) increased in the diets (Colette *et al*., 2013; Elfaki & Abdelatti, 2015; Tesfaye *et al*., 2013).

In this study, even though the growth performance of birds decreased as the level of dried goat rumen content (DGRC) in the diets was increased from 5% to 10%, this was far better than the average body weight gain of birds fed on the control diet (Table 14). This is explained by the better nutrient digestibility (Table 14) which improved feed efficiency translating into better body weight gains. This further indicates that, even the 10% DGRC diet could be effective in replacing the control diet (0% inclusion of DGRC) without compromising the birds' performance and at even a better feed conversion ratio (FCR). The lower FCR exhibited by the birds fed on diets with DGRC is in line with the findings of Makinde *et al*. (2008) who observed similar effects while investigating the conversion of abattoir wastes into livestock feed. These results are handy and come at a time when poultry farmers are grappling with rampant adulteration of feed ingredients especially those of animal protein origin (fish meal) which are more expensive (Jazi *et al*., 2017; Mohanta, 2012; Mwesigwa *et al*., 2013; Raza *et al*., 2015). Rumen contents are less expensive and readily available at most slaughter houses, therefore, efficient utilization of rumen contents in livestock feeds would not only save farmers a great deal of costs but also safeguard the environment from pollution (Elfaki & Abdelatti, 2015; Katongole *et al*., 2009; Mwesigwa *et al*., 2013). The mechanisms through which dried goat rumen contents (DGRC) based diets improved the performance of the birds could be due to moderate fiber content in the diet which could have improved the gut morphology thereby stimulating mucosa enzyme activity eventually improving nutrient digestibility (Jha *et al*., 2019; Molist *et al*., 2009). Additionally, the extraction of energy and nutrients from ingested food requires the interaction of both biochemical reactions of the chicken and the microbiota (Brisbin *et al*., 2008; Sergeant *et al*., 2014) present in the gastrointestinal tract (GIT). Therefore, incorporation of rumen contents in the diets may have led to increase in the digestive and absorptive capacity of the birds through encouraging the proliferation of beneficial microbiota. These microorganisms play an important role in digestion thereby encouraging a greater flow and absorption of nutrients in the small intestines (Jha & Berrocoso, 2016).

### 5.2.5 Effects of dried goat rumen content based diets on carcass and organ characteristics of broiler chickens

The success in the broiler industry is reflected by improvements in growth and carcass weights of commercial interest to the consumer (Faria *et al*., 2010; Musa *et al*., 2006). In this study, carcass (wings, thigh and breast) weights were improved by incorporating rumen contents in broiler diets (Table 16), this finding is in agreement with Fathalla *et al*. (2015) and Inci *et al*. (2013). Similarly, Colette *et al*. (2013) showed that feeding broilers with diets in which dried rumen contents was incorporated resulted in better carcass yield as compared to when broilers are fed on a mixture of dried rumen contents at 25% castor oil seed cake. However, this contrasts with several studies that found no significant effect of adding dried rumen content (DRC) on chicken carcass weight (Onu *et al*., 2011). The increase in carcass weights could be as a result of improved nutrient digestibility with incorporation of dried goat rumen contents in the diets of growing birds (Table 14). In relation to organ weight, results of this study revealed increase in organ weights with increasing levels of DGRC in the diets which was is in line with the findings of Fathalla *et al*.(2015) and Esonu *et al*. (2006) who reported increase in gizzard and heart weights. This could be due to increased amount of work of these organs as a result of increased fiber digestion leading to organ hypertrophy (Molist *et al*., 2009). However, this was contrary to the findings of Esonu *et al*. (2006) who reported no difference in organ weights despite increase in body weights as result of feeding broilers on dried rumen digesta.

Fiber is a component of plant based feed ingredients and is of significant importance to birds in that it stimulates digestive organ (ileum, gizzard, pancreas and large intestines) developments and more so enhances the growth performance of broilers (Banfield *et al*., 2002; González-Alvarado *et al*., 2007; Kheravii *et al*., 2017; Sadeghi *et al*., 2015). However, there is a limit to which fiber elicits improved growth responses beyond which performance becomes compromised. In this study, the fiber content increased with increasing dietary inclusion of dried goat rumen content (DGRC). In this study, liver, gizzard, and large intestines weights, length of proventiculus and caecum increased with increase in dietary fiber. However, despite this increase, the fiber content remained within the recommended range (3-5%) for normal bird growth.

In relation to abdominal fat deposits, birds fed on diets with 5% dried goat rumen contents (DGRC) had a higher abdominal fat content than those fed on 0% and 10 % DGRC diets. This may have been due to higher digestibility of the diet by the birds on this diet which led to increased dietary energy intake in excess of the body energy requirements (Fouad & El-Senousey, 2014; Ghaffari *et al*., 2007). As the birds increased in body weight, the excess energy was deposited as abdominal fat. The high abdominal fat is not only usually considered as a waste especially when the birds are processed and therefore an economical loss for poultry producers but also a significant factor that affects carcass quality (Suzuki *et al*., 2019).

Additionally, consumption of broiler meat with too much fat may lead to obesity and other associated diseases in humans (Le Mignon *et al*., 2009).

### 5.2.6 Effect of dried goat rumen contents (DGRC) based diets on broiler bird hematological parameters

Blood examination provides vital information about the poultry health status. Through such information, necessary remedies can then be initiated by the farmer for the sustainability of the poultry business. In this study, inclusion of dried goat rumen contents (DGRC) in broiler diets did not affect granulocytes (white blood cells) and red blood cells (RBC). This signified that the roles granulocytes and RBCs play were un- interrupted (Gebrehawariat *et al*., 2016) by incorporation of rumen contents in the diets. Granulocytes are the immune system's main cellular defense against pathogen invasion of bacterial and fungal origin. This further showed that, immune responses of birds were not compromised and birds were able to defend themselves in response to pathogen attack (Iheukwumere & Herbert, 2003). On the other hand, red blood cells (RBC) transport oxygen to all body parts. The results of both red blood cells (RBC) and white blood cells were within the normal ranges for the normal growth of the birds which was in line with the findings of Iheukwumere & Herbert (2003). Most blood parameters for instance, lymphocytes, hemoglobin (HGB), mean corpuscular volume (MCV) and mean corpuscular hemoglobin (MCH) were not affected by dietary inclusion of dried goat rumen contents (DGRC) in broiler diets. This implied that DGRC is safe to use as feed ingredient to the birds, this is line with the findings of Ajayi & Imouokhome (2015) and Fathalla *et al*. (2015).

Lipid metabolites including, triglycerides, lipoproteins, total cholesterol (TC) as well as fractions fatty acid profiles in chicken blood are indicative of level of fat metabolism (Safaa *et al*., 2014). Lowered triglycerides in poultry meat would be beneficial to consumers as they lead to risk reduction of ischemic heart diseases (Kratz, 2006). The results of this study indicated that incorporation of DGRC in broiler diets was beneficial in reducing total blood cholesterol (TC) and high density lipoproteins (HDL) in broilers. Cholesterol and lipoprotein are excreted from the body through bile. The mechanism through which cholesterol and lipoprotein are formed might have partly been slowed down by incorporation of dried goat rumen content (DGRC) in the diets. Dietary effect on serum triglycerides showed a quadratic trend, increasing in birds on 5% DGRC diet and then decreasing as the level of DGRC in the diet increased to 10%. Generally, the mechanisms through which triglycerides increased and decreased at 5 and 10% DGRC inclusion in the diet respectively cannot be clearly elucidated by this study. However, goats following grazing consume a mixture of plants, shrubs and herbs which have been reported to possess high medicinal values and therefore of multiple health applications (Alagawany *et al*., 2019; Tiwari *et al*., 2018; Upadhayay *et al*., 2012; Yatoo *et al*., 2017). It is possible that, the medicinal properties may have mirrored in dried goat rumen contents (DGRC). Thus, at 10% DGRC inclusion in broiler diet may have led to inhibition of enzymes involved in the synthesis of cholesterol and lipids hence the registered low triglycerides levels. In their works, Saeed *et al*.(2017) and Kamboh *et al*. (2018) reported that herbs contain secondary metabolites such as alkaloids, tannins and flavonoids which could positively influence the bird's health.

Levels of triglycerides (TGs) in blood are also influenced by dietary fatty acid (DFA) profile particularly the ratio of polyunsaturated fatty acids (PUFAs) to saturated fatty acids (SFAs) (Sanz, 1999; Viveros *et al*., 2009). Higher PUFAs: SFAs ratio decreases chylomicron secretion from intestinal cells and suppress hepatic fatty acid synthesis and TGs production in chicken. Incorporating grass as part of chicken nutrition improves polyunsaturated fatty acids (PUFAs) content in relation to saturated fatty acids (SFAs) (Bessa *et al*., 2006; Crespo & Esteve-Garcia, 2002). Since rumen contents is composed of a mixture of partially digested grass species, its use in broiler diets could have elicited similar effects on PUFAs: SFAs ratio in broilers.

Triglycerides are produced in the liver by hepatic lipogenesis and then secreted in blood plasma. This process may have been altered by increasing levels of dried goat rumen contents (DGRC) in broiler diets and hence the observed decrease in triglycerides. Even though the fatty acid profile of chicken meat was not determined in this study, dietary lipid intake in chicken is reflected in tissue fatty acid profile (Khatun *et al*., 2017) and can alter the level of triglycerides (TG) and lipoproteins (LP) in blood (Abdulla *et al*., 2015).

### 5.2.7 Effect of dietary composition on broiler meat chemical composition

Meat quality has gained immense support globally as a result of consumers increasing awareness with regard to maintenance of peoples' health status (Delgado-Pando *et al*., 2019; John *et al*., 2016). The variation in moisture content (MC) of the broiler meat (Table 18) could be attributed to differences in biochemical processes in the meat post slaughter. Despite variation in moisture content (MC) of broiler meat with increasing levels of DGRC in the diets, carcass moisture content was within the range (60-80%) reported in several studies

(Chepkemoi *et al*., 2017; de Oliveira *et al*., 2016). Moisture is an important constituent of meat and a major contributing factor to meat perishability. However, apart from reduction in shelf life, moisture has a strong impact on meat color, texture and flavor. Poultry meat is made up of approximately 60 to 80% water, 15 to 25% protein, and 1.5 to 5.3% lipids (Mbaga *et al*., 2014).

Ash content is an important indicator of not only the number of minerals that can be found in a given food but also the extent to which dietary minerals would be available in food (Ogunmola, 2013). In this study, a step further to determine the individual mineral profiles in the meat samples was done, however, minerals are essential nutrients that play a vital role in skeletal development, growth and remodeling (Prabhu *et al*., 2016). The ash content among meat samples in this study (Table 18) was improved by incorporation of DGRC in broiler diets. This signified that even though average daily feed intake (ADFI) was different across diets (Table 15), this did not affect mineral metabolism in the birds, however, the reason behind this is still unclear but could be due to increased bio availability of minerals in the diet. Li *et al*. (2016) elucidated that concetrations of minerals in the body is tightly monitored under the metabolic control and alternations in intake impacts little effect on body mineral circulation. The results of ash content in this study are in agreement with the findings of Chepkemoi *et al*. (2017) for commercial chickens.

The fat content (EE) of broiler meat did not differ across diets (Table 18), implying that fat accretion by the birds was not influenced by dietary inclusion of dried goat rumen contents (DGRC) in broiler diets. In this study, the diets were formulated to provide same level of energy (Table 12) and subsequently fat content is dependent on the dietary energy intake from feeds, the birds must have consumed just enough feed to satisfy their metabolic energy requirements. This finding differs from Mbaga *et al*. (2014) who found more fat (EE) in the thigh of local chicken than in the breast meat, they attributed the thigh muscle energy store to the daily energy requirement for walking. However, in our study, the birds were kept indoors throughout the experiment and therefore required minimal energy for moving around the cages.

Apart from providing energy, lipids in broiler meat also play a significant role in the organoleptic quality of the product due to the influence on sensory properties like texture, color, and flavor (de Lavergne *et al*., 2015; Zerehdaran *et al*., 2004). However, the presence of lipids in food, especially cholesterol and saturated fatty acids **(**SFA**)**, is often associated with the risk of cardiovascular diseases (Frank *et al*., 2016; WHO, 2008). This reduces the meat quality and therefore commercial quality.

Crude protein (CP) was higher for breast meat of birds fed on 5 % DGRC diets. This could be probably due to better growth rates of bird fed on this diet, which translated into better breast weight as a result of improved CP utilization. Proteins are required by the animals for their growth and development and therefore protein accretion into body tissues and blood is indicative of how good the protein is in terms of quality.

### 5.2.8 Effect of dried goat rumen contents (DGRC) based diets on broiler meat water holding capacity

Water holding capacity (WHC) of meat refers to the ability of meat to retain water when subjected to external pressure like compression and centrifugation (Cheng & Sun, 2008; Pearce *et al*., 2011). It reflects the extent to which proteins bind water which is a very important attribute in determining visual acceptability, weight loss, cook yield as well as sensory traits on consumption (Bertram *et al*., 2003; Rosenvold & Andersen, 2003). In this study, incorporation of DGRC in broiler diets led to improved water holding capacity (WHC) of the breast meat in comparison to the diet with no DGRC. This was probably due to the higher protein content of the breast meat for broilers fed on DGRC diets (Table 18). Meat with high protein content provides a high space for protein to bind water molecules. Proteins make the largest contribution to WHC, myofibrillar and sarcoplasmic protein contribute 50 and 3% respectively while the non-protein component contribute 47% of the WHC (Hamm, 1986; Petracci *et al*., 2013). Proteins in the breast meat also play a significant role in sensory, processing and nutritional traits. The ability of meat to hold water is a complex trait that is influenced by biochemical and structural process that accompany processing of muscle to meat (Samiullah *et al*., 2017). Decrease in pH forces intramyofibrillar water into the extracellular space resulting into a potential drip.

### 5.2.9 Effect of dried goat rumen contents (DGRC) based diets on sensory characteristics of broiler meat

Sensory evaluation of food products provides an understanding and guidance on the key attributes for the consumers that enable a product to become competitive in the market (Maria, 2019). Meat appearance in relation to texture, juiciness, wateriness, firmness, tenderness, odour and flavor influences the judgment by consumers prior and post meat product purchasing (Mir *et al*., 2017). Adding rumen contents in the diets improved juiciness, wetness and oiliness of broiler meat (Table 20). In meat, proteins and fat perform a primary role in taste, juiciness and flavor, thus a decrease in protein and fat content negatively impacts on consumer meat acceptability (Cofrades *et al*., 2000). Despite the interrelationship between fat, flavor and juiciness of meat (Table 21), utmost care should be taken to avoid over fattening of meat as this is linked to health hazards by most consumers (Frank *et al*., 2016). In this study, oiliness of the meat was negatively associated with hardness of meat which was similar to findings of de Lavergne *et al*. (2015) and Frank *et al*. (2016) who reported that, fat content of meat is positively correlated with meat softness. This could have contributed to the improved tenderness of broiler meat (Table 20).

Inclusion of dried goat rumen contents (DGRC) in the diets had no effect on cooked meat colour. Since color of meat is influenced by the content of myoglobin in the muscle, it implied that use of DGRC in the diet did not influence myoglobin roles which includes storing and transporting muscle oxygen (Joo *et al*., 2013). However, visual observation of carcasses at the time of slaughtering revealed differences in skin colour. This signified that, rumen content in the diets influenced this color change (Plate 3 and 4). Rumen contents contain xanthophyll which could have impacted carotenoid deposition in the skin. Yellow carcass skin is also observed from birds reared on free range system (scavenging with access to forage). Several reports attribute meat colour appearance to be major factor that influences acceptability of meat by consumers (Mir *et al*., 2017). Most consumers often link yellow color with freshness and nutritional value (Adeyemi *et al*., 2016; Joo *et al*., 2013; Mennecke *et al*., 2007). The results suggested that inclusion of DGRC in broiler diets could produce meat with attractive color and of good sensory characteristics to consumers which eventually increase its market demand. This was similar to the finding of (Colette *et al*., 2013) who observed improvement in broiler meat sensory attributes as a result of inclusion of dried rumen contents in the diets that eventually improved consumer preference.

**Plate 2.** Yellowish skin color **Plate 3.** White skin color (0%DGRC

(**Photo credit:** Mwesigwa Robert)

### 5.2.10 Economics of inclusion of dried goat rumen contents (DGRC) in broiler diets

Incorporation of DGRC in broiler diets resulted in reduced cost per kilogram feed (Table 22). This was due to price differences between fish meal and rumen contents. At the time when this study was conducted, the cost per kilogram of DGRC (inclusive of collection, drying, transportation and milling) was estimated at \$0.081 whereas that for fish meal (FM) was at \$0.81. The reduced cost per kilogram of feed as result of DGRC incorporation was also reported by Esonu *et al.* (2006) who observed that, the use of dried rumen contents as supplements in broiler diets provides cheaper cost of feed per kilogram of meat produced which made an economic sense. The study further revealed that, higher economical returns can be realized from incorporation of 5% dried goat rumen contents in the broiler diets. Beyond this level, economical returns start to decline. This concurs with the finding that incorporating food processing by-products in broiler diets reduces production costs (Sugiharto *et al.*, 2019). However, there is a threshold at which by-products should be incorporated in poultry feeds. The results are not only crucial for poultry business but also to the abattoir operators who have been grappling with rumen content disposal challenges (Aniebo *et al.*, 2009).

