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Nutritional Composition of Animal Feeds and Ingredients in Addis Ababa and Formulation of Feeds from Selected Ingredients

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DECLARATION

I, the undersigned, declare that this is an original work and has never been presented in this or any other university, as well as research center previously and all the source materials used for this thesis have been fully acknowledged.

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Contents

ABBREVIATIONS AND ACRONYMS

AAS	Atomic Absorption Spectrophotometer
ANOVA	Analysis of Variance
AOAC	Association of Official Analytical Chemists
AR	Analytical grade Reagent
BSG	Brewers Spent Grain
CFU/g	Colony Forming Unit per gram
CSA	Central Statistics Agency
ESA	Ethiopian Standards Agency
FAO	United Nation Organization for Food and Agriculture
g/100g	gram per hundred grams
LMP	Livestock Master Plan
mg/100g	milli gram per hundred grams
PDA	Potato Dextrose Agar
SD	Standard Deviation
SPSS	Statistical Product for System Solutions
VDFACA	Veterinary Drug and Animal Feed Administration and Control Authority

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ABSTRACT

Animal source foods supply not only high quality and readily digested protein and energy but also a variety of micronutrients that are difficult to obtain in adequate quantities from plant source foods alone. Animal feeds should be formulated based on a standard requirement to get maximum yield of animal source foods. This study was conducted to analyze the nutritional composition of animal feeds and ingredients in Addis Ababa and to formulate dairy and poultry feeds. A total of 42 samples were collected consisting of 25 ingredients and 17 feeds. Proximate, mineral, antinutritional factor and microbiological analysis were evaluated for the samples. The mean content of the ingredients maize, wheat bran, wheat middling, soyabean cake and niger seed cake was for moisture (14.32, 11.75, 10.79, 5.75 & 7.54%), crude protein (6.48, 11.83, 13.05, 46.70 & 37.36%), crude fat(3.13, 3.24, 2.63, 5.49 & 8.60%), crude fiber (2.30, 7.89, 5.96, 7.92 & 15.62%) and total ash (1.29, 3.27, 2.13,6.29 & 6.99%) respectively. There was a significant difference among the ingredients of the factories. The mean values of dairy, layer and broiler feeds was for moisture (10.79, 9.33 & 9.92%), crude protein (18.3, 19.05 & 21.23%), crude fat (4.14, 4.58 & 4.98%), crude fiber (12.68, 12.98 & 11.81%) and total ash (10.38, 15.67 & 18.6%) respectively. The analysis showed that there is a significant difference among the factories ($P < 0.05$). All of the dairy feeds had crude fat value below the limit (10%). 17% (1 out of 6) of layer feeds and broiler feeds had crude protein values below the limits (16.5% & 20%). All of the layer and broiler feeds had crude fiber values above the limits (7% & 6%). 60% (3 out of 5) of dairy feeds, 67% (4 out of 6) of layer feeds and 33% (2 out of 6) broiler feeds had calcium values below the limts (0.8, 3-4 & 1.4%) respectively. All of the feed samples had phosphorus content below the given limits (0.5, 0.4 & 0.45%). The total mold counts of all samples were above the set limit (2×10^4 CFU/g). In conclusion, there is a significant difference among feed producers ($P < 0.05$) and deviation from feed standards of Ethiopian Standard Agency. This calls for better control of quality of animal feeds and ingredients and has to be considered in feed formulation. The dairy, layer and broiler feeds formulated in this study have good quality nutritional composition and can be used for the production of animal source foods (milk, meat and eggs).

Key words – animal feed ingredients, dairy feeds, layer feeds, broiler feeds, nutritional composition

1. INTRODUCTION

1.1. Background of the study

Animal source foods supply high quality and readily digested protein, energy and a variety of micronutrients. Milk, meat and eggs can also serve as functional foods since they provide nutrients such as calcium, probiotics, whey proteins and peptides, n-3 fatty acids, conjugated linoleic acid and sphingolipids that have health benefits (Jose and Cristina, 2002). Provision of animal source foods also helps to improve cognitive function, physical activity, growth, micronutrient status and morbidity (Charlotte *et al*., 2007).

Milk, meat and eggs currently provide around 13% of the energy and 28% of the protein consumed globally; in developed countries, this rises to 20% and 48% respectively. Consumption of livestock products per capita has shown greater growth over the consumption of other major food commodity groups. Since the early sixtys, consumption per capita of milk, meat and eggs has been ever increasing in the developing countries (FAO, 2009).

The production of livestock is showing an increasing trend globally with cattle, sheep, goats, pigs and buffaloes ranking the top five. Asia is experiencing the world's highest growth rates in the production of livestock products. There is also an increased livestock production in Africa due to an increase in human population, income growth and urbanization (FAO, 2015). Ethiopia is home to the largest livestock population in Africa with an estimate of about 56.71 million cattle, 29.33 million sheep and 29.11 million goats (CSA, 2015). And poultry population of the country was around 51.35 million.