## 5.3 Effect of inclusion of dried goat rumen contents in layer diets on laying percentage, egg characteristics, profitability and consumer egg acceptability

### 5.3.1 Chemical composition of layer experimental diets

Dietary fiber content increased with increased use of DGRC. This was because rumen contents are high fiber rich feed stuffs and therefore there is a limit to which they can be incorporated in layer diets without compromising performance. This finding is in line with the results of

Djordjevic *et al*. (2006). Despite the disparities in the CF content in layers diets, CF of the diets was within the range (2-5%) for optimum layer performance as reported by NRC (2001). Protein and metabolizable energy in the diets for both the growing and laying stages were within the range to elicit proper growth and laying responses. Protein and energy are vital nutrients for poultry (Dairo *et al*., 2010), and they play a significant role in growth, egg production, immunity and more so help the bird adapt to the environment (Adedokun & Olojede, 2019; Banfield *et al*., 2002). In general, diets for poultry should be properly formulated with precision in order to me*et al*l the nutritional requirements for optimal performance (Neves *et al*., 2014).

### 5.3.2 Effect of dried goat rumen contents (DGRC) based diets on nutrient digestibility in layers

In this study, incorporation of DGRC at 5% level in layer diets led to improvements in digestibility of crude protein (CP), crude fiber (CF) and dry matter (DM). This could be probably due to improvement in GIT functionality brought about by beneficial effects of fiber (Bindelle *et al*., 2008). This further shows that there is a limit to which rumen content can be incorporated in broiler diets beyond which digestibility coefficients become compromised. Rumen content also contains good quality protein with high profile of essential amino acids (Agbabiaka, 2012; Elfaki & Abdelatti, 2015; Esonu *et al*., 2006). Improvement in crude fiber digestibility at 5% DGRC incorporation in layer diets could have led to better gastrointestinal tract (GIT) health, thereby stimulating more microbial colonization which led to higher fiber digestion (Kheravii *et al*., 2017). Although the diets were formulated to contain the same dietary fiber content, there were differences in fiber content with increase in DGRC in the diets (Table 23). Despite the variability in dietary fiber content, it was within the range recommended for proper growth and laying phases in layer diets (NRC, 2001).

### 5.3.3 Effect of DGRC based diets on daily feed intake, feed conversion ratio and mortality rate in layers

Since feeds contribute the highest percentage of production cost, average daily feed intake (ADFI) of birds therefore remains an important economic factor that determines growth and profitable poultry enterprise. The increase in average daily feed intake (ADFI) as the levels of DGRC increased in layers diets was line with reports of Bekele *et al*. (2020) and Elfaki & Abdelatti (2016). Higher levels of DGRC led to increase in crude fiber content (CF) that consequently might have decreased dietary energy density thereby increasing feed intake by the birds in order to meet optimal energy requirements to sustain growth. As dietary fiber increases there is also a tendency for nutrient dilution, improvement in nutrient digestion which forces the birds to consume more feed inorder to meet body nutrient requirements. However, despite the increase in ADFI with increased levels of DGRC in the diets, there was low average daily gain (ADG) among the birds. It is possible that there could have been interferences in nutrient digestibility especially dry matter and metabolizable energy (Table 24).

Feed conversion ratio (FCR) in both the growing and laying phase was better for birds fed 0% DGRC diets than those fed on 5% and 10% DGRC diets. This could be attributed to improved nutrient digestibility (Table 24) by the bird fed on 0% DGRC diets in comparison to the birds on 5% and 10% DGRC diets.

### 5.3.4 Effect of DGRC on body weight gain in layers

Incorporation of DGRC in layer diets led to a significant linear reduction in body weight gain (BWG) in both grower's and laying stage of production (Table 25). In general, this study revealed slow growth rate of chickens especially during the grower stage.

### 5.3.5 Effects of DGRC based diets on egg production

Egg production and laying percentage was high in layers fed 0 and 5 % DGRC than their counterpart fed on 10% DGRC diets. However, no observed significant differences in laying percentage of hens on 0 and 5% diets. This could have been due to better growth rates exhibited by the birds on 0 and 5% DGRC diet. This finding concurred with those of Bekele *et al*. (2020) and Odunsi (2003) who reported a stepwise decrease in egg production for the pullets fed high levels of blood and rumen contents. Even though laying hens on 10% DGRC diets were the first to reach point of lay in this study, the dietary effect on egg production was short lived. In poultry, just like any other animals, impaired efficiency of feed utilization compromises performance (Adedokun & Olojede, 2019; Motamedi & Taklimi, 2014). Laying hens on the 10% DGRC were characterized by poor feed conversion ration (FCR) in both growing and laying stages despite the increased dry matter intake (DMI) exhibited by the birds. The poor feed efficiency exhibited by these birds could have been due to higher fiber content in the diets, which might have diluted energy content of the diet. Additionally, the 10% DGRC diet had low DM and energy digestibility which could have contributed to the poor performance of the birds (Table 24). Generally, the growing stage of experimental birds was characterized by relatively low DM intake, poor efficiency of feed utilization and slow growth rate (Table 25).

This is probably because of change of diets from what birds were subjected to prior to experimental diets. The experimental birds were bought at 2.5 month old and continued on grower diets prior to switch to experimental diets at 3months old. Furthermore, at the growing stage birds utilize nutrients to a lesser extent as compared to adult birds which could affect egg production (Cozannet *et al*., 2010; Svihus & Gullord, 2002).

In relation to percentage egg production, hen day egg production (HDEP) and hen house egg production (HHEP) which are among the factors that contribute to the total number of eggs laid. Inclusion of DGRC in diets for laying hens, led to a decrease in percentage HDEP and HHEP. However, there was no significant differences in egg laying percentage between layers fed 0% DGRC (DT) and those fed 5% DGRC (DT2). The decrease in HDEP and HHEP could be as a result of nutrient dilution by adding DGRC in the diet, which could have led to nutrient imbalances. This result concurs with the findings of Bekele et al. (2020) and Odunsi (2003). The differences in HDEP among treatments indicate uniformity in laying pattern and the quantities of eggs laid. More so, in this study, despite the increase in average daily feed intake (ADFI) (Table 25) by the birds with increasing levels of DGRC in the diets, average daily gain (ADG) by the hens was low and subsequently resulted to low production performance and low HDEP and HHEP.

### 5.3.6 Effect of diets based on DGRC based diets on egg characteristics

Dietary nutrient supply and feed characteristics (texture, composition and energy) are the most important factors that affect egg physical and quality characteristics. Birds fed on 0% DGRC diet had heavier eggs across the diets throughout the sampling period (Table 27).

Egg weight, a primary criterion used in the grading of eggs for the market is influenced by the feed, protein and energy consumption (Mwaniki *et al*., 2018; Wang *et al*., 2017). Since, average daily feed intake (ADFI) was higher for birds fed on 0% DGRC diet, this could have led to increased protein and energy intake (efficiency of feed utilization) and hence the observed higher egg weights.

However, this result contrasts sharply from those of Gebrehawariat *et al*. (2016) who observed increased egg weights in birds on high rumen content diets. This was due to differences in dry matter (DM) intake. In this study DM intake decreased with increasing levels of rumen content in diets. Increased levels of DM intake was reported by Gebrehawariat *et al*. (2016) which led to increased intake of crude protein and energy and hence increased egg weight. The observed increase in egg weight with increasing age of laying birds is in relation with increase in both albumen and yolk weights relative to yolk proportion which is similar with the findings of Tůmová & Gous (2012).

Egg shell is a biological barrier that protects internal egg contents (Portugal *et al*., 2014). The shell constist of an array of minerals with calcium contributing more than 90%. Egg shell quality is therefore of paramount importance in that, it determines marketability of the eggs (Jiang *et al*., 2013; Maxkwee *et al*., 2014; Pastore *et al*., 2012). In this study, egg shell weight was generally higher in eggs of birds fed on 0% DGRC diets and increased as the laying period progressed, this was also reported by Roberts *et al*. (2013). In the early egg production, the hens are still growing hence utilizing minerals for growth and less is available for egg shell formation. As laying proceeds, there is egg shell quality probably due improved calcium and phosphorus metabolism in birds (Jonchère *et al*., 2012). In addition to length of lay, egg shell quality was also affected by egg storage conditions and feedstuff nutritional composition (Wilson, 2017). During storage, egg shell through its pores allows carbondioxide and moisture to escape thereby increasing albumen pH as result of broken down albumen carbonic acid which compromises egg quality (Akyurek & Okur, 2009; Biladeau & Keener, 2009; Yuceer & Caner, 2014). Similarly, egg shell quality is affected by the levels of Ca, P and Vitamin D3 in feeds. Efficient Ca metabolism ensures that sellable eggs are of good quality with stronger shell strength (de Matos, 2008; Kaur *et al*., 2013; Rossi *et al*., 2013). Mean egg shell thickness in this study revealed no significant differences between diets. This could be due adequate supply of calium and phosphorus by the diet and efficient calcium metabolism by the birds. Egg shells are majory a mixture of bioceramic material with 95% calcium carbonate as a polymorphic calcite and 3.5% organic matrix material (Marie *et al*., 2014; Schreiweis *et al*., 2003). Thus, the similarity in overall mean of egg shell thickness implied that diets supplied adequate calcium and phosphorus that could have impoved the metabolism of these minerals during egg shell calcification (Zhang *et al*., 2019). In this study, despite the little variability in calcium digestibility (Table 24) in the laying phase, digestibility of phosphorus across diets was the same.

Yolk weight increased linearly as rumen contents were increased in the diets in the 2nd month of lay. This could be due increase in feed intake with increase in DGRC in the diet resulting in increased nutrient intake and hence the size egg components. This was similar to the finding of Gebrehawariat *et al*. (2016) while investigating the use of sun dried bovine rumen content as a ration ingredient for white leghorn layers. Egg yolk is directly proportional to egg weight (Mwaniki *et al*., 2018) and is composed of 55.02% water, 26.71% fat, 15.50% proteins, 1.09% carbohydrates and 1.68% ash.

Albumen weight showed a linear relationship with egg weight, it was higher in eggs from the hens fed on 0% DGRC diet. Egg weight is positively associated with albumen weight. Larger eggs consist of greater amount of albumen than small eggs. Albumen (egg white) is a protein rich jelly portion of a fresh egg and one of the internal egg quality parameters which serves as the main reservoir of water and proteins. Albumen plays an important role of regulating water exchange between the yolk and the developing embryo (Willems *et al*., 2014).

### 5.3.7 Effect of diets based on DGRC on egg sensory characteristics

In this study, there was change in yolk color with use of DGRC in the diets as scored by the panelists. Eggs presented variations in yolk color that was mainly attributed to sources of pigmentation which may be natural or synthetic (Titcomb *et al*., 2019). The change in color in of the egg yolk with use DGRC in the diets was also reported by Gebrehawariat *et al*. (2016). The yolk color change could have been as consequency of xanthophyll content improvement in the diets as a result of rumen content incorporation. Xanthophyll (oxygen derivative of carotenoid) is found in pastures consumed by animals in form of carotenoids (Prache *et al*., 2003). Xanthophyll in the rumen content is responsible for egg yolk pigmentation (Mugnai *et al*., 2009; Titcomb *et al*., 2019) which in turn depends on digestibility, metabolism, transfer and deposition of carotenoid within the yolk. The content and profiles of carotenoids are responsible for the yolk colour change.

Plate 4 and 5 Show the yolk color changes as result of rumen content use in the diets.

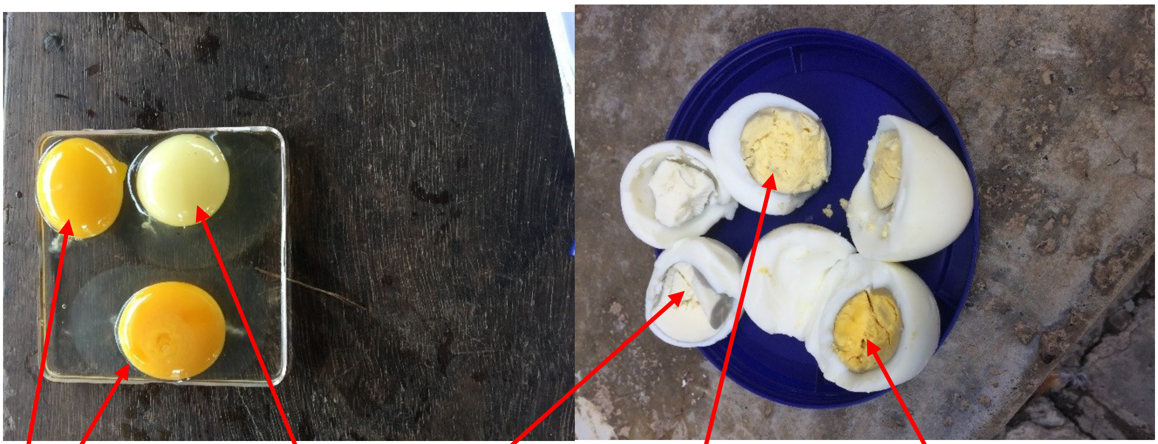


**Plate 4.** Fresh egg yolks **Plate 5.** Boiled eggs

Feed with DGRC diet 0%DGRC diet 5% DGRC diet Feed with 10% DGRC diet

***(Photo credit:*** *Mwesigwa Robert)*

Plates 4 and 5 show egg yolk colour in fresh and boiled eggs as a result of DGRC use in the diets.

Yolk color change with use DGRC in the diets was reported to influence acceptability of the eggs Englmaierová *et al*. (2014). This was further revealed by strong positive correlation between yolk colour and egg acceptability (Table 29). While investigating synthetic carotenoid effect on yolk colour, Englmaierová *et al*. (2013) revealed that the choice of consumers for eggs is no longer based on the internal quality characteristics like level of cholesterol and fatty acid profile but yolk color too. Hens do not have the capacity to synthesize carotenoids and therefore, for yolk color pigmentation, carotenoids must be supplied as dietary ingredients (Bouvarel *et al*., 2011; Hammershøj *et al*., 2010; Karadas *et al*., 2006). Incorporation of DGRC in the diets must have led to increased levels of carotenoid which were digested and deposited in the egg and hence the change in yellow yolk as compared to yolk color of eggs from diets with DGRC. Inclusion of rumen contents in layer diets has had mixed reactions in relation to acceptability eggs by the consumers, with some reports indicating increased in egg acceptance (Englmaierová *et al*., 2013), while others reports showing no difference in egg acceptance (Bekele *et al*., 2020). Increased egg acceptability could have been due to improved quality of the eggs with yellow yolk color. Consumers are increasingly becoming aware of quality and get more attracted to better quality eggs with firm albumen and dense yolk yellow color

(Samiullah *et al*., 2017). Feeding layers on DGRC had not affect on appearance, odour and texture of eggs which was similar to observations by Bekele *et al*. (2020). Generally, all egg quality parameters are affected by a number of factors that take into account of nutrition, disease, housing and management system, quality of water given to the birds and oviposition time (Ahmadi & Rahimi, 2011; Anderson *et al*., 2004).

### 5.3.8 Costs and benefit Effect of inclusion of DGRC in layer diets

Negative marginal rate of return (MRR) with use of DGRC in layer diets was probably due to relatively low growth which translated into low egg production rates of birds on these diets.

# CHAPTER SIX

# CONCLUSIONS AND RECOMMENDATIONS

## 6.1 Conclusions

From the results of this study, it can be concluded that;

i. Extent of use of rumen contents in livestock diets differed among farmers in Uganda and was not widely spread due to lack of knowledge on effective inclusion levels.
ii. Use of dried goat rumen contents in broiler diet at 5% improved growth rate, nutrient digestibility, carcass wing and breast weights.
iii. Inclusion of dried goat rumen contents (DGRC) in broiler diets improved carcass composition (CP and minerals), sensory attributes of broiler meat, reduced total blood cholesterol (TC), high-density lipoproteins, did not affect granulocytes and red blood cells (RBCs).
iv. Use of dried goat rumen content based diets led to delayed point of lay, improved egg quality and egg sensory attributes.
v. Incorporation of dried goat rumen content in broiler diets improved profitability but was not profitable in layers.

## 6.2 Recommendations

i. The government of Uganda through its agencies; the Ministry of Agriculture, Animal Industry and Fisheries (MAAIF), the National Environmental Management Authority (NEMA) should support the initiatives (extension services, provision of user friendly drying technologies like solar driers) towards the use of goat rumen content as a poultry feed ingredient to reduce feed costs and environmental degradation.
ii. Livestock farmers should utilize dried goat rumen contents in broiler diet at 5% level for improved performance of broiler birds.
iii. For improved egg yolk color and consumer egg acceptability, dried goat rumen contents should be incorporated in the layer diets at 5-10%.

## 6.3 Areas for further research

i. To determine the effect of ensiling of goat rumen contents on utilization in pig diets.
ii. To determine the effect of incorporation of fibrolytic enzymes in goat rumen contents-based diets on utilization in pig and poultry diets.
iii. Conduct research on the mechanisms through which dried goat rumen contents influences lipid metabolism in broiler chicken.
iv. Use of DGRC in indigenous chicken (IC) since they constitute 60-70% of the poultry kept in Uganda and given the fact that their ability to handle fiber better than commercial hybrids.

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# APPENDICES

## APPENDIX 1: Questionnaire on extent of rumen contents in livestock diets in Uganda

**Back ground information**

This questionnaire aims to explore the different ways rumen contents are processed and utilized in different agro-enterprise. The data given by respondents will strictly be used for academic purposes only.

**(A) ABBATOIR WORKERS & OPERATORS**

**Section1: BIO-DATA**

**1. Name of respondent ……………………………Mobile…………………………………..**

**County…………………………Parish…………………Village……………………….**

**2. Age (yrs) (i) 10 -20 (ii) 20-30 (iii) 30-45 (iv) 45-60 (V) 60-90**

**3. Position in family: 1.** Head **2.** Mother **3.** Uncle **4.** Son **5.** Daughter **6.** Other

**4. Marital status:** 1. Single 2. Married 3.Divorced 4. Widowed

**5. Number of people in the household: 1. 1-5 2. 5-10 3. >10**

**6. Level of education of the head:** 1. None 2. Primary 3. Secondary 4. A level 5. University

**10.** Type of animals do you slaughter at the abattoir?

(a) Cattle (b) Goats (C) Sheep (d) others specify…………………………………….

**11**. How many animals are slaughtered/day?

| Type of Animal slaughtered | Wet season | Dry season |
|---|---|---|
| Cattle | | |
| Goat | | |
| Sheep | | |

**12**. Places where the animals are mostly got from

| **Season** | **Dry** | | | | **Wet** | | | |
|---|---|---|---|---|---|---|---|---|
| **Animals** | **Place 1** | **Place 2** | **Place 3** | **Place 4** | **Place 1** | **Place 2** | **Place 3** | **Place 4** |
| Cattle | | | | | | | | |
| Goat | | | | | | | | |
| Sheep | | | | | | | | |

**13.** Are there regulation you follow with regards to slaughter waste disposal 1.YES **2**. No

**14.** If yes, name the regulations?

**15.** How do you handle rumen contents during processing?

(a) Separate it according to the type of animal (b) does not separate

**16.** Do you separate discarded carcass from rumen contents 1**.** Yes **2.** No

| **Type of waste** | **Methods of waste disposal** |
|---|---|
| Blood | |
| Gastro intestinal content | |
| Bones | |
| Waste tissues | |

**17. Storage of rumen contents**

(a) Put it drums (b) goes with running water (c) throws it away after slaughter

**18.** After slaughter, how rumen content is stored

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

………………………………………………………………………………………………

…………………………………………………………………………………………………

…………………………………………………………………………………………………

**19.** Where do you put rejected carcasses (offals and meat?)

**(a.**) Sold for dog meat (**b**). Thrown away (**c**). Incinerated (**d**). Processed to other products

**20**. If sold, at what price…………………………………………………………………...

**21**. Contaminants found in rumen contents

| | Type of contaminant | | | | |
|---|---|---|---|---|---|
| Rumen content | 1 | 2 | 3 | 4 | 5 |
| Cattle | | | | | |
| Goat | | | | | |
| Sheep | | | | | |

**22**. Rank the contaminants according to the level of occurrence

1. ……….. ..2. ……………….. 3……………………4…………………5………………..

**23.** What are the challenges encountered with slaughter wastes?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

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…………………………………………………………………………………………………

…………………………………………………………………………………………………

**The End: Thank you**

**(B) LIVESTOCK FARMER INTERVIEW**

**Back ground information**

This questionnaire aims to explore the different ways rumen contents are processed and utilized in different agro-enterprise. It also explores the feed related challenges at individual farm level and the coping strategies farmers use to keep in business. The data given by respondents will strictly be used for academic purposes only.

**1. Name of respondent …………………………….Mobile…………………………………..**

**County…………………………Parish…………………Village……………………….**

**2. Age (yrs) (i) 10 -20 (ii) 21-30 (iii) 31-45 (iv) 46-60 (V) 61-90**

**3. Position in family: 1.** Head **2.** Mother **3.** Uncle **4.** Son **5.** Daughter **6.** Other

**4. Marital status:** 1. Single 2. Married 3.Divorced 4. Widowed

**5. Number of people in the household: 1. 1-4 2. 5-10 3. >10**

**6. Level of education of the head:** 1. None 2. Primary 3. Secondary 4. A level 5. University

**7. Farm type:** 1.Mixed farming 2. Subsistence 3.Large scale 4. Not applicable

**8**. Land size acres………………………………………………………………

**9**. Area under: 1. Livestock………………… 2. Crop …………………………

**10.** Dairy animals (No Kept-------) b) Sheep & Goats (No. kept----------) c) Indigenous chicken (No. kept----------) d) Layers…….. e) Broilers…….. f) Others (specify No. ---------)

**11**. What major feed related problems do you encounter at the farm in chronological order?

…………………………………………………………………………………………………

………………………………………………………………………………………………….

………………………………………………………………………………………………….

…………………………………………………………………………………………………

…………………………………………………………………………………………………

**12**. What alternative feeding strategies do you use?

…………………………………………………………………………………………………

…………………………………………………………………………………………………

………………………………………………………………………………………………….

………………………………………………………………………………………………….

**13**. Do you use slaughter house waste in your operations   1. Yes   2. No

**14**. If yes, which one in particular

1. Offals   2. Rejected meat   3. Rumen contents

**15**. (a) If 3. (Rumen contents) where do use them

1. Manure   2. As feed for livestock   3. Others specify…………………………

**16** (b) If 2. Which treatments do you subject them before use?

1. Drying them and mill   2. Boiling   3. Mix them with blood 3. Others specify………………………………………………..

**17** (c). Which livestock animals do you give rumen contents wastes?

1. Pigs   2. Chicken   3 Dogs   4. Others state……………………………..

**18**. In what proportions are rumen contents given to the animals

| **Livestock type** | **Proportion of rumen content use in the diets** |
|---|---|
| Pigs | |
| Goats | |
| Dogs | |
| Others | |

**19.** Are there benefits registered so far with use of rumen contents? 1 Yes 2. No

If yes name them

…………………………………………………………………………………………………..

…………………………………………………………………………………………………
…………………………………………………………………………………………………

…………………………………………………………………………………………………
…………………………………………………………………………………………………

**20**. What challenges do you encounter when utilizing slaughter house wastes?

…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………
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…………………………………………………………………………………………………
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…………………………………………………………………………………………………

**21.** Would you need advice on how best to use rumen contents in animal feeds? **1**. Yes 2. NO

If yes where exactly

1. Pig diets 2. Poultry diets 3. Other specify……………………………………………….

**22**. Which type of knowledge would you require?

1. Processing methods 2. Levels of use 3. Storage length 4. Others specify………..

**The End: Thank you**

**APPENDIX 2: Score sheet for descriptive quality analysis of cooked broiler meat and boiled layer eggs**

**PART 1: Participant screening questionnaire**

**Panelist No.** ______________________ **Name:** ________________________________

a) Are you currently on a restricted diet? If yes, please explain.

______________________________________________________________________

______________________________________________________________________

b) How often do you eat chicken meat in a week?

________________________________________

c) How do you like your chicken? ☐ Raw, ☐Medium ☐Well done

d) What cuts of chicken do you usually eat (legs, drum stick, wings, etc.)?

______________________________________________________________________

______________________________________________________________________

e) List three chicken based foods you wouldn't eat. Briefly state reasons why.

| Food | **Reasons as to why** |
|---|---|
| | |
| | |
| | |

f) Rate your ability to distinguish smell and tastes

| | | | | | | |
|---|---|---|---|---|---|---|
| **SMELL** | Better than average | | Average | | Worse than average | |
| **TASTE** | Better than average | | Average | | Worse than average | |

g) How would you describe the difference between flavor and aroma?

h) How would you describe the difference between flavor and texture?

i) What do you consider the most prominent characteristic of a ripe piece of fruit?

j) If a recipe calls for vinegar and there is none available, what would you substitute?

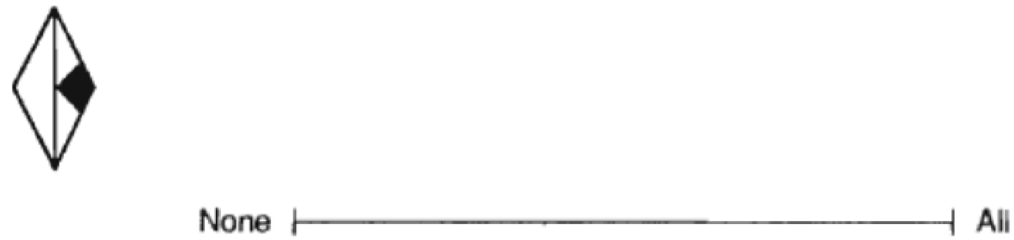
k) What are some other foods that taste like yogurt?

l) What is the best (one or two word description) of chicken sausage?

m) What’s the color of coke, the drink from the famous coca cola company?

n) Describe some of the noticeable flavors in sausage.

o) Indicate the proportion of the shape that is shaded:


p) List the days and times you will be available for sensory evaluation within a week depending on your personal time schedule.

______________________________________________________________

______________________________________________________________

______________________________________________________________

______________________________________________________________

**Part 2: Screening for taste (salt, sweet, sour)**

**Introduction:**

This questionnaire is meant to test your ability to identify and describe qualitative aspects of a food product: aroma, appearance, flavor, texture, and after taste characteristics. All samples presented to you are edible unless otherwise stated.

You have been provided with the samples randomly marked as WVB, XDZ, ZXY you are to taste each sample with the spoon provided and record your results in the score sheets below:

**Taste (Salty, sweet, sour)**

**Intensity scale: (Neither sweet nor bland, A little sweet, sweet, very sweet, extremely sweet).**

| **Sample** | **Dominant taste** | **Intensity** |
|---|---|---|
| XYZ, | | |
| YXZ, | | |
| ZXY | | |

| | | PANELIST SCORE | | | | | |
|---|---|---|---|---|---|---|---|
| **ATTRIBUTE** | **SUBJECTIVE RANKING** | **WXB** | **WYB** | **WDT** | **XCB** | **XDB** | **WCT** |
| **Aroma intensity** | (1 =Extremely bland to 9 = Extremely intense) | | | | | | |
| **Initial impression of juiciness (moisture release)** | (1 = Extremely dry to 9 = Extremely juicy) | | | | | | |
| **First bite (initial hardness)** | (1 = Extremely tough to 9 = Extremely tender) | | | | | | |
| **Cohesiveness of mass** | (1=Extremely loose to 9=Extremely compact) | | | | | | |
| **Sustained impression of juiciness** | (1 = Extremely dry to 9 = Extremely juicy) | | | | | | |
| **Muscle fiber and overall tenderness (chewiness)** | (1 = Extremely tough, to 9= Extremely tender | | | | | | |
| **Amount of connective tissue (fibrousness)** | (1= Extremely abundant to 9 = none | | | | | | |
| **Overall chicken flavor intensity** | (1= Extremely bland to 9 = extremely intense) | | | | | | |
| **Brown color intensity** | (1= None to 9 = Extremely intense) | | | | | | |

| EGG SENSORY ANALYSIS | | | | | | | |
|---|---|---|---|---|---|---|---|
| Appearance | 1 = dislike extremely;<br>10 = like extremely | | | | | | |
| Odor | 1 = dislike extremely;<br>10 = like extremely | | | | | | |
| Texture | 1 = dislike extremely;<br>10= like extremely | | | | | | |
| Acceptance | 1 = dislike extremely;<br>10 = like extremely | | | | | | |
| Color of the egg yolk | 1= extremely pale;<br>10=extremely yellow | | | | | | |

**The end: Thank you**

## APPENDIX 3: Research Approvals

**NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY AND INNOVATION**

Telephone:+254-20-2213471, 2241349,3310571,2219420
Fax:+254-20-318245,318249
Email: dg@nacosti.go.ke
Website : www.nacosti.go.ke
When replying please quote

NACOSTI, Upper Kabete
Off Waiyaki Way
P.O. Box 30623-00100
NAIROBI-KENYA

Ref: No. **NACOSTI/P/19/96187/28085**

Date: **13th March, 2019**

Robert Mwesigwa
Egerton University
P.O. Box 536-20115
**NJORO**

**RE: RESEARCH AUTHORIZATION**

Following your application for authority to carry out research on ***"Effects of dried goat rumen contents on performance of broiler and layer chickens"*** I am pleased to inform you that you have been authorized to undertake research in **Nakuru County** for the period ending **12th March, 2020.**

You are advised to report to **the County Commissioner and the County Director of Education, Nakuru County** before embarking on the research project.

Kindly note that, as an applicant who has been licensed under the Science, Technology and Innovation Act, 2013 to conduct research in Kenya, you shall deposit **a copy** of the final research report to the Commission within **one year** of completion. The soft copy of the same should be submitted through the Online Research Information System.

**GODFREY P. KALERWA MSc., MBA, MKIM**
**FOR: DIRECTOR-GENERAL/CEO**

Copy to:

The County Commissioner
Nakuru County.

The County Director of Education
Nakuru County.

## APPENDIX 4: Ethical Approval

Institute of Primate Research

NATIONAL MUSEUMS OF KENYA
WHERE HERITAGE LIVES ON

# Institute of Primate Research

Address: P. O. Box 24481-00502 Karen Nairobi Kenya | Tel: +254 02 2606235 | Fax: +254 02 2606231
URL: www.primateresearch.org | Email: directoripr@primateresearch.org

aaalac INTERNATIONAL

INSTITUTIONAL REVIEW COMMITTEE (IRC)

**FINAL PROPOSAL APPROVAL FORM**

Our ref: **ISERC/02/19**

Dear **Mr. Mwesigwe Robert**

It is my pleasure to inform you that your proposal entitled **"EFFECTS OF DRIED GOAT RUMEN CONTENTS ON PERFORMANCE OF BROILER AND LAYER CHICKENS"** has been reviewed by the Institutional Review Committee (IRC) at a meeting of 23rd May 2019. The proposal was reviewed on the scientific merit and ethical considerations on the use of animals for research purposes.

The committee is guided by the Institutional guidelines as well as International regulations, including those of WHO, NIH, PVEN and Helsinki Convention on the humane treatment of animals for scientific purposes and GLP.

This proposal has been approved and you are bound by the IPR Intellectual Property Policy.

Signed...[signature]...For Chairman IRC: DR. LUCY OCHOLA.

Signed ....[signature]........ Secretary IRC: DR FAITH ONDITI

Date

INSTITUTE OF PRIMATE RESEARCH
INSTITUTIONAL REVIEW COMMITTEE
P. O. Box 24481-00502 KAREN
NAIROBI - KENYA
APPROVED...10/7/2019...

## APPENDIX 5: ANOVA TABLES

### Carcass parameters

The SAS System 15:00 Tuesday, November 9, 2019 327

The GLM Procedure

Class Level Information

| Class | Levels | Values |
|---|---|---|
| DIET | 3 | 1 2 3 |

Number of observations 36

The SAS System 15:00 Tuesday, November 9, 2019 328

The GLM Procedure

Dependent Variable: Carcas1

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 0.26331667 | 0.13165833 | 48.50 | <.0001 |
| Error | 33 | 0.08958333 | 0.00271465 | | |
| Corrected Total | 35 | 0.35290000 | | | |

| R-Square | Coeff Var | Root MSE | Carcas1 Mean |
|---|---|---|---|
| 0.746151 | 4.498038 | 0.052102 | 1.158333 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| DIET | 2 | 0.26331667 | 0.13165833 | 48.50 | <.0001 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| DIET | 2 | 0.26331667 | 0.13165833 | 48.50 | <.0001 |

The SAS System 15:00 Tuesday, November 9, 2019 329

The GLM Procedure

Dependent Variable: Dressing

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 14.16886667 | 7.08443333 | 30.70 | <.0001 |
| Error | 33 | 7.61453333 | 0.23074343 | | |
| Corrected Total | 35 | 21.78340000 | | | |

| R-Square | Coeff Var | Root MSE | Dressing Mean |
|---|---|---|---|
| 0.650443 | 0.745936 | 0.480358 | 64.39667 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| DIET | 2 | 14.16886667 | 7.08443333 | 30.70 | <.0001 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| DIET | 2 | 14.16886667 | 7.08443333 | 30.70 | <.0001 |

The SAS System 15:00 Tuesday, November 9, 2019 330

The GLM Procedure

Dependent Variable: BRSTW

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 26691.16667 | 13345.58333 | 27.32 | <.0001 |
| Error | 33 | 16119.83333 | 488.47980 | | |
| Corrected Total | 35 | 42811.00000 | | | |

| R-Square | Coeff Var | Root MSE | BRSTW Mean |
|---|---|---|---|
| 0.623465 | 7.290240 | 22.10158 | 303.1667 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| DIET | 2 | 26691.16667 | 13345.58333 | 27.32 | <.0001 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| DIET | 2 | 26691.16667 | 13345.58333 | 27.32 | <.0001 |

The SAS System 15:00 Tuesday, November 9, 2019 331

The GLM Procedure

Dependent Variable: BRSTCm

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 5.30480000 | 2.65240000 | 21.48 | <.0001 |
| Error | 33 | 4.07530000 | 0.12349394 | | |
| Corrected Total | 35 | 9.38010000 | | | |

| R-Square | Coeff Var | Root MSE | BRSTCm Mean |
|---|---|---|---|
| 0.565538 | 2.381681 | 0.351417 | 14.75500 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| DIET | 2 | 5.30480000 | 2.65240000 | 21.48 | <.0001 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| DIET | 2 | 5.30480000 | 2.65240000 | 21.48 | <.0001 |

The SAS System 15:00 Tuesday, November 9, 2019 332

The GLM Procedure

Dependent Variable: LegCm

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| Model | 2 | 6.46205000 | 3.23102500 | 17.33 | <.0001 |
| Error | 33 | 6.15335000 | 0.18646515 | | |
| Corrected Total | 35 | 12.61540000 | | | |

| R-Square | Coeff Var | Root MSE | LegCm Mean |
|---|---|---|---|
| 0.512235 | 2.873028 | 0.431816 | 15.03000 |

The SAS System 15:00 Tuesday, November 9, 2019 333

The GLM Procedure

Dependent Variable: LegWt

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 10485.98302 | 5242.99151 | 25.75 | <.0001 |
| Error | 33 | 6719.95987 | 203.63515 | | |
| Corrected Total | 35 | 17205.94289 | | | |

| R-Square | Coeff Var | Root MSE | LegWt Mean |
|---|---|---|---|
| 0.609440 | 4.080365 | 14.27008 | 349.7256 |