The highest growth rate of livestock production requires an increased supply of animal feeds. Feeds can be classified as natural pasture, crop residue, improved forage and agro industrial byproducts. (FAO, 2002). Livestock should get a balanced ration formulated from several raw materials that provides the energy, protein, fats and vitamins required based on the class of the animal in order to provide a high quality food. The lack of sufficient quality feed will further lead to health consequences in turn affecting productivity. This is because animal feed is an integral part of the food supply chain and it is critical to the efficient and profitable production of food (Tolera, 2009).

Following the growing demand for animal products thus livestock production, the production of animal feeds is advancing worldwide but in Ethiopia, the major animal feed resources that are utilized for livestock production are natural pasture and crop residues. These resources are not sufficient and vary seasonally. There is a lesser utilization of improved feeds and industrial by products which is due to inavailability and high cost of such products and in some areas due to lack of awareness (Demissie, 2018).

1.2. Statement of the problem

Ethiopia, although having the largest livestock population in Africa, the productivity of its livestock resources is very low. The livestock sector in Ethiopia contributes only 12 and 33% of the total and agricultural gross domestic product respectively (Ayele *et al*., 2003). The per capita consumption of animal source foods is very low as compared to the average per capita consumption of Africa (Solomon *et al.*, 2003). This lack of dietary diversity is among the factors that lead to stunting. In Ethiopia, approximately 38 % of children less than 5 years are stunted (CSA, 2011).

The very low productivity of livestock in Ethiopia is primarily due to a shortage in the quality and quantity of animal feeds (Tolera, 2009).There is only very few areas of improved pastures and fodder crops and the available natural pastures and fodder crops are overgrazed. There is a deficiency of feeds able to grow in different seasons and the consumption of agro-industrial by-products is low (Mengistu, 1985). There is a high demand for manufactured compound animal feeds but there is shortage of supply of such products and the marketing system is not developed (Demissie, 2017).

Over the past few decades crop residues such as weeds and crop thinnings have become a larger part of feeds when compared to grazing grasslands. Livestock producers manage feed shortage by managing herds and by purchasing and conserving feed. The quality and quantity of animal feeds must be improved in order to be able to produce feeds throughout the year and in different climates (Mekasha *et al.*, 2014).

The recommended intake of one cattle is 2 kg/head and the average intake of one chicken is 100g per day. Of all the animal feed resources in the country manufactured animal feed accounts only a small proportion. The number of cattle and poultry population is increasing at a high rate. In

Ethiopia, nowadays livestock producers have started to use improved animal feeds that are produced commercially but there is still a gap since there is a very limited feed production in comparison to animal production rate (Bediye and Feyissa, 2006).

The demand for animal feeds is increasing from time to time while the feed industry hasn't showed much growth in capacity. This proves that the current production of animal feeds in Ethiopia is very low (Bediye *et al.*, 2018). This study was proposed to analyze the nutritional quality of animal feeds and ingredients found in Addis Ababa and to formulate feeds with improved quality and safety that will enable the production of safe and quality animal source foods.

1.3. Significance of the study

- The study will provide an insight in to the current nutritional quality of animal feeds of dairy cattle, poultry layers and poultry broilers and also the ingredients used for animal feed production in Addis Ababa.
- The result of the study will enable for animal feed producers to assess where they lie in terms of the given standards and in comparison to other factories so as to improve future productions.
- The output of the study could be used by livestock producers to produce nutritious animal feeds for dairy cattle, poultry layers and poultry broilers which could result in the production of an increased yield of quality and safe animal source foods; meat, milk and eggs. It will also create awareness on the need to utilize quality and safe feeds.
- The result of the study may also be used for decision making and enforcement by regulatory bodies like VDFACA to control the production of animal feeds in the study area.

1.4. Objectives of the study

1.4.1. General objective

The general objective of the study was to assess the nutritional status of the available animal feeds and the raw materials used for feed manufacturing and to formulate new nutritious animal feeds for dairy cattle and poultry production.

1.4.2. Specific objectives

The study had the following sub – objectives:

1. To analyze the nutritional composition of currently available animal feeds and the component ingredients for dairy and poultry feeds in Addis Ababa
2. To analyze the mineral composition and antinutritional factors of feeds
3. To analyze the microbial quality (total mould count) of the animal feeds and ingredients
4. To develop new dairy and poultry feeds from selected ingredients by using a least cost formulation method and analyze their nutritional composition

2. LITERATURE REVIEW

2.1. Livestock production

Livestock production is the farming of domesticated terrestrial animals to produce food, fiber and labor. Livestock occupies around one-third of the world and are an integral part of human history, providing multiple benefits beyond the obvious supply of food and fiber. The livestock species play very important economic, social and cultural roles. In many parts of the world livestock are a very close part of culture of different societies by serving as a banking system as collateral for loans in Africa through to being a religious symbol in India (Garg *et al*., 2013).