The SAS System 15:00 Tuesday, November 9, 2019 334

The GLM Procedure

Dependent Variable: Abdofat

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 1108.955072 | 554.477536 | 521.32 | <.0001 |
| Error | 33 | 35.099017 | 1.063607 | | |
| Corrected Total | 35 | 1144.054089 | | | |

| R-Square | Coeff Var | Root MSE | Abdofat Mean |
|---|---|---|---|
| 0.969320 | 3.572953 | 1.031313 | 28.86444 |

The SAS System 15:00 Tuesday, November 9, 2019 335

The GLM Procedure

Dependent Variable: Trunk

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 11.76542222 | 5.88271111 | 23.01 | <.0001 |
| Error | 33 | 8.43500833 | 0.25560631 | | |
| Corrected Total | 35 | 20.20043056 | | | |

| R-Square | Coeff Var | Root MSE | Trunk Mean |
|---|---|---|---|
| 0.582434 | 2.669156 | 0.505575 | 18.94139 |

The SAS System 15:00 Tuesday, November 9, 2019 336

The GLM Procedure

Dependent Variable: Wing

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 3354.172772 | 1677.086386 | 391.71 | <.0001 |
| Error | 33 | 141.286717 | 4.281416 | | |
| Corrected Total | 35 | 3495.459489 | | | |

| R-Square | Coeff Var | Root MSE | Wing Mean |
|---|---|---|---|
| 0.959580 | 0.930902 | 2.069158 | 222.2744 |

The SAS System 15:00 Tuesday, November 9, 2019 337

The GLM Procedure

Dependent Variable: Shank

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 0.20780000 | 0.10390000 | 9.36 | 0.0006 |
| Error | 33 | 0.36627500 | 0.01109924 | | |
| Corrected Total | 35 | 0.57407500 | | | |

| R-Square | Coeff Var | Root MSE | Shank Mean |
|---|---|---|---|
| 0.361974 | 1.312128 | 0.105353 | 8.029167 |

The SAS System 15:00 Tuesday, November 9, 2019 338

The SAS System 15:00 Tuesday, November 9, 2019 363

The GLM Procedure

Dependent Variable: Carcas1

| Contrast | DF | Contrast SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| linear | 1 | 0.01126667 | 0.01126667 | 4.15 | 0.0497 |
| quad | 1 | 0.25205003 | 0.25205003 | 92.85 | <.0001 |

The SAS System 15:00 Tuesday, November 9, 2019 364

The GLM Procedure

Dependent Variable: Dressing

| Contrast | DF | Contrast SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| linear | 1 | 3.45041667 | 3.45041667 | 14.95 | 0.0005 |
| quad | 1 | 10.71844656 | 10.71844656 | 46.45 | <.0001 |

The SAS System 15:00 Tuesday, November 9, 2019 365

The GLM Procedure

Dependent Variable: BRSTW

| Contrast | DF | Contrast SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| linear | 1 | 10.66667 | 10.66667 | 0.02 | 0.8834 |
| quad | 1 | 26680.49970 | 26680.49970 | 54.62 | <.0001 |

The SAS System 15:00 Tuesday, November 9, 2019 366

The GLM Procedure

Dependent Variable: BRSTCm

| Contrast | DF | Contrast SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| linear | 1 | 1.21500000 | 1.21500000 | 9.84 | 0.0036 |
| quad | 1 | 4.08979874 | 4.08979874 | 33.12 | <.0001 |

The SAS System 15:00 Tuesday, November 9, 2019 367

The GLM Procedure

Dependent Variable: LegCm

| Contrast | DF | Contrast SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| linear | 1 | 0.17853750 | 0.17853750 | 0.96 | 0.3349 |
| quad | 1 | 6.28351190 | 6.28351190 | 33.70 | <.0001 |

The SAS System 15:00 Tuesday, November 9, 2019 368

The GLM Procedure

Dependent Variable: LegWt

| Contrast | DF | Contrast SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| linear | 1 | 1149.827267 | 1149.827267 | 5.65 | 0.0234 |
| quad | 1 | 9336.157609 | 9336.157609 | 45.85 | <.0001 |

The SAS System 15:00 Tuesday, November 9, 2019 369

The GLM Procedure

Dependent Variable: Abdofat

| Contrast | DF | Contrast SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| linear | 1 | 126.4545042 | 126.4545042 | 118.89 | <.0001 |
| quad | 1 | 982.5003687 | 982.5003687 | 923.74 | <.0001 |

The SAS System 15:00 Tuesday, November 9, 2019 370

The GLM Procedure

Dependent Variable: Trunk

| Contrast | DF | Contrast SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| linear | 1 | 1.52006667 | 1.52006667 | 5.95 | 0.0203 |
| quad | 1 | 10.24535332 | 10.24535332 | 40.08 | <.0001 |

The SAS System 15:00 Tuesday, November 9, 2019 371

The GLM Procedure

Dependent Variable: Wing

| Contrast | DF | Contrast SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| linear | 1 | 2.142037 | 2.142037 | 0.50 | 0.4843 |
| quad | 1 | 3352.030687 | 3352.030687 | 782.93 | <.0001 |

The SAS System 15:00 Tuesday, November 9, 2019 372

The GLM Procedure

Dependent Variable: Shank

| Contrast | DF | Contrast SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| linear | 1 | 0.20535000 | 0.20535000 | 18.50 | 0.0001 |
| quad | 1 | 0.00245001 | 0.00245001 | 0.22 | 0.6416 |

**Intestines**

The SAS System 15:00 Tuesday, November 9, 2019 541

The GLM Procedure

Class Level Information

| Class | Levels | Values |
|---|---|---|
| DIET | 3 | 1 2 3 |

Number of observations 36

The SAS System 15:00 Tuesday, November 9, 2019 542

The GLM Procedure

Dependent Variable: Liver

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 82.0098389 | 41.0049194 | 34.00 | <.0001 |
| Error | 33 | 39.7989917 | 1.2060301 | | |
| Corrected Total | 35 | 121.8088306 | | | |

| R-Square | Coeff Var | Root MSE | Liver Mean |
|---|---|---|---|
| 0.673267 | 3.683189 | 1.098194 | 29.81639 |

The SAS System 15:00 Tuesday, November 9, 2019 543

The GLM Procedure

Dependent Variable: spleen

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 0.24541667 | 0.12270833 | 48.45 | <.0001 |
| Error | 33 | 0.08358333 | 0.00253283 | | |
| Corrected Total | 35 | 0.32900000 | | | |

| R-Square | Coeff Var | Root MSE | spleen Mean |
|---|---|---|---|
| 0.745947 | 2.881329 | 0.050327 | 1.746667 |

The SAS System 15:00 Tuesday, November 9, 2019 544

The GLM Procedure

Dependent Variable: Provent

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 8.10185000 | 4.05092500 | 27.44 | <.0001 |
| Error | 33 | 4.87142500 | 0.14761894 | | |
| Corrected Total | 35 | 12.97327500 | | | |

| R-Square | Coeff Var | Root MSE | Provent Mean |
|---|---|---|---|
| 0.624503 | 3.850142 | 0.384212 | 9.979167 |

The SAS System 15:00 Tuesday, November 9, 2019 545

The GLM Procedure

Dependent Variable: ProvenCm

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 1.48460556 | 0.74230278 | 16.54 | <.0001 |
| Error | 33 | 1.48135833 | 0.04488965 | | |
| Corrected Total | 35 | 2.96596389 | | | |

| R-Square | Coeff Var | Root MSE | ProvenCm Mean |
|---|---|---|---|
| 0.500547 | 4.619018 | 0.211872 | 4.586944 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| DIET | 2 | 1.48460556 | 0.74230278 | 16.54 | <.0001 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| DIET | 2 | 1.48460556 | 0.74230278 | 16.54 | <.0001 |

The SAS System 15:00 Tuesday, November 9, 2019 546

The GLM Procedure

Dependent Variable: Gizard

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 50.32487222 | 25.16243611 | 42.37 | <.0001 |
| Error | 33 | 19.59649167 | 0.59383308 | | |
| Corrected Total | 35 | 69.92136389 | | | |

| R-Square | Coeff Var | Root MSE | Gizard Mean |
|---|---|---|---|
| 0.719735 | 1.395189 | 0.770606 | 55.23306 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| DIET | 2 | 50.32487222 | 25.16243611 | 42.37 | <.0001 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| DIET | 2 | 50.32487222 | 25.16243611 | 42.37 | <.0001 |

The SAS System 15:00 Tuesday, November 9, 2019 547

The GLM Procedure

Dependent Variable: Duode

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 86.4112889 | 43.2056444 | 49.56 | <.0001 |
| Error | 33 | 28.7702750 | 0.8718265 | | |
| Corrected Total | 35 | 115.1815639 | | | |

| R-Square | Coeff Var | Root MSE | Duode Mean |
|---|---|---|---|
| 0.750218 | 2.970125 | 0.933717 | 31.43694 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| DIET | 2 | 86.41128889 | 43.20564444 | 49.56 | <.0001 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| DIET | 2 | 86.41128889 | 43.20564444 | 49.56 | <.0001 |

The SAS System 15:00 Tuesday, November 9, 2019 548

The GLM Procedure

Dependent Variable: ileum

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 131.1415389 | 65.5707694 | 42.72 | <.0001 |
| Error | 33 | 50.6458250 | 1.5347220 | | |
| Corrected Total | 35 | 181.7873639 | | | |

| R-Square | Coeff Var | Root MSE | ileum Mean |
|---|---|---|---|
| 0.721401 | 1.847305 | 1.238839 | 67.06194 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| DIET | 2 | 131.1415389 | 65.5707694 | 42.72 | <.0001 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| DIET | 2 | 131.1415389 | 65.5707694 | 42.72 | <.0001 |

The SAS System 15:00 Tuesday, November 9, 2019 549

The GLM Procedure

Dependent Variable: jejenum

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| Model | 2 | 186.6877167 | 93.3438583 | 24.36 | <.0001 |
| Error | 33 | 126.4417833 | 3.8315692 | | |
| Corrected Total | 35 | 313.1295000 | | | |

| R-Square | Coeff Var | Root MSE | jejenum Mean |
|---|---|---|---|
| 0.596200 | 2.748248 | 1.957439 | 71.22500 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| DIET | 2 | 186.6877167 | 93.3438583 | 24.36 | <.0001 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| DIET | 2 | 186.6877167 | 93.3438583 | 24.36 | <.0001 |

The SAS System 15:00 Tuesday, November 9, 2019 550

The GLM Procedure

Dependent Variable: CecuCm

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 4.15350556 | 2.07675278 | 22.78 | <.0001 |
| Error | 33 | 3.00811667 | 0.09115505 | | |
| Corrected Total | 35 | 7.16162222 | | | |

| R-Square | Coeff Var | Root MSE | CecuCm Mean |
|---|---|---|---|
| 0.579967 | 1.719574 | 0.301919 | 17.55778 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| DIET | 2 | 4.15350556 | 2.07675278 | 22.78 | <.0001 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| DIET | 2 | 4.15350556 | 2.07675278 | 22.78 | <.0001 |



The GLM Procedure

Dependent Variable: CecWt

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 33.44402222 | 16.72201111 | 126.83 | <.0001 |
| Error | 33 | 4.35103333 | 0.13184949 | | |
| Corrected Total | 35 | 37.79505556 | | | |

| R-Square | Coeff Var | Root MSE | CecWt Mean |
|---|---|---|---|
| 0.884878 | 2.871829 | 0.363111 | 12.64389 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| DIET | 2 | 33.44402222 | 16.72201111 | 126.83 | <.0001 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| DIET | 2 | 33.44402222 | 16.72201111 | 126.83 | <.0001 |



The GLM Procedure

Dependent Variable: InteCm

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 29.44735556 | 14.72367778 | 236.52 | <.0001 |
| Error | 33 | 2.05430000 | 0.06225152 | | |
| Corrected Total | 35 | 31.50165556 | | | |

| R-Square | Coeff Var | Root MSE | InteCm Mean |
|---|---|---|---|

| | | | |
|---|---|---|---|
| 0.934788 | 2.266945 | 0.249503 | 11.00611 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| DIET | 2 | 29.44735556 | 14.72367778 | 236.52 | <.0001 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| DIET | 2 | 29.44735556 | 14.72367778 | 236.52 | <.0001 |

The SAS System 15:00 Tuesday, November 9, 2019 553

The GLM Procedure

Dependent Variable: Heart

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 13.16055556 | 6.58027778 | 20.88 | <.0001 |
| Error | 33 | 10.39833333 | 0.31510101 | | |
| Corrected Total | 35 | 23.55888889 | | | |

| R-Square | Coeff Var | Root MSE | Heart Mean |
|---|---|---|---|
| 0.558624 | 5.292873 | 0.561339 | 10.60556 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| DIET | 2 | 13.16055556 | 6.58027778 | 20.88 | <.0001 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| DIET | 2 | 13.16055556 | 6.58027778 | 20.88 | <.0001 |

The SAS System 15:00 Tuesday, November 9, 2019 554

The GLM Procedure

Dependent Variable: Pancreas

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 6.05733889 | 3.02866944 | 54.18 | <.0001 |
| Error | 33 | 1.84469167 | 0.05589975 | | |
| Corrected Total | 35 | 7.90203056 | | | |

| R-Square | Coeff Var | Root MSE | Pancreas Mean |
|---|---|---|---|
| 0.766555 | 5.329363 | 0.236431 | 4.436389 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| DIET | 2 | 6.05733889 | 3.02866944 | 54.18 | <.0001 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| DIET | 2 | 6.05733889 | 3.02866944 | 54.18 | <.0001 |

The SAS System 15:00 Tuesday, November 9, 2019 555

The SAS System 15:00 Tuesday, November 9, 2019 587

The GLM Procedure

Dependent Variable: Liver

| Contrast | DF | Contrast SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| linear | 1 | 3.30041667 | 3.30041667 | 2.74 | 0.1076 |
| quad | 1 | 78.70941310 | 78.70941310 | 65.26 | <.0001 |

The SAS System 15:00 Tuesday, November 9, 2019 588

The GLM Procedure

Dependent Variable: spleen

| Contrast | DF | Contrast SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| linear | 1 | 0.23010417 | 0.23010417 | 90.85 | <.0001 |
| quad | 1 | 0.01531253 | 0.01531253 | 6.05 | 0.0194 |

The SAS System 15:00 Tuesday, November 9, 2019 589

The GLM Procedure

Dependent Variable: Provent

| Contrast | DF | Contrast SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| linear | 1 | 2.67333750 | 2.67333750 | 18.11 | 0.0002 |
| quad | 1 | 5.42851035 | 5.42851035 | 36.77 | <.0001 |

The SAS System 15:00 Tuesday, November 9, 2019 590

The GLM Procedure

Dependent Variable: ProvenCm

| Contrast | DF | Contrast SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| linear | 1 | 0.17510417 | 0.17510417 | 3.90 | 0.0567 |
| quad | 1 | 1.30950112 | 1.30950112 | 29.17 | <.0001 |

The SAS System 15:00 Tuesday, November 9, 2019 591

The GLM Procedure

Dependent Variable: Gizard

| Contrast | DF | Contrast SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| linear | 1 | 37.20060000 | 37.20060000 | 62.64 | <.0001 |
| quad | 1 | 13.12428472 | 13.12428472 | 22.10 | <.0001 |

The SAS System 15:00 Tuesday, November 9, 2019 592

The GLM Procedure

Dependent Variable: Duode

| Contrast | DF | Contrast SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| linear | 1 | 57.78406667 | 57.78406667 | 66.28 | <.0001 |
| quad | 1 | 28.62724523 | 28.62724523 | 32.84 | <.0001 |

The SAS System 15:00 Tuesday, November 9, 2019 593

The GLM Procedure

Dependent Variable: ileum

| Contrast | DF | Contrast SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| linear | 1 | 65.57120417 | 65.57120417 | 42.73 | <.0001 |
| quad | 1 | 65.57029763 | 65.57029763 | 42.72 | <.0001 |

The SAS System 15:00 Tuesday, November 9, 2019 594

The GLM Procedure

Dependent Variable: jejenum

| Contrast | DF | Contrast SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| linear | 1 | 186.5952667 | 186.5952667 | 48.70 | <.0001 |
| quad | 1 | 0.0924477 | 0.0924477 | 0.02 | 0.8775 |

The SAS System 15:00 Tuesday, November 9, 2019 595

The GLM Procedure

Dependent Variable: CecuCm

| Contrast | DF | Contrast SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| linear | 1 | 0.18200417 | 0.18200417 | 2.00 | 0.1670 |
| quad | 1 | 3.97150091 | 3.97150091 | 43.57 | <.0001 |

The SAS System 15:00 Tuesday, November 9, 2019 596

The GLM Procedure

Dependent Variable: CecWt

| Contrast | DF | Contrast SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| linear | 1 | 32.85360000 | 32.85360000 | 249.18 | <.0001 |
| quad | 1 | 0.59042471 | 0.59042471 | 4.48 | 0.0420 |

The SAS System 15:00 Tuesday, November 9, 2019 597

The GLM Procedure

Dependent Variable: InteCm

| Contrast | DF | Contrast SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| linear | 1 | 0.08401667 | 0.08401667 | 1.35 | 0.2537 |
| quad | 1 | 29.36333800 | 29.36333800 | 471.69 | <.0001 |

The SAS System 15:00 Tuesday, November 9, 2019 598

The GLM Procedure

Dependent Variable: Heart

| Contrast | DF | Contrast SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| linear | 1 | 0.07041667 | 0.07041667 | 0.22 | 0.6395 |
| quad | 1 | 13.09013835 | 13.09013835 | 41.54 | <.0001 |

The SAS System 15:00 Tuesday, November 9, 2019 599

The GLM Procedure

Dependent Variable: Pancreas

| Contrast | DF | Contrast SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| linear | 1 | 5.03250417 | 5.03250417 | 90.03 | <.0001 |
| quad | 1 | 1.02483601 | 1.02483601 | 18.33 | 0.0002 |