Livestock enable in improving earnings for low income households and help in food security when produced in an environmental friendly method of less green house gas emission by adaptation to climate change (Herrero *et al.*, 2013). Animals especially pigs and poultry compete with humans since they feed on grains but they are capable of converting these low value materials into meat, milk and eggs (Smith *et al.*, 2013).

The yield and quality of edible animal by-products depends on multiple interactive factors of genotype (breed), sex, animal species, production system (feed lot or pasture-based system), physiological and health condition of the animal, age, weight, post-mortem handling and processing (Florek *et al*., 2012).

2.2. Animal feed

Animal nutrition is important for animal health and productivity expressed in growth, maintenance and energy for vital activities. Animals need varying nutrients according to factors such as age, pregnancy and use. Poor feeding decreases productivity of animals. Several studies show that good feeding increases milk production of lactating animals. It also increases growth rate of meat producing animals, giving more meat. Good nutrition also increases reproductive efficiency: higher cyclicity, lower age at first calving, lower inter-calving interval, higher productive life and higher profitability to farmers (FAO, 2002).

Animal feed is mixture of plant or animal source raw materials that are either processed, semi processed or unprocessed nutritious products that come in the form of a finished product or a supplement. The products with a high content of vitamins, minerals, amino acids and additives that are mixed with feed are called pre-mixes while mixed feed are products that contain nutrients , supplements and additives mixed together (Pavlova *et al.,* 2013).

Feed quality is characterized by physical, physico-chemical and nutritional attributes of the feed important for the efficient and profitable production of healthy livestock. Animal feeds should be analyzed for their nutritional value, microbiological and chemical safety to ensure the productivity of livestock (FAO, 2004).

Yami and Desie (1997) reported that the quality of mixed feed for commercial poultry production is generally poor in Ethiopia. Most formulations available do not have vitamin/ mineral premixes. Ingredients and processed feeds vary in nutritive value and there is no regular quality control mechanism in the country. Unavailability of feed quality legislation and laboratory facilities for chemical analysis also contributes greatly to the poor quality of processed feeds. Quality control of raw materials is a mutual concern for suppliers and the animal feed industry (Tadelle *et al.*, 2002).

Feed cost is one of the major factors that affect livestock production. In Africa and other developing countries feeds comprise 60-70% of total production costs (Lukuyu *et al*., 2011). Shortages of feeds and forages are especially acute during the dry season causing an increase in price of feeds globally (Ayantunde *et al.*, 2005).A major reason for high feed cost is lack of feed processing materials and added cost of distribution to distant areas. The lack of convenient roads is the major problem that hinders supply of feeds to some areas (Achoja *et al.,* 2006).

There are several animal feed resources that are limited to some seasons and areas only. This requires for a replacement of these feeds with a similar resource. In such cases, improved forages can be utilized by selecting suitability to the environment (Biratu and Haile, 2017). Consistent availability of good quality ingredients and fully balanced complete feeds are essential for efficient livestock production. There is less shortage of products that can be found locally. The most serious problems arise from the unavailability of suitable micro-nutrient sources: vitamins and minerals (Haftu, 2016).

2.2.1. Animal feed resources

Animal feed resources could be plant source, animal source or mixed source. Plant source resources include grains, oil seed cakes and meals, grain by products, fruits and fruit by products, molasses and sugar and alfalfa products. Animal source resources include byproducts of slaughtered animals and animal waste. Mixed products include fats and oils and contaminated or adulterated human food. Other forms of recently introduced resources include drugs, preservatives and probiotics (Sapkota *et al.*, 2007).

Roughages (Natural pasture and crop residues)

Roughages are fibrous and low energy feeds such as grasses, hays, and silages. There is variation among natural pasture and hay from place to place due to environmental conditions. Now adays crop residues are being used increasingly due to insufficient amount of natural pastures. The most common crop residues are cereal crop residues like barley/wheat straw, green maize fodder, sorghum and oat fodder (Tolera, 2007).

Maize

Maize is the most common grain that is used for animal feed production. The maize plant is efficient at converting large amounts of sunlight into stable forms of chemical energy stored as starch, cellulose, and oil. High digestibility and energy content of maize makes it preferable in commercial poultry diets. The amino acid profile of the protein in maize complements the amino acid profile of the other ingredients, such as soybean meal, typically used in feed. Alternative grains are typically evaluated in relation to maize (Robertson *et al*, 2006).