**Blood parameters**

The SAS System 22:34 Thursday, November 11, 2019 46

The GLM Procedure

Class Level Information

| Class | Levels | Values |
|---|---|---|
| Diet | 3 | 1 2 3 |

Number of observations 6

The SAS System 22:34 Thursday, November 11, 2019 47

The GLM Procedure

Dependent Variable: Glucose

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 0.36653333 | 0.18326667 | 215.61 | 0.0006 |
| Error | 3 | 0.00255000 | 0.00085000 | | |
| Corrected Total | 5 | 0.36908333 | | | |

| R-Square | Coeff Var | Root MSE | Glucose Mean |
|---|---|---|---|
| 0.993091 | 1.882977 | 0.029155 | 1.548333 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 0.36653333 | 0.18326667 | 215.61 | 0.0006 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 0.36653333 | 0.18326667 | 215.61 | 0.0006 |

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The GLM Procedure

Dependent Variable: WBC

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 2593.903333 | 1296.951667 | 12.45 | 0.0353 |
| Error | 3 | 312.550000 | 104.183333 | | |
| Corrected Total | 5 | 2906.453333 | | | |

| R-Square | Coeff Var | Root MSE | WBC Mean |
|---|---|---|---|
| 0.892463 | 2.921579 | 10.20702 | 349.3667 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| Diet | 2 | 2593.903333 | 1296.951667 | 12.45 | 0.0353 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 2593.903333 | 1296.951667 | 12.45 | 0.0353 |

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The GLM Procedure

Dependent Variable: LYMPH

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 57.37333333 | 28.68666667 | 2.17 | 0.2617 |
| Error | 3 | 39.73500000 | 13.24500000 | | |
| Corrected Total | 5 | 97.10833333 | | | |

| R-Square | Coeff Var | Root MSE | LYMPH Mean |
|---|---|---|---|
| 0.590818 | 5.591859 | 3.639368 | 65.08333 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 57.37333333 | 28.68666667 | 2.17 | 0.2617 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 57.37333333 | 28.68666667 | 2.17 | 0.2617 |

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The GLM Procedure

Dependent Variable: HGB

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 1.09613333 | 0.54806667 | 2.07 | 0.2720 |

| | | | | | |
|---|---|---|---|---|---|
| Error | 3 | 0.79320000 | 0.26440000 | | |
| Corrected Total | 5 | 1.88933333 | | | |

| R-Square | Coeff Var | Root MSE | HGB Mean |
|---|---|---|---|
| 0.580169 | 2.881201 | 0.514198 | 17.84667 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 1.09613333 | 0.54806667 | 2.07 | 0.2720 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 1.09613333 | 0.54806667 | 2.07 | 0.2720 |



The GLM Procedure

Dependent Variable: RBC

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 0.14013333 | 0.07006667 | 2.38 | 0.2401 |
| Error | 3 | 0.08820000 | 0.02940000 | | |
| Corrected Total | 5 | 0.22833333 | | | |

| R-Square | Coeff Var | Root MSE | RBC Mean |
|---|---|---|---|
| 0.613723 | 5.254268 | 0.171464 | 3.263333 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 0.14013333 | 0.07006667 | 2.38 | 0.2401 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 0.14013333 | 0.07006667 | 2.38 | 0.2401 |

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The GLM Procedure

Dependent Variable: HCT

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 9.02333333 | 4.51166667 | 5.12 | 0.1079 |
| Error | 3 | 2.64500000 | 0.88166667 | | |
| Corrected Total | 5 | 11.66833333 | | | |

| R-Square | Coeff Var | Root MSE | HCT Mean |
|---|---|---|---|
| 0.773318 | 1.905251 | 0.938971 | 49.28333 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 9.02333333 | 4.51166667 | 5.12 | 0.1079 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 9.02333333 | 4.51166667 | 5.12 | 0.1079 |

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The GLM Procedure

Dependent Variable: MVC

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 15.05333333 | 7.52666667 | 3.96 | 0.1438 |
| Error | 3 | 5.69500000 | 1.89833333 | | |
| Corrected Total | 5 | 20.74833333 | | | |

| R-Square | Coeff Var | Root MSE | MVC Mean |
|---|---|---|---|
| 0.725520 | 0.917412 | 1.377800 | 150.1833 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 15.05333333 | 7.52666667 | 3.96 | 0.1438 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 15.05333333 | 7.52666667 | 3.96 | 0.1438 |



The GLM Procedure

Dependent Variable: MCH

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 6.92333333 | 3.46166667 | 3.30 | 0.1746 |
| Error | 3 | 3.14500000 | 1.04833333 | | |
| Corrected Total | 5 | 10.06833333 | | | |

| R-Square | Coeff Var | Root MSE | MCH Mean |
|---|---|---|---|
| 0.687634 | 2.008267 | 1.023882 | 50.98333 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 6.92333333 | 3.46166667 | 3.30 | 0.1746 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 6.92333333 | 3.46166667 | 3.30 | 0.1746 |



The GLM Procedure

Dependent Variable: MCHC

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| Model | 2 | 131.4900000 | 65.7450000 | 204.39 | 0.0006 |
| Error | 3 | 0.9650000 | 0.3216667 | | |
| Corrected Total | 5 | 132.4550000 | | | |

| R-Square | Coeff Var | Root MSE | MCHC Mean |
|---|---|---|---|
| 0.992715 | 1.539095 | 0.567157 | 36.85000 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 131.4900000 | 65.7450000 | 204.39 | 0.0006 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 131.4900000 | 65.7450000 | 204.39 | 0.0006 |

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The GLM Procedure

Dependent Variable: MPV

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 0.32333333 | 0.16166667 | 2.37 | 0.2417 |
| Error | 3 | 0.20500000 | 0.06833333 | | |
| Corrected Total | 5 | 0.52833333 | | | |

| R-Square | Coeff Var | Root MSE | MPV Mean |
|---|---|---|---|
| 0.611987 | 2.145607 | 0.261406 | 12.18333 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 0.32333333 | 0.16166667 | 2.37 | 0.2417 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| Diet | 2 | 0.32333333 | 0.16166667 | 2.37 | 0.2417 |

The GLM Procedure

Dependent Variable: Glucose

| Contrast | DF | Contrast SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| linear | 1 | 0.05290000 | 0.05290000 | 62.24 | 0.0042 |
| quad | 1 | 0.31363326 | 0.31363326 | 368.98 | 0.0003 |

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The GLM Procedure

Dependent Variable: WBC

| Contrast | DF | Contrast SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| linear | 1 | 59.290000 | 59.290000 | 0.57 | 0.5054 |
| quad | 1 | 2534.613114 | 2534.613114 | 24.33 | 0.0160 |

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The GLM Procedure

Dependent Variable: LYMPH

| Contrast | DF | Contrast SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| linear | 1 | 29.16000000 | 29.16000000 | 2.20 | 0.2345 |
| quad | 1 | 28.21334956 | 28.21334956 | 2.13 | 0.2405 |

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The GLM Procedure

Dependent Variable: MID

| Contrast | DF | Contrast SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| linear | 1 | 380.2500000 | 380.2500000 | 30.25 | 0.0118 |
| quad | 1 | 239.4135040 | 239.4135040 | 19.05 | 0.0222 |

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The GLM Procedure

Dependent Variable: GRAN

| Contrast | DF | Contrast SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| linear | 1 | 174.2400000 | 174.2400000 | 13.38 | 0.0353 |
| quad | 1 | 40.3332859 | 40.3332859 | 3.10 | 0.1766 |



The GLM Procedure

Dependent Variable: LYMP_P

| Contrast | DF | Contrast SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| linear | 1 | 30.80250000 | 30.80250000 | 102.11 | 0.0021 |
| quad | 1 | 5.46750734 | 5.46750734 | 18.12 | 0.0238 |



The GLM Procedure

Dependent Variable: MID_P

| Contrast | DF | Contrast SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| linear | 1 | 5.29000000 | 5.29000000 | 0.23 | 0.6634 |
| quad | 1 | 88.56332109 | 88.56332109 | 3.87 | 0.1437 |



The GLM Procedure

Dependent Variable: GRAN_P

| Contrast | DF | Contrast SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| linear | 1 | 21.6225000 | 21.6225000 | 2.81 | 0.1922 |
| quad | 1 | 156.2408005 | 156.2408005 | 20.32 | 0.0204 |



The GLM Procedure

Dependent Variable: HGB

| Contrast | DF | Contrast SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| linear | 1 | 0.62410000 | 0.62410000 | 2.36 | 0.2220 |
| quad | 1 | 0.47203364 | 0.47203364 | 1.79 | 0.2738 |



The GLM Procedure

Dependent Variable: RBC

| Contrast | DF | Contrast SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| linear | 1 | 0.00360000 | 0.00360000 | 0.12 | 0.7495 |
| quad | 1 | 0.13653335 | 0.13653335 | 4.64 | 0.1201 |



The GLM Procedure

Dependent Variable: HCT

| Contrast | DF | Contrast SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| linear | 1 | 0.01000000 | 0.01000000 | 0.01 | 0.9219 |
| quad | 1 | 9.01333316 | 9.01333316 | 10.22 | 0.0494 |



The GLM Procedure

Dependent Variable: MVC

| Contrast | DF | Contrast SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| linear | 1 | 12.25000000 | 12.25000000 | 6.45 | 0.0847 |
| quad | 1 | 2.80333002 | 2.80333002 | 1.48 | 0.3112 |



The GLM Procedure

Dependent Variable: MCH

| Contrast | DF | Contrast SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| linear | 1 | 0.02250000 | 0.02250000 | 0.02 | 0.8928 |
| quad | 1 | 6.90083356 | 6.90083356 | 6.58 | 0.0828 |

The GLM Procedure

Dependent Variable: MCHC

| Contrast | DF | Contrast SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| linear | 1 | 0.8100000 | 0.8100000 | 2.52 | 0.2107 |
| quad | 1 | 130.6800058 | 130.6800058 | 406.26 | 0.0003 |

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The GLM Procedure

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The GLM Procedure

Dependent Variable: MPV

| Contrast | DF | Contrast SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| linear | 1 | 0.16000000 | 0.16000000 | 2.34 | 0.2235 |
| quad | 1 | 0.16333324 | 0.16333324 | 2.39 | 0.2198 |

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The GLM Procedure

**Lipoproteins**

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The GLM Procedure

Class Level Information

| Class | Levels | Values |
|---|---|---|
| Diet | 3 | 1 2 3 |

Number of observations 12

The SAS System 00:41 Friday, November 12, 2019 2

The GLM Procedure

Dependent Variable: T_chole

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 4.80666667 | 2.40333333 | 13.78 | 0.0018 |
| Error | 9 | 1.57000000 | 0.17444444 | | |
| Corrected Total | 11 | 6.37666667 | | | |

| R-Square | Coeff Var | Root MSE | T_chole Mean |
|---|---|---|---|
| 0.753790 | 12.22436 | 0.417665 | 3.416667 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 4.80666667 | 2.40333333 | 13.78 | 0.0018 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 4.80666667 | 2.40333333 | 13.78 | 0.0018 |



The GLM Procedure

Dependent Variable: HD_lipo

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 2.24666667 | 1.12333333 | 17.74 | 0.0008 |
| Error | 9 | 0.57000000 | 0.06333333 | | |
| Corrected Total | 11 | 2.81666667 | | | |

| R-Square | Coeff Var | Root MSE | HD_lipo Mean |
|---|---|---|---|
| 0.797633 | 19.11350 | 0.251661 | 1.316667 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| Diet | 2 | 2.24666667 | 1.12333333 | 17.74 | 0.0008 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 2.24666667 | 1.12333333 | 17.74 | 0.0008 |



The GLM Procedure

Dependent Variable: LD_lipo

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 0.07421667 | 0.03710833 | 37.63 | <.0001 |
| Error | 9 | 0.00887500 | 0.00098611 | | |
| Corrected Total | 11 | 0.08309167 | | | |

| R-Square | Coeff Var | Root MSE | LD_lipo Mean |
|---|---|---|---|
| 0.893190 | 1.790161 | 0.031402 | 1.754167 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 0.07421667 | 0.03710833 | 37.63 | <.0001 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 0.07421667 | 0.03710833 | 37.63 | <.0001 |



The GLM Procedure

Dependent Variable: Triglyc

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 1.16666667 | 0.58333333 | 6.18 | 0.0205 |
| Error | 9 | 0.85000000 | 0.09444444 | | |

| | | |
|---|---|---|
| Corrected Total | 11 | 2.01666667 |

| R-Square | Coeff Var | Root MSE | Triglyc Mean |
|---|---|---|---|
| 0.578512 | 22.21577 | 0.307318 | 1.383333 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 1.16666667 | 0.58333333 | 6.18 | 0.0205 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 1.16666667 | 0.58333333 | 6.18 | 0.0205 |

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The GLM Procedure

Dependent Variable: T_chole

| Contrast | DF | Contrast SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| linear | 1 | 4.20500000 | 4.20500000 | 24.11 | 0.0008 |
| quad | 1 | 0.60166577 | 0.60166577 | 3.45 | 0.0962 |

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The GLM Procedure

Dependent Variable: HD_lipo

| Contrast | DF | Contrast SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| linear | 1 | 2.20500000 | 2.20500000 | 34.82 | 0.0002 |
| quad | 1 | 0.04166684 | 0.04166684 | 0.66 | 0.4382 |

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The GLM Procedure

Dependent Variable: LD_lipo

| Contrast | DF | Contrast SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| linear | 1 | 0.00911250 | 0.00911250 | 9.24 | 0.0140 |
| quad | 1 | 0.06510415 | 0.06510415 | 66.02 | <.0001 |

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The GLM Procedure

Dependent Variable: Triglyc

| Contrast | DF | Contrast SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| linear | 1 | 0.12500000 | 0.12500000 | 1.32 | 0.2796 |
| quad | 1 | 1.04166646 | 1.04166646 | 11.03 | 0.0089 |

**Meat sample chemical composition**

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The GLM Procedure

Class Level Information

| Class | Levels | Values |
|---|---|---|
| Diet | 3 | 1 2 3 |
| C_Part | 2 | Breast Thigh |

Number of observations 18

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The GLM Procedure

Dependent Variable: MC

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 3 | 65.65302792 | 21.88434264 | 12.00 | 0.0004 |
| Error | 14 | 25.52854178 | 1.82346727 | | |
| Corrected Total | 17 | 91.18156970 | | | |

| R-Square | Coeff Var | Root MSE | MC Mean |
|---|---|---|---|
| 0.720025 | 1.940380 | 1.350358 | 69.59247 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 30.24363315 | 15.12181658 | 8.29 | 0.0042 |
| C_Part | 1 | 35.40939476 | 35.40939476 | 19.42 | 0.0006 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 30.24363315 | 15.12181658 | 8.29 | 0.0042 |
| C_Part | 1 | 35.40939476 | 35.40939476 | 19.42 | 0.0006 |



The GLM Procedure

Dependent Variable: Ash

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 5 | 0.12317778 | 0.02463556 | 13.94 | 0.0001 |
| Error | 12 | 0.02120000 | 0.00176667 | | |
| Corrected Total | 17 | 0.14437778 | | | |

| R-Square | Coeff Var | Root MSE | Ash Mean |
|---|---|---|---|
| 0.853163 | 5.132776 | 0.042032 | 0.818889 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 0.11421111 | 0.05710556 | 32.32 | <.0001 |
| C_part | 1 | 0.00642222 | 0.00642222 | 3.64 | 0.0808 |
| Diet*C_part | 2 | 0.00254444 | 0.00127222 | 0.72 | 0.5066 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 0.11421111 | 0.05710556 | 32.32 | <.0001 |
| C_part | 1 | 0.00642222 | 0.00642222 | 3.64 | 0.0808 |

| | | | | | |
|---|---|---|---|---|---|
| Diet*C_part | 2 | 0.00254444 | 0.00127222 | 0.72 | 0.5066 |

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The GLM Procedure

Dependent Variable: CP

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 5 | 10.56271111 | 2.11254222 | 16.01 | <.0001 |
| Error | 12 | 1.58360000 | 0.13196667 | | |
| Corrected Total | 17 | 12.14631111 | | | |

| R-Square | Coeff Var | Root MSE | CP Mean |
|---|---|---|---|
| 0.869623 | 1.833062 | 0.363272 | 19.81778 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 8.07591111 | 4.03795556 | 30.60 | <.0001 |
| C_part | 1 | 0.51342222 | 0.51342222 | 3.89 | 0.0720 |
| Diet*C_part | 2 | 1.97337778 | 0.98668889 | 7.48 | 0.0078 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 8.07591111 | 4.03795556 | 30.60 | <.0001 |
| C_part | 1 | 0.51342222 | 0.51342222 | 3.89 | 0.0720 |
| Diet*C_part | 2 | 1.97337778 | 0.98668889 | 7.48 | 0.0078 |

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The GLM Procedure

Dependent Variable: EE

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 3 | 0.90753343 | 0.30251114 | 6.63 | 0.0051 |

| | | | |
|---|---|---|---|
| Error | 14 | 0.63839098 | 0.04559936 |
| Corrected Total | 17 | 1.54592441 | |

| R-Square | Coeff Var | Root MSE | EE Mean |
|---|---|---|---|
| 0.587049 | 4.422822 | 0.213540 | 4.828141 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 0.88054489 | 0.44027244 | 9.66 | 0.0023 |
| C_Part | 1 | 0.02698854 | 0.02698854 | 0.59 | 0.4545 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 0.88054489 | 0.44027244 | 9.66 | 0.0023 |
| C_Part | 1 | 0.02698854 | 0.02698854 | 0.59 | 0.4545 |

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The GLM Procedure

Dependent Variable: CF

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 3 | 0.00201054 | 0.00067018 | 457.05 | <.0001 |
| Error | 14 | 0.00002053 | 0.00000147 | | |
| Corrected Total | 17 | 0.00203107 | | | |

| R-Square | Coeff Var | Root MSE | CF Mean |
|---|---|---|---|
| 0.989893 | 2.878536 | 0.001211 | 0.042067 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 0.00200970 | 0.00100485 | 685.29 | <.0001 |
| C_Part | 1 | 0.00000084 | 0.00000084 | 0.57 | 0.4615 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| Diet | 2 | 0.00200970 | 0.00100485 | 685.29 | <.0001 |
| C_Part | 1 | 0.00000084 | 0.00000084 | 0.57 | 0.4615 |

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Dependent Variable: CP

| Contrast | DF | Contrast SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| linear | 1 | 0.04813333 | 0.04813333 | 0.36 | 0.5571 |
| quad | 1 | 8.02777813 | 8.02777813 | 60.83 | <.0001 |

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The GLM Procedure

Dependent Variable: Ash

| Contrast | DF | Contrast SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| linear | 1 | 0.02520833 | 0.02520833 | 14.27 | 0.0026 |
| quad | 1 | 0.08900275 | 0.08900275 | 50.38 | <.0001 |

The GLM Procedure

Dependent Variable: MC

| Contrast | DF | Contrast SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| linear | 1 | 1.66167696 | 1.66167696 | 1.13 | 0.3097 |
| quad | 1 | 28.58196009 | 28.58196009 | 19.35 | 0.0009 |

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The GLM Procedure

Dependent Variable: EE

| Contrast | DF | Contrast SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| linear | 1 | 0.50041697 | 0.50041697 | 30.45 | 0.0001 |
| quad | 1 | 0.38012816 | 0.38012816 | 23.13 | 0.0004 |

The SAS System 11:35 Thursday, September 23, 2019 109

The GLM Procedure

Dependent Variable: CF

| Contrast | DF | Contrast SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| linear | 1 | 0.00192691 | 0.00192691 | 2255.09 | <.0001 |
| quad | 1 | 0.00008279 | 0.00008279 | 96.89 | <.0001 |

**Layer grower diets**

The SAS System 17:38 Friday, January 29, 2020 464

The GLM Procedure

Class Level Information

| Class | Levels | Values |
|---|---|---|
| Diet | 3 | Diet1 Diet2 Diet3 |

Number of observations 6

The SAS System 17:38 Friday, January 29, 2020 465

The GLM Procedure

Dependent Variable: DM

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 0.55710000 | 0.27855000 | 3.30 | 0.1745 |
| Error | 3 | 0.25290000 | 0.08430000 | | |
| Corrected Total | 5 | 0.81000000 | | | |

R-Square Coeff Var Root MSE DM Mean

| | | | |
|---|---|---|---|
| 0.687778 | 0.321000 | 0.290345 | 90.45000 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 0.55710000 | 0.27855000 | 3.30 | 0.1745 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 0.55710000 | 0.27855000 | 3.30 | 0.1745 |

The SAS System 17:38 Friday, January 29, 2020 466

The GLM Procedure

Dependent Variable: Ash

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 53.76280000 | 26.88140000 | 11.69 | 0.0383 |
| Error | 3 | 6.89760000 | 2.29920000 | | |
| Corrected Total | 5 | 60.66040000 | | | |

| R-Square | Coeff Var | Root MSE | Ash Mean |
|---|---|---|---|
| 0.886292 | 5.974434 | 1.516311 | 25.38000 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 53.76280000 | 26.88140000 | 11.69 | 0.0383 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 53.76280000 | 26.88140000 | 11.69 | 0.0383 |

The SAS System 17:38 Friday, January 29, 2020 467

The GLM Procedure

Dependent Variable: CP

Sum of

| Source | DF | Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 0.15743333 | 0.07871667 | 2.20 | 0.2576 |
| Error | 3 | 0.10710000 | 0.03570000 | | |
| Corrected Total | 5 | 0.26453333 | | | |

| R-Square | Coeff Var | Root MSE | CP Mean |
|---|---|---|---|
| 0.595136 | 1.062281 | 0.188944 | 17.78667 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 0.15743333 | 0.07871667 | 2.20 | 0.2576 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 0.15743333 | 0.07871667 | 2.20 | 0.2576 |

The SAS System 17:38 Friday, January 29, 2020 468

The GLM Procedure

Dependent Variable: CF

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 1.81173333 | 0.90586667 | 28.49 | 0.0112 |
| Error | 3 | 0.09540000 | 0.03180000 | | |
| Corrected Total | 5 | 1.90713333 | | | |

| R-Square | Coeff Var | Root MSE | CF Mean |
|---|---|---|---|
| 0.949977 | 3.191985 | 0.178326 | 5.586667 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 1.81173333 | 0.90586667 | 28.49 | 0.0112 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 1.81173333 | 0.90586667 | 28.49 | 0.0112 |



The GLM Procedure

Dependent Variable: Ca

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 0.09603333 | 0.04801667 | 2.63 | 0.2186 |
| Error | 3 | 0.05470000 | 0.01823333 | | |
| Corrected Total | 5 | 0.15073333 | | | |

| R-Square | Coeff Var | Root MSE | Ca Mean |
|---|---|---|---|
| 0.637107 | 3.594433 | 0.135031 | 3.756667 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 0.09603333 | 0.04801667 | 2.63 | 0.2186 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 0.09603333 | 0.04801667 | 2.63 | 0.2186 |



The GLM Procedure

Dependent Variable: P

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 0.00723333 | 0.00361667 | 24.11 | 0.0142 |
| Error | 3 | 0.00045000 | 0.00015000 | | |
| Corrected Total | 5 | 0.00768333 | | | |

| R-Square | Coeff Var | Root MSE | P Mean |
|---|---|---|---|
| 0.941432 | 1.191000 | 0.012247 | 1.028333 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 0.00723333 | 0.00361667 | 24.11 | 0.0142 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 0.00723333 | 0.00361667 | 24.11 | 0.0142 |

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The GLM Procedure

Dependent Variable: EE

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 0.62920000 | 0.31460000 | 9.46 | 0.0506 |
| Error | 3 | 0.09975000 | 0.03325000 | | |
| Corrected Total | 5 | 0.72895000 | | | |

| R-Square | Coeff Var | Root MSE | EE Mean |
|---|---|---|---|
| 0.863159 | 6.047954 | 0.182346 | 3.015000 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 0.62920000 | 0.31460000 | 9.46 | 0.0506 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 0.62920000 | 0.31460000 | 9.46 | 0.0506 |

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The GLM Procedure

Dependent Variable: ME

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 166014.6313 | 83007.3157 | 18.58 | 0.0204 |
| Error | 3 | 13406.1079 | 4468.7026 | | |
| Corrected Total | 5 | 179420.7392 | | | |

| R-Square | Coeff Var | Root MSE | ME Mean |
|---|---|---|---|
| 0.925281 | 2.587081 | 66.84836 | 2583.930 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 166014.6313 | 83007.3157 | 18.58 | 0.0204 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 166014.6313 | 83007.3157 | 18.58 | 0.0204 |

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The GLM Procedure

Dependent Variable: NFE

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 84.34630000 | 42.17315000 | 16.66 | 0.0237 |
| Error | 3 | 7.59525000 | 2.53175000 | | |
| Corrected Total | 5 | 91.94155000 | | | |

| R-Square | Coeff Var | Root MSE | NFE Mean |
|---|---|---|---|
| 0.917390 | 3.298740 | 1.591147 | 48.23500 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| Diet | 2 | 84.34630000 | 42.17315000 | 16.66 | 0.0237 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 84.34630000 | 42.17315000 | 16.66 | 0.0237 |

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**Layer Diets**

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The GLM Procedure

Class Level Information

| Class | Levels | Values |
|---|---|---|
| Diet | 3 | 1 2 3 |

Number of observations 6

The SAS System 17:38 Friday, January 29, 2020 529

The GLM Procedure

Dependent Variable: DM

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 0.60130000 | 0.30065000 | 10.31 | 0.0453 |
| Error | 3 | 0.08750000 | 0.02916667 | | |
| Corrected Total | 5 | 0.68880000 | | | |

| R-Square | Coeff Var | Root MSE | DM Mean |
|---|---|---|---|
| 0.872967 | 0.193412 | 0.170783 | 88.30000 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 0.60130000 | 0.30065000 | 10.31 | 0.0453 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 0.60130000 | 0.30065000 | 10.31 | 0.0453 |



The GLM Procedure

Dependent Variable: Ash

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 0.73623333 | 0.36811667 | 2.19 | 0.2589 |
| Error | 3 | 0.50365000 | 0.16788333 | | |
| Corrected Total | 5 | 1.23988333 | | | |

| R-Square | Coeff Var | Root MSE | Ash Mean |
|---|---|---|---|
| 0.593792 | 2.394948 | 0.409736 | 17.10833 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 0.73623333 | 0.36811667 | 2.19 | 0.2589 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 0.73623333 | 0.36811667 | 2.19 | 0.2589 |



The GLM Procedure

Dependent Variable: CP

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 0.07230000 | 0.03615000 | 2.71 | 0.2128 |
| Error | 3 | 0.04005000 | 0.01335000 | | |

| | | | | | |
|---|---|---|---|---|---|
| Corrected Total | 5 | 0.11235000 | | | |

| R-Square | Coeff Var | Root MSE | CP Mean |
|---|---|---|---|
| 0.643525 | 0.670782 | 0.115542 | 17.22500 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 0.07230000 | 0.03615000 | 2.71 | 0.2128 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 0.07230000 | 0.03615000 | 2.71 | 0.2128 |

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The GLM Procedure

Dependent Variable: CF

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 0.03803333 | 0.01901667 | 11.64 | 0.0386 |
| Error | 3 | 0.00490000 | 0.00163333 | | |
| Corrected Total | 5 | 0.04293333 | | | |

| R-Square | Coeff Var | Root MSE | CF Mean |
|---|---|---|---|
| 0.885870 | 0.897436 | 0.040415 | 4.503333 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 0.03803333 | 0.01901667 | 11.64 | 0.0386 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 0.03803333 | 0.01901667 | 11.64 | 0.0386 |

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The GLM Procedure

Dependent Variable: Ca

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 0.03163333 | 0.01581667 | 3.10 | 0.1861 |
| Error | 3 | 0.01530000 | 0.00510000 | | |
| Corrected Total | 5 | 0.04693333 | | | |

| R-Square | Coeff Var | Root MSE | Ca Mean |
|---|---|---|---|
| 0.674006 | 1.764768 | 0.071414 | 4.046667 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 0.03163333 | 0.01581667 | 3.10 | 0.1861 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 0.03163333 | 0.01581667 | 3.10 | 0.1861 |

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The GLM Procedure

Dependent Variable: P

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 0.00163333 | 0.00081667 | 5.44 | 0.1004 |
| Error | 3 | 0.00045000 | 0.00015000 | | |
| Corrected Total | 5 | 0.00208333 | | | |

| R-Square | Coeff Var | Root MSE | P Mean |
|---|---|---|---|
| 0.784000 | 1.333660 | 0.012247 | 0.918333 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 0.00163333 | 0.00081667 | 5.44 | 0.1004 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 0.00163333 | 0.00081667 | 5.44 | 0.1004 |

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The GLM Procedure

Dependent Variable: EE

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 9.01813333 | 4.50906667 | 33818.0 | <.0001 |
| Error | 3 | 0.00040000 | 0.00013333 | | |
| Corrected Total | 5 | 9.01853333 | | | |

| R-Square | Coeff Var | Root MSE | EE Mean |
|---|---|---|---|
| 0.999956 | 0.537904 | 0.011547 | 2.146667 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 9.01813333 | 4.50906667 | 33818.0 | <.0001 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 9.01813333 | 4.50906667 | 33818.0 | <.0001 |

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The GLM Procedure

Dependent Variable: ME

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 27987.73110 | 13993.86555 | 67.36 | 0.0032 |

| | | | | | |
|---|---|---|---|---|---|
| Error | 3 | 623.22325 | 207.74108 | | |
| Corrected Total | 5 | 28610.95435 | | | |

| R-Square | Coeff Var | Root MSE | ME Mean |
|---|---|---|---|
| 0.978217 | 0.485221 | 14.41323 | 2970.445 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 27987.73110 | 13993.86555 | 67.36 | 0.0032 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 27987.73110 | 13993.86555 | 67.36 | 0.0032 |

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The GLM Procedure

Dependent Variable: NFE

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 7.47363333 | 3.73681667 | 19.68 | 0.0189 |
| Error | 3 | 0.56970000 | 0.18990000 | | |
| Corrected Total | 5 | 8.04333333 | | | |

| R-Square | Coeff Var | Root MSE | NFE Mean |
|---|---|---|---|
| 0.929171 | 0.738393 | 0.435775 | 59.01667 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 7.47363333 | 3.73681667 | 19.68 | 0.0189 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 7.47363333 | 3.73681667 | 19.68 | 0.0189 |

The SAS System 17:38 Friday, January 29, 2020 538

**Digestibility in laying hens diets**

The SAS System 17:38 Friday, January 29, 2020 671

The GLM Procedure

Class Level Information

| Class | Levels | Values |
|---|---|---|
| Diet | 3 | 1 2 3 |

Number of observations 6

The SAS System 17:38 Friday, January 29, 2020 672

The GLM Procedure

Dependent Variable: DM

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 172.1022333 | 86.0511167 | 15.87 | 0.0254 |
| Error | 3 | 16.2690500 | 5.4230167 | | |
| Corrected Total | 5 | 188.3712833 | | | |

| R-Square | Coeff Var | Root MSE | DM Mean |
|---|---|---|---|
| 0.913633 | 3.208142 | 2.328737 | 72.58833 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 172.1022333 | 86.0511167 | 15.87 | 0.0254 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 172.1022333 | 86.0511167 | 15.87 | 0.0254 |

The SAS System 17:38 Friday, January 29, 2020 673

The GLM Procedure

Dependent Variable: Ash

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 737.6848000 | 368.8424000 | 9.61 | 0.0496 |
| Error | 3 | 115.1412000 | 38.3804000 | | |
| Corrected Total | 5 | 852.8260000 | | | |

| R-Square | Coeff Var | Root MSE | Ash Mean |
|---|---|---|---|
| 0.864989 | 19.79927 | 6.195192 | 31.29000 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 737.6848000 | 368.8424000 | 9.61 | 0.0496 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 737.6848000 | 368.8424000 | 9.61 | 0.0496 |

The SAS System 17:38 Friday, January 29, 2020 674

The GLM Procedure

Dependent Variable: CP

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 7.53730000 | 3.76865000 | 7.53 | 0.0677 |
| Error | 3 | 1.50130000 | 0.50043333 | | |
| Corrected Total | 5 | 9.03860000 | | | |

| R-Square | Coeff Var | Root MSE | CP Mean |
|---|---|---|---|

| | | | |
|---|---|---|---|
| 0.833901 | 1.070055 | 0.707413 | 66.11000 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 7.53730000 | 3.76865000 | 7.53 | 0.0677 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 7.53730000 | 3.76865000 | 7.53 | 0.0677 |

The SAS System 17:38 Friday, January 29, 2020 675

The GLM Procedure

Dependent Variable: CF

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 223.8776333 | 111.9388167 | 89.41 | 0.0021 |
| Error | 3 | 3.7558500 | 1.2519500 | | |
| Corrected Total | 5 | 227.6334833 | | | |

| R-Square | Coeff Var | Root MSE | CF Mean |
|---|---|---|---|
| 0.983500 | 1.590221 | 1.118906 | 70.36167 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 223.8776333 | 111.9388167 | 89.41 | 0.0021 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 223.8776333 | 111.9388167 | 89.41 | 0.0021 |

The SAS System 17:38 Friday, January 29, 2020 676

The GLM Procedure

Dependent Variable: Ca

Sum of

| Source | DF | Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 799.5044333 | 399.7522167 | 59.15 | 0.0039 |
| Error | 3 | 20.2744500 | 6.7581500 | | |
| Corrected Total | 5 | 819.7788833 | | | |

| R-Square | Coeff Var | Root MSE | Ca Mean |
|---|---|---|---|
| 0.975268 | 3.888869 | 2.599644 | 66.84833 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 799.5044333 | 399.7522167 | 59.15 | 0.0039 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 799.5044333 | 399.7522167 | 59.15 | 0.0039 |

The SAS System 17:38 Friday, January 29, 2020 677

The GLM Procedure

Dependent Variable: P

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 26.74360000 | 13.37180000 | 7.43 | 0.0688 |
| Error | 3 | 5.39855000 | 1.79951667 | | |
| Corrected Total | 5 | 32.14215000 | | | |

| R-Square | Coeff Var | Root MSE | P Mean |
|---|---|---|---|
| 0.832041 | 1.881036 | 1.341461 | 71.31500 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 26.74360000 | 13.37180000 | 7.43 | 0.0688 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 26.74360000 | 13.37180000 | 7.43 | 0.0688 |



The GLM Procedure

Dependent Variable: EE

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 6818.123200 | 3409.061600 | 932.92 | <.0001 |
| Error | 3 | 10.962550 | 3.654183 | | |
| Corrected Total | 5 | 6829.085750 | | | |

| R-Square | Coeff Var | Root MSE | EE Mean |
|---|---|---|---|
| 0.998395 | 2.881724 | 1.911592 | 66.33500 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 6818.123200 | 3409.061600 | 932.92 | <.0001 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 6818.123200 | 3409.061600 | 932.92 | <.0001 |



The GLM Procedure

Dependent Variable: ME

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 11.62210000 | 5.81105000 | 3.31 | 0.1741 |
| Error | 3 | 5.26670000 | 1.75556667 | | |
| Corrected Total | 5 | 16.88880000 | | | |

| R-Square | Coeff Var | Root MSE | ME Mean |
|---|---|---|---|
| 0.688154 | 1.794391 | 1.324978 | 73.84000 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 11.62210000 | 5.81105000 | 3.31 | 0.1741 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 11.62210000 | 5.81105000 | 3.31 | 0.1741 |

The SAS System 17:38 Friday, January 29, 2020 680

The GLM Procedure

Dependent Variable: NFE

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 1.65223333 | 0.82611667 | 20.92 | 0.0173 |
| Error | 3 | 0.11845000 | 0.03948333 | | |
| Corrected Total | 5 | 1.77068333 | | | |

| R-Square | Coeff Var | Root MSE | NFE Mean |
|---|---|---|---|
| 0.933105 | 0.204748 | 0.198704 | 97.04833 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 1.65223333 | 0.82611667 | 20.92 | 0.0173 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 1.65223333 | 0.82611667 | 20.92 | 0.0173 |

**Layer Grower diets Digestibility**

The SAS System 17:38 Friday, January 29, 2020 864

The GLM Procedure

Class Level Information

| Class | Levels | Values |
|---|---|---|
| Diet | 3 | 1 2 3 |

Number of observations 6



The GLM Procedure

Dependent Variable: DM

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 318.2664333 | 159.1332167 | 30.66 | 0.0101 |
| Error | 3 | 15.5720500 | 5.1906833 | | |
| Corrected Total | 5 | 333.8384833 | | | |

| R-Square | Coeff Var | Root MSE | DM Mean |
|---|---|---|---|
| 0.953355 | 3.195456 | 2.278307 | 71.29833 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 318.2664333 | 159.1332167 | 30.66 | 0.0101 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 318.2664333 | 159.1332167 | 30.66 | 0.0101 |



The GLM Procedure

Dependent Variable: CP

Sum of

| Source | DF | Squares | Mean Square | F Value | Pr > F |
| --- | --- | --- | --- | --- | --- |
| Model | 2 | 146.9106333 | 73.4553167 | 18.98 | 0.0198 |
| Error | 3 | 11.6114500 | 3.8704833 | | |
| Corrected Total | 5 | 158.5220833 | | | |

| R-Square | Coeff Var | Root MSE | CP Mean |
| --- | --- | --- | --- |
| 0.926752 | 2.550644 | 1.967354 | 77.13167 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
| --- | --- | --- | --- | --- | --- |
| Diet | 2 | 146.9106333 | 73.4553167 | 18.98 | 0.0198 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
| --- | --- | --- | --- | --- | --- |
| Diet | 2 | 146.9106333 | 73.4553167 | 18.98 | 0.0198 |

The SAS System 17:38 Friday, January 29, 2020 867

The GLM Procedure

Dependent Variable: CF

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
| --- | --- | --- | --- | --- | --- |
| Model | 2 | 124.3702333 | 62.1851167 | 26.92 | 0.0121 |
| Error | 3 | 6.9310500 | 2.3103500 | | |
| Corrected Total | 5 | 131.3012833 | | | |

| R-Square | Coeff Var | Root MSE | CF Mean |
| --- | --- | --- | --- |
| 0.947213 | 2.429318 | 1.519984 | 62.56833 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
| --- | --- | --- | --- | --- | --- |
| Diet | 2 | 124.3702333 | 62.1851167 | 26.92 | 0.0121 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 124.3702333 | 62.1851167 | 26.92 | 0.0121 |



The GLM Procedure

Dependent Variable: Ca

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 93.5557000 | 46.7778500 | 12.63 | 0.0346 |
| Error | 3 | 11.1112500 | 3.7037500 | | |
| Corrected Total | 5 | 104.6669500 | | | |

| R-Square | Coeff Var | Root MSE | Ca Mean |
|---|---|---|---|
| 0.893842 | 2.826633 | 1.924513 | 68.08500 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 93.55570000 | 46.77785000 | 12.63 | 0.0346 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 93.55570000 | 46.77785000 | 12.63 | 0.0346 |



The GLM Procedure

Dependent Variable: P

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 177.2425333 | 88.6212667 | 6.43 | 0.0823 |
| Error | 3 | 41.3612000 | 13.7870667 | | |
| Corrected Total | 5 | 218.6037333 | | | |

| R-Square | Coeff Var | Root MSE | P Mean |
|---|---|---|---|
| 0.810794 | 5.966407 | 3.713094 | 62.23333 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 177.2425333 | 88.6212667 | 6.43 | 0.0823 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 177.2425333 | 88.6212667 | 6.43 | 0.0823 |

The SAS System 17:38 Friday, January 29, 2020 870

The GLM Procedure

Dependent Variable: EE

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 452.1984333 | 226.0992167 | 3.06 | 0.1887 |
| Error | 3 | 221.7048500 | 73.9016167 | | |
| Corrected Total | 5 | 673.9032833 | | | |

| R-Square | Coeff Var | Root MSE | EE Mean |
|---|---|---|---|
| 0.671014 | 13.04921 | 8.596605 | 65.87833 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 452.1984333 | 226.0992167 | 3.06 | 0.1887 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 452.1984333 | 226.0992167 | 3.06 | 0.1887 |

The SAS System 17:38 Friday, January 29, 2020 871

The GLM Procedure

Dependent Variable: ME

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 117.0571000 | 58.5285500 | 28.65 | 0.0111 |
| Error | 3 | 6.1290500 | 2.0430167 | | |
| Corrected Total | 5 | 123.1861500 | | | |

| R-Square | Coeff Var | Root MSE | ME Mean |
|---|---|---|---|
| 0.950246 | 2.163538 | 1.429341 | 66.06500 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 117.0571000 | 58.5285500 | 28.65 | 0.0111 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 117.0571000 | 58.5285500 | 28.65 | 0.0111 |

The SAS System 17:38 Friday, January 29, 2020 872

The GLM Procedure

Dependent Variable: NFE

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 75.69403333 | 37.84701667 | 45.15 | 0.0058 |
| Error | 3 | 2.51465000 | 0.83821667 | | |
| Corrected Total | 5 | 78.20868333 | | | |

| R-Square | Coeff Var | Root MSE | NFE Mean |
|---|---|---|---|
| 0.967847 | 0.997993 | 0.915542 | 91.73833 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| Diet | 2 | 75.69403333 | 37.84701667 | 45.15 | 0.0058 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 75.69403333 | 37.84701667 | 45.15 | 0.0058 |

The SAS System 17:38 Friday, January 29, 2020 873

**Egg characteristics Month 2**

The SAS System 10:58 Sunday, February 7, 2020 597

The GLM Procedure

Class Level Information

| Class | Levels | Values |
|---|---|---|
| Diet | 3 | 1 2 3 |

Number of observations 30

The SAS System 10:58 Sunday, February 7, 2020 598

The GLM Procedure

Dependent Variable: shellW

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 0.57058667 | 0.28529333 | 21.33 | <.0001 |
| Error | 27 | 0.36116000 | 0.01337630 | | |
| Corrected Total | 29 | 0.93174667 | | | |

| R-Square | Coeff Var | Root MSE | shellW Mean |
|---|---|---|---|
| 0.612384 | 1.736228 | 0.115656 | 6.661333 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 0.57058667 | 0.28529333 | 21.33 | <.0001 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 0.57058667 | 0.28529333 | 21.33 | <.0001 |



The GLM Procedure

Dependent Variable: EggW

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 105.3634867 | 52.6817433 | 38.84 | <.0001 |
| Error | 27 | 36.6262500 | 1.3565278 | | |
| Corrected Total | 29 | 141.9897367 | | | |

| R-Square | Coeff Var | Root MSE | EggW Mean |
|---|---|---|---|
| 0.742050 | 1.987397 | 1.164701 | 58.60433 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 105.3634867 | 52.6817433 | 38.84 | <.0001 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 105.3634867 | 52.6817433 | 38.84 | <.0001 |



The GLM Procedure

Dependent Variable: P_Yolk

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 18.39492667 | 9.19746333 | 5.84 | 0.0078 |
| Error | 27 | 42.54941000 | 1.57590407 | | |
| Corrected Total | 29 | 60.94433667 | | | |

| R-Square | Coeff Var | Root MSE | P_Yolk Mean |
|---|---|---|---|
| 0.301832 | 4.792449 | 1.255350 | 26.19433 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 18.39492667 | 9.19746333 | 5.84 | 0.0078 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 18.39492667 | 9.19746333 | 5.84 | 0.0078 |

The SAS System 10:58 Sunday, February 7, 2020 601

The GLM Procedure

Dependent Variable: YolkW

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 3.71306000 | 1.85653000 | 4.26 | 0.0247 |
| Error | 27 | 11.77481000 | 0.43610407 | | |
| Corrected Total | 29 | 15.48787000 | | | |

| R-Square | Coeff Var | Root MSE | YolkW Mean |
|---|---|---|---|
| 0.239740 | 4.595239 | 0.660382 | 14.37100 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 3.71306000 | 1.85653000 | 4.26 | 0.0247 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 3.71306000 | 1.85653000 | 4.26 | 0.0247 |

The SAS System 10:58 Sunday, February 7, 2020 602

The GLM Procedure

Dependent Variable: shell_P

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 0.23084667 | 0.11542333 | 4.57 | 0.0196 |
| Error | 27 | 0.68254000 | 0.02527926 | | |
| Corrected Total | 29 | 0.91338667 | | | |

| R-Square | Coeff Var | Root MSE | shell_P Mean |
|---|---|---|---|
| 0.252737 | 1.400915 | 0.158995 | 11.34933 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 0.23084667 | 0.11542333 | 4.57 | 0.0196 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 0.23084667 | 0.11542333 | 4.57 | 0.0196 |



The GLM Procedure

Dependent Variable: AlbumW

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 1.84166000 | 0.92083000 | 2.06 | 0.1466 |
| Error | 27 | 12.05001000 | 0.44629667 | | |
| Corrected Total | 29 | 13.89167000 | | | |

| R-Square | Coeff Var | Root MSE | AlbumW Mean |
|---|---|---|---|
| 0.132573 | 2.022630 | 0.668054 | 33.02900 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 1.84166000 | 0.92083000 | 2.06 | 0.1466 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 1.84166000 | 0.92083000 | 2.06 | 0.1466 |



The GLM Procedure

Dependent Variable: AlbumP

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 3.98220667 | 1.99110333 | 4.04 | 0.0293 |
| Error | 27 | 13.31933000 | 0.49330852 | | |
| Corrected Total | 29 | 17.30153667 | | | |

| R-Square | Coeff Var | Root MSE | AlbumP Mean |
|---|---|---|---|
| 0.230165 | 1.165271 | 0.702359 | 60.27433 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 3.98220667 | 1.99110333 | 4.04 | 0.0293 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 3.98220667 | 1.99110333 | 4.04 | 0.0293 |



The GLM Procedure

Dependent Variable: YolkI

Sum of

| Source | DF | Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 0.00011047 | 0.00005523 | 4.43 | 0.0218 |
| Error | 27 | 0.00033700 | 0.00001248 | | |
| Corrected Total | 29 | 0.00044747 | | | |

| R-Square | Coeff Var | Root MSE | YolkI Mean |
|---|---|---|---|
| 0.246871 | 0.866902 | 0.003533 | 0.407533 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 0.00011047 | 0.00005523 | 4.43 | 0.0218 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 0.00011047 | 0.00005523 | 4.43 | 0.0218 |

The SAS System 10:58 Sunday, February 7, 2020 606

**Egg characteristics Month 3**

The SAS System 10:58 Sunday, February 7, 2020 556

The GLM Procedure

Class Level Information

| Class | Levels | Values |
|---|---|---|
| Diet | 3 | 1 2 3 |

Number of observations 30

The SAS System 10:58 Sunday, February 7, 2020 557

The GLM Procedure

Dependent Variable: Egg_W

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
| --- | --- | --- | --- | --- | --- |
| Model | 2 | 47.33152667 | 23.66576333 | 107.74 | <.0001 |
| Error | 27 | 5.93057000 | 0.21965074 | | |
| Corrected Total | 29 | 53.26209667 | | | |

| R-Square | Coeff Var | Root MSE | Egg_W Mean |
| --- | --- | --- | --- |
| 0.888653 | 0.822510 | 0.468669 | 56.98033 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
| --- | --- | --- | --- | --- | --- |
| Diet | 2 | 47.33152667 | 23.66576333 | 107.74 | <.0001 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
| --- | --- | --- | --- | --- | --- |
| Diet | 2 | 47.33152667 | 23.66576333 | 107.74 | <.0001 |

The SAS System 10:58 Sunday, February 7, 2020 558

The GLM Procedure

Dependent Variable: shell_w

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
| --- | --- | --- | --- | --- | --- |
| Model | 2 | 7.04450000 | 3.52225000 | 354.42 | <.0001 |
| Error | 27 | 0.26833000 | 0.00993815 | | |
| Corrected Total | 29 | 7.31283000 | | | |

| R-Square | Coeff Var | Root MSE | shell_w Mean |
| --- | --- | --- | --- |
| 0.963307 | 1.561809 | 0.099690 | 6.383000 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
| --- | --- | --- | --- | --- | --- |
| Diet | 2 | 7.04450000 | 3.52225000 | 354.42 | <.0001 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 7.04450000 | 3.52225000 | 354.42 | <.0001 |



The GLM Procedure

Dependent Variable: yolk_w

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 3.75234667 | 1.87617333 | 200.83 | <.0001 |
| Error | 27 | 0.25224000 | 0.00934222 | | |
| Corrected Total | 29 | 4.00458667 | | | |

| R-Square | Coeff Var | Root MSE | yolk_w Mean |
|---|---|---|---|
| 0.937012 | 0.561057 | 0.096655 | 17.22733 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 3.75234667 | 1.87617333 | 200.83 | <.0001 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 3.75234667 | 1.87617333 | 200.83 | <.0001 |



The GLM Procedure

Dependent Variable: Shell_p

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 12.77548667 | 6.38774333 | 128.33 | <.0001 |
| Error | 27 | 1.34390000 | 0.04977407 | | |
| Corrected Total | 29 | 14.11938667 | | | |

| R-Square | Coeff Var | Root MSE | Shell_p Mean |
|---|---|---|---|
| 0.904819 | 1.993279 | 0.223101 | 11.19267 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 12.77548667 | 6.38774333 | 128.33 | <.0001 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 12.77548667 | 6.38774333 | 128.33 | <.0001 |



The GLM Procedure

Dependent Variable: Yolk_P

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 26.56060667 | 13.28030333 | 158.61 | <.0001 |
| Error | 27 | 2.26069000 | 0.08372926 | | |
| Corrected Total | 29 | 28.82129667 | | | |

| R-Square | Coeff Var | Root MSE | Yolk_P Mean |
|---|---|---|---|
| 0.921562 | 0.956552 | 0.289360 | 30.25033 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 26.56060667 | 13.28030333 | 158.61 | <.0001 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 26.56060667 | 13.28030333 | 158.61 | <.0001 |



The GLM Procedure

Dependent Variable: Album_W

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 38.46898667 | 19.23449333 | 283.08 | <.0001 |
| Error | 27 | 1.83460000 | 0.06794815 | | |
| Corrected Total | 29 | 40.30358667 | | | |

| R-Square | Coeff Var | Root MSE | Album_W Mean |
|---|---|---|---|
| 0.954480 | 0.782147 | 0.260669 | 33.32733 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 38.46898667 | 19.23449333 | 283.08 | <.0001 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 38.46898667 | 19.23449333 | 283.08 | <.0001 |

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The GLM Procedure

Dependent Variable: Album_P

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 25.66228667 | 12.83114333 | 28.51 | <.0001 |
| Error | 27 | 12.15141000 | 0.45005222 | | |
| Corrected Total | 29 | 37.81369667 | | | |

| R-Square | Coeff Var | Root MSE | Album_P Mean |
|---|---|---|---|
| 0.678651 | 1.147154 | 0.670859 | 58.48033 |

Source DF Type I SS Mean Square F Value Pr > F

| | | | | | |
|---|---|---|---|---|---|
| Diet | 2 | 25.66228667 | 12.83114333 | 28.51 | <.0001 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 25.66228667 | 12.83114333 | 28.51 | <.0001 |



The GLM Procedure

Dependent Variable: Shell_Th

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 0.00086000 | 0.00043000 | 20.37 | <.0001 |
| Error | 27 | 0.00057000 | 0.00002111 | | |
| Corrected Total | 29 | 0.00143000 | | | |

| R-Square | Coeff Var | Root MSE | Shell_Th Mean |
|---|---|---|---|
| 0.601399 | 1.157351 | 0.004595 | 0.397000 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 0.00086000 | 0.00043000 | 20.37 | <.0001 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 0.00086000 | 0.00043000 | 20.37 | <.0001 |



The GLM Procedure

Dependent Variable: YI

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 0.00054607 | 0.00027303 | 55.10 | <.0001 |

| | | | | | |
|---|---|---|---|---|---|
| Error | 27 | 0.00013380 | 0.00000496 | | |
| Corrected Total | 29 | 0.00067987 | | | |

| R-Square | Coeff Var | Root MSE | YI Mean |
|---|---|---|---|
| 0.803197 | 0.559230 | 0.002226 | 0.398067 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 0.00054607 | 0.00027303 | 55.10 | <.0001 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 0.00054607 | 0.00027303 | 55.10 | <.0001 |

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**Egg characteristics for Month 4**

The SAS System 11:16 Monday, February 8, 2020 91

The GLM Procedure

Class Level Information

| Class | Levels | Values |
|---|---|---|
| Diet | 3 | 1 2 3 |

Number of observations 30

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The GLM Procedure

Dependent Variable: Egg_W

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 32.84120667 | 16.42060333 | 157.28 | <.0001 |
| Error | 27 | 2.81898000 | 0.10440667 | | |

| | | | | | |
|---|---|---|---|---|---|
| Corrected Total | 29 | 35.66018667 | | | |

| R-Square | Coeff Var | Root MSE | Egg_W Mean |
|---|---|---|---|
| 0.920949 | 0.536560 | 0.323120 | 60.22067 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 32.84120667 | 16.42060333 | 157.28 | <.0001 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 32.84120667 | 16.42060333 | 157.28 | <.0001 |



The GLM Procedure

Dependent Variable: Shell_W

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 2.62200667 | 1.31100333 | 225.62 | <.0001 |
| Error | 27 | 0.15689000 | 0.00581074 | | |
| Corrected Total | 29 | 2.77889667 | | | |

| R-Square | Coeff Var | Root MSE | Shell_W Mean |
|---|---|---|---|
| 0.943542 | 1.060149 | 0.076228 | 7.190333 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 2.62200667 | 1.31100333 | 225.62 | <.0001 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 2.62200667 | 1.31100333 | 225.62 | <.0001 |

The GLM Procedure

Dependent Variable: Album_W

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 168.4838867 | 84.2419433 | 23.87 | <.0001 |
| Error | 27 | 95.2922100 | 3.5293411 | | |
| Corrected Total | 29 | 263.7760967 | | | |

| R-Square | Coeff Var | Root MSE | Album_W Mean |
|---|---|---|---|
| 0.638738 | 5.235985 | 1.878654 | 35.87967 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 168.4838867 | 84.2419433 | 23.87 | <.0001 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 168.4838867 | 84.2419433 | 23.87 | <.0001 |

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The GLM Procedure

Dependent Variable: yolkwt

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 21.17048000 | 10.58524000 | 133.19 | <.0001 |
| Error | 27 | 2.14584000 | 0.07947556 | | |
| Corrected Total | 29 | 23.31632000 | | | |

| R-Square | Coeff Var | Root MSE | yolkwt Mean |
|---|---|---|---|
| 0.907968 | 2.017419 | 0.281914 | 13.97400 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 21.17048000 | 10.58524000 | 133.19 | <.0001 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 21.17048000 | 10.58524000 | 133.19 | <.0001 |



The GLM Procedure

Dependent Variable: Shell_P

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 11.93880667 | 5.96940333 | 398.74 | <.0001 |
| Error | 27 | 0.40421000 | 0.01497074 | | |
| Corrected Total | 29 | 12.34301667 | | | |

| R-Square | Coeff Var | Root MSE | Shell_P Mean |
|---|---|---|---|
| 0.967252 | 1.024034 | 0.122355 | 11.94833 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 11.93880667 | 5.96940333 | 398.74 | <.0001 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 11.93880667 | 5.96940333 | 398.74 | <.0001 |

The GLM Procedure

Dependent Variable: Album_P

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 317.0808200 | 158.5404100 | 16.03 | <.0001 |
| Error | 27 | 267.0120600 | 9.8893356 | | |
| Corrected Total | 29 | 584.0928800 | | | |

| R-Square | Coeff Var | Root MSE | Album_P Mean |
|---|---|---|---|
| 0.542860 | 5.280648 | 3.144731 | 59.55200 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 317.0808200 | 158.5404100 | 16.03 | <.0001 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 317.0808200 | 158.5404100 | 16.03 | <.0001 |

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The GLM Procedure

Dependent Variable: Yolk_P

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 66.12316667 | 33.06158333 | 153.13 | <.0001 |
| Error | 27 | 5.82957000 | 0.21591000 | | |
| Corrected Total | 29 | 71.95273667 | | | |

| R-Square | Coeff Var | Root MSE | Yolk_P Mean |
|---|---|---|---|
| 0.918981 | 2.001613 | 0.464661 | 23.21433 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 66.12316667 | 33.06158333 | 153.13 | <.0001 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 66.12316667 | 33.06158333 | 153.13 | <.0001 |



The GLM Procedure

Dependent Variable: Shell_TH

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 0.00685980 | 0.00342990 | 93.87 | <.0001 |
| Error | 27 | 0.00098650 | 0.00003654 | | |
| Corrected Total | 29 | 0.00784630 | | | |

| R-Square | Coeff Var | Root MSE | Shell_TH Mean |
|---|---|---|---|
| 0.874272 | 1.728507 | 0.006045 | 0.349700 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 0.00685980 | 0.00342990 | 93.87 | <.0001 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 0.00685980 | 0.00342990 | 93.87 | <.0001 |



The GLM Procedure

Dependent Variable: yI

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 0.00135407 | 0.00067703 | 79.27 | <.0001 |

| | | | | | |
|---|---|---|---|---|---|
| Error | 27 | 0.00023060 | 0.00000854 | | |
| Corrected Total | 29 | 0.00158467 | | | |

| R-Square | Coeff Var | Root MSE | yI Mean |
|---|---|---|---|
| 0.854480 | 0.758422 | 0.002922 | 0.385333 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 0.00135407 | 0.00067703 | 79.27 | <.0001 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 0.00135407 | 0.00067703 | 79.27 | <.0001 |

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**Laying phase: DM1, FCR**

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The GLM Procedure

Class Level Information

| Class | Levels | Values |
|---|---|---|
| Diet | 3 | 1 2 3 |

Number of observations 45

The SAS System 20:55 Monday, March 1, 2020 42

The GLM Procedure

Dependent Variable: DM_I

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 759.5654444 | 379.7827222 | 277.57 | <.0001 |

| | | | |
|---|---|---|---|
| Error | 42 | 57.4670000 | 1.3682619 |
| Corrected Total | 44 | 817.0324444 | |

| R-Square | Coeff Var | Root MSE | DM_I Mean |
|---|---|---|---|
| 0.929664 | 0.709145 | 1.169727 | 164.9489 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 759.5654444 | 379.7827222 | 277.57 | <.0001 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 759.5654444 | 379.7827222 | 277.57 | <.0001 |



The GLM Procedure

Dependent Variable: FCR

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 4.45501778 | 2.22750889 | 28.74 | <.0001 |
| Error | 42 | 3.25530667 | 0.07750730 | | |
| Corrected Total | 44 | 7.71032444 | | | |

| R-Square | Coeff Var | Root MSE | FCR Mean |
|---|---|---|---|
| 0.577799 | 9.018183 | 0.278401 | 3.087111 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 4.45501778 | 2.22750889 | 28.74 | <.0001 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 4.45501778 | 2.22750889 | 28.74 | <.0001 |

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**Layer diets grower stage**

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The GLM Procedure

Class Level Information

| Class | Levels | Values |
|---|---|---|
| Diet | 3 | 1 2 3 |

Number of observations 27

The SAS System 20:55 Monday, March 1, 2020 72

The GLM Procedure

Dependent Variable: DM_I

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 594.7861556 | 297.3930778 | 118.58 | <.0001 |
| Error | 24 | 60.1894444 | 2.5078935 | | |
| Corrected Total | 26 | 654.9756000 | | | |

| R-Square | Coeff Var | Root MSE | DM_I Mean |
|---|---|---|---|
| 0.908104 | 2.766977 | 1.583633 | 57.23333 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 594.7861556 | 297.3930778 | 118.58 | <.0001 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 594.7861556 | 297.3930778 | 118.58 | <.0001 |

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The GLM Procedure

Dependent Variable: FCR

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 1.66785274 | 0.83392637 | 518.98 | <.0001 |
| Error | 24 | 0.03856444 | 0.00160685 | | |
| Corrected Total | 26 | 1.70641719 | | | |

| R-Square | Coeff Var | Root MSE | FCR Mean |
|---|---|---|---|
| 0.977400 | 1.116198 | 0.040086 | 3.591259 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 1.66785274 | 0.83392637 | 518.98 | <.0001 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 1.66785274 | 0.83392637 | 518.98 | <.0001 |

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**Mortality : Growers stage**

The SAS System 20:55 Monday, March 1, 2020 81

The GLM Procedure

Class Level Information

| Class | Levels | Values |
|---|---|---|
| Diet | 3 | 1 2 3 |

Number of observations 9

The SAS System 20:55 Monday, March 1, 2020 82

The GLM Procedure

Dependent Variable: Perc

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 155.5555556 | 77.7777778 | 0.78 | 0.5008 |
| Error | 6 | 600.0000000 | 100.0000000 | | |
| Corrected Total | 8 | 755.5555556 | | | |

| R-Square | Coeff Var | Root MSE | Perc Mean |
|---|---|---|---|
| 0.205882 | 31.03448 | 10.00000 | 32.22222 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 155.5555556 | 77.7777778 | 0.78 | 0.5008 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 155.5555556 | 77.7777778 | 0.78 | 0.5008 |

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The GLM Procedure
Least Squares Means

Mortality (laying period)

The SAS System 20:55 Monday, March 1, 2020 87

The GLM Procedure

Class Level Information

| Class | Levels | Values |
|---|---|---|
| Diet | 3 | 1 2 3 |

Number of observations 10

NOTE: Due to missing values, only 9 observations can be used in this analysis.

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The GLM Procedure

Dependent Variable: Perc

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 420.2616667 | 210.1308333 | 1720.19 | <.0001 |
| Error | 6 | 0.7329333 | 0.1221556 | | |
| Corrected Total | 8 | 420.9946000 | | | |

| R-Square | Coeff Var | Root MSE | Perc Mean |
|---|---|---|---|
| 0.998259 | 1.998328 | 0.349508 | 17.49000 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 420.2616667 | 210.1308333 | 1720.19 | <.0001 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 420.2616667 | 210.1308333 | 1720.19 | <.0001 |

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**ADG-Layer growing stage**

The GLM Procedure

Dependent Variable: ADG

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 0.14206667 | 0.07103333 | 13.35 | 0.0062 |

| | | | | | |
|---|---|---|---|---|---|
| Error | 6 | 0.03193333 | 0.00532222 | | |
| Corrected Total | 8 | 0.17400000 | | | |

| R-Square | Coeff Var | Root MSE | ADG Mean |
|---|---|---|---|
| 0.816475 | 0.457389 | 0.072954 | 15.95000 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 0.14206667 | 0.07103333 | 13.35 | 0.0062 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 0.14206667 | 0.07103333 | 13.35 | 0.0062 |

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**ADG-Laying period**

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The GLM Procedure

Class Level Information

| Class | Levels | Values |
|---|---|---|
| Diet | 3 | 1 2 3 |

Number of observations 9

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The GLM Procedure

Dependent Variable: ADG

| Source | DF | Sum of Squares | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Model | 2 | 169.4432000 | 84.7216000 | 367.34 | <.0001 |

| | | | |
|---|---|---|---|
| Error | 6 | 1.3838000 | 0.2306333 |
| Corrected Total | 8 | 170.8270000 | |

| R-Square | Coeff Var | Root MSE | ADG Mean |
|---|---|---|---|
| 0.991899 | 0.894307 | 0.480243 | 53.70000 |

| Source | DF | Type I SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 169.4432000 | 84.7216000 | 367.34 | <.0001 |

| Source | DF | Type III SS | Mean Square | F Value | Pr > F |
|---|---|---|---|---|---|
| Diet | 2 | 169.4432000 | 84.7216000 | 367.34 | <.0001 |

## APPENDIX 6. Published papers

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# Abattoir waste use in livestock diets: Uganda's current situation

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**ABSTRACT**

In this study, we investigated the various ways slaughter wastes are utilized, problems encountered in order to give insights in future prospects of abattoir wastes as livestock feeds. A total of 100 abattoir workers were interviewed through semi-structured questionnaires covering Kampala, Wakiso and Mukono districts in Uganda. Results revealed that majority of abattoir work force were middle-aged adults between 30-45 years contributing 37% of total workers. There was a significant association between abattoir workers responses in relation to the proportion of livestock slaughtered (Chi square 147.55; df =2; $p<0.0001$) in the abattoirs. With reference to cattle, 1.06 and 1.01 more sheep and goats were slaughtered respectively in the dry season in comparison to the wet season. Blood was mostly disposed as animal feed ingredient (blood meal) by 40% of the respondents while rumen contents were mostly sold as manure by 59% of the respondents. Only 16% of the respondents processed rumen contents for livestock feeding. 92.3% of bones were sold for dog feeding while 7.7% of bones were processed for livestock feed ingredients. Polythene bags were reported the biggest contaminants found in slaughter wastes. Stench from slaughter wastes contents was the biggest problem encountered with handling of waste products by (62%) of the respondents. The handling of abattoir wastes was still rudimental at most abattoirs as envisaged by lack of proper handling facilities at the abattoirs. There is need for regular enforcements to ensure proper abattoir waste disposal mechanisms for enhanced livestock use.

**Keywords**: Regulation Awareness, Livestock Slaughtered, Slaughter Waste Contaminants.

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## Introduction

Abattoirs are designated licensed places for hygienic meat processing (Alonge, 2005). As a consequence of abattoir operations, several inedible byproducts that are unfit for direct human consumption both of organic and inorganic nature are generated (Zhang *et al.*, 2017). These byproducts are potential animal feed ingredients if subjected to precautious further processing (Mwesigwa *et al.*, 2020a). However, in most abattoir operations especially in developing countries the major aim is to maximize edible meat products for human consumption leaving the byproducts to the detriment of land degradation, environmental pollution and biodiversity devastation (Ojekunle and Lateef, 2017). Several measures have been undertaken by a number of regulatory bodies to ensure that abattoir byproducts are disposed in manner that adheres to environmental safety and health standards. In Uganda, these enforcements are mainly done by the local government veterinary officers (DVOs), public health officers (PHOs) and the national environmental management authority (NEMA). Despite the intergovernmental agency interventions to ensure abattoirs products remains safe to both consumers and the environment, there are concerns of laxity in implementation of these measures by both enforcement agencies and abattoir operators that has put consumers and environment at risk (Kyayesimira *et al.*, 2019). This has not only left most abattoirs to operate at questionable healthy standards but also put livelihoods that depend on abattoir operations at great risk. In this study, we investigated abattoir wastes as source of livestock feeds, different ways the wastes are being utilized and challenges faced in order to give insight of the current state and future prospects of waste management in the central region of Uganda.

## Methodology

### *Description of the study areas*

 

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# Improvement of growth performance and meat sensory attributes through use of dried goat rumen contents in broiler diets

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**The study investigated the use of dried goat rumen contents (DGRC) on growth performance of broiler chickens. Rumen contents were obtained from goats immediately after slaughter during the wet season, sundried, milled and incorporated in experimental diets at levels of 0, 5 and 10%. The 0% DGRC diet was the control. The experimental diets were formulated on iso-caloric and iso-nitrogenous principles in line with the nutritional requirements for growing broiler birds. Experimental birds were first fed on a common starter broiler diet comprising of 21% CP and 3100 Kcal/kg feed from 0 to 21 days of age; thereafter the birds (21-42 days) were allotted to the experimental treatments in a completely randomized design (CRD) with three replications. A cage with 10 birds was the experimental unit. Experimental diets were offered in the morning and evening, water was provided *ad lib*. Feed offered and leftovers were weighed daily, and body weight changes were recorded on a weekly basis. The results showed that birds on the 5% diet had significantly (Linear, Quadratic *P*<0.05) higher final body weights (FBWs), average daily gain (ADG) and better feed conversion ratio (FCR) compared to those o on diets with 0 and 10% DGRC. Apparent and ileal digestibility of nutrients was improved with incorporation of dried goat rumen contents in the diets. Sensory analysis showed that meat from birds on 5% DGRC diet had (*P*<0.05) more oil content and softer meat across diets. It is concluded that, use of dried goat rumen contents (DGRC) in broiler diets improves growth performance and organoleptic qualities of broiler chicken meat.**

**Key words:** Digestibility, growth performance, rumen contents, sensory attributes.

## INTRODUCTION

In Uganda, many commercial poultry farmers are grappling with feed related costs that have pushed

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*Full Length Research Paper*

# Extent of rumen contents use in livestock diets among farmers in Uganda

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**This study was conducted with the aim of finding how rumen contents are used in livestock diets, problems encountered and areas that needs improvement to enhance livestock production. One hundred livestock farmers from Kampala, Wakiso and Mukono districts were interviewed using a structured questionnaire. The results showed that majority of the work force involved in livestock farming were middle aged adults between 30 and 45 years contributing 37% of total work force; this was followed by young adults between 20 and 30 years contributing 26% of the work force. The highest household (HH) size was (1-5) people contributing 68% of the total HH structure. Poultry farming, indigenous birds in particular were the most practiced enterprise among the respondents. High feed input prices (67%) were reported as the biggest problem faced by livestock farmers, followed by feed adulteration (44%). The use of peels and industrial by-products was reported as the most commonly used alternative feeding strategies to increasing feed prices. The use of rumen contents was still low and limited to pigs and layers. Inadequate knowledge in relation to rumen content inclusion rates in livestock diets was reported as the major hindrance to utilization of rumen contents in livestock. In general, farmers need sensitization from extension staff and research scientists with regard to efficient use of rumen contents in livestock diets.**

**Key words:** Feed scarcity, inclusion levels, rumen content processing.

## INTRODUCTION

Rumen content is partially digested feed found in the fore stomach of ruminants. They are fairly rich in crude protein as they contain microbial protein from bacteria, fungi, and protozoa (Agbabiaka et al., 2012). Rumen contents are also important source of energy, minerals and vitamins, especially vitamin B complex (Ravindra et al., 2017; Sakaba et al., 2017). These attributes make rumen contents a potential candidate feed ingredient for livestock (Cherdthong, 2019) and could also be vital in reducing the competition between man and animal for food. Despite these attributes that make rumen content a potential livestock feed ingredient, it is still largely underutilized which complicates its efficient disposal and therefore making it a potential environmental pollutant.

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