Agro-industrial by-products

Agro-industrial by-products are rich in energy and protein contents. They have less fiber content, high digestibility, and energy values compared with the other class of feeds. The major feed resources as by-products of the agro-industries are milling by-products (wheat bran, wheat middling, wheat short, rice bran and screenings), edible oil processing by-products (soya bean cake, niger seed cake, rapeseed cake, cottonseed cake, linseed cake, ground nut cake, sesame cake, sunflower cake, peanut cake and safflower cakes), molasses, spent brewery grain and spent brewery yeast (Mirzaei and Maheri, 2008).

Agro-industrial by-products produced in Ethiopia include by-products from flour milling, sugar factory, oilseed and brewery factories. These by products are mainly used for dairy, poultry and fattening animals (Alemu *et al*., 1991).

Soya bean cake is the most common oil cake for animal feed production. Soybean is not only a source of high quality edible oil for humans, but also a high quality vegetable protein in animal feed worldwide. It has a very high protein content with suitable amino acid profile. It has consistent availability and nutrition throughout the year and has low amount of antinutritional factors that can be reduced by minimal processing. It is also preferred against animal proteins that have low allowed limits of inclusion (Dei, 2011).

Soybean meal protein has a good digestibility in poultry (Woodworth *et al*., 2001). However, carbohydrates in soybean meal are incompletely digested by colonic micro biota in mono-gastric animals (Kerley and Allee, 2003). This can be improved by removal of raffinose and stachyose that increases metabolisable energy content by 12% (Graham *et al*., 2002). Recently, kidney bean meal has been found to be a possible poultry feed able to provide nutrients similar to that of soy meal (Hussien *et al*., 2015).

Niger seed cake is one of the oilseed cakes commonly used as a protein supplement for livestock in Ethiopia. About 84,802.34 tons of noug seed is processed every year in the country from which about 50% niger seed cake is produced. The protein content of noug seed cake varies from 28-38% with most values lying between 30-35%. The fat content varies from 2.1- 12.6% with an average of 8.4% and has high fiber (34.4%) and 8.4% lignin content and low digestibility of 61.7% compared to most other oilseed cakes (Adugna, 2008).

Wheat Bran

The wheat grain consists of about 82% endosperm, 15% bran, and 3% germ. Wheat bran is the major milling by-product used as livestock feed in Ethiopia. It is the outer fibrous layer separated from the rest of the grain and germ. It is the physically fibrous and flaky product. It is the outer kernel plus some flour with a protein content of 14-18%. It has high phosphorus (1%) but low calcium (0.1%) content. Wheat bran is quite palatable and is well known for its laxative characteristics because of its swelling and water holding capacity. This is due to its high fiber and non-starch carbohydrate content (Adugna *et al*., 2008).

Wheat Middling

Wheat middling is a by-product of wheat milling. During milling, 70-75 % of the wheat grain becomes flour, and the remaining 25-30 % results in by-products. Wheat middling consist of fine particles of wheat bran, wheat shorts, wheat germ, wheat flour, and some of the by-product from the tail of the mill. Wheat middling cannot contain more than 9.5% crude fiber and must have minimums of 14% protein and 3% fat (Jacob, 2015).

Molasses

Molasses contains high level of sugars which are readily digested in the rumen. It is also a good source of minerals such as calcium, potassium, sulfur and trace minerals but deficient in nitrogen and phosphorus. It can be a major or minor component of drought feed. It is a concentrated source of energy that can be stored for a long period. Since the protein content of molasses is negligible, it is usually fed with high-quality protein or urea. Molasses is often used as a carrier for urea because it is palatable and provides a wide range of minerals (Jabbar *et al*., 2000).

Brewery Grain

Brewers' spent grain (BSG) is the most abundant by-product generated from the beer-brewing process, representing 85% of the total by-products obtained. After the mashing process the insoluble part of the barley grain, the BSG, is in solution with the soluble (liquid) wort. The wort, which will be fermented into beer, is filtered through the BSG, which is a by-product and must be disposed of (Mussatto, 2014). Brewery grain and spent yeast from the brewing industry which is high in protein are animal feeds that can be found in higher quantities in areas near breweries (Tolera, 2008).

2.2.2. Animal feed production

Production of a balanced ration benefits not only livestock productivity but also environment conservation by utilizing locally available raw materials. Animal feed production causes environmental pollution but feeding a diet containing nutrients such as protein, carbohydrates and minerals in the right proportion and in an amount that meets the nutrient requirements of animals for achieving the targeted production would decrease nitrogen, phosphorus and methane release in the environment and the biodiversity loss (Garg *et al*., 2013).

In the production of feeds, the first step is cleaning of the raw materials. Reducing size (grinding) is the next step in this process. All ingredients need to be reduced in size to accomplish a homogeneous process into the mixer. Once ground, the ingredients are stored separately prior to weighing, dosing and then mixing. In the mixer, the ingredients remain for a certain amount of time. From here the mash goes to pelletization. Once molded, the feed is cooled and packed.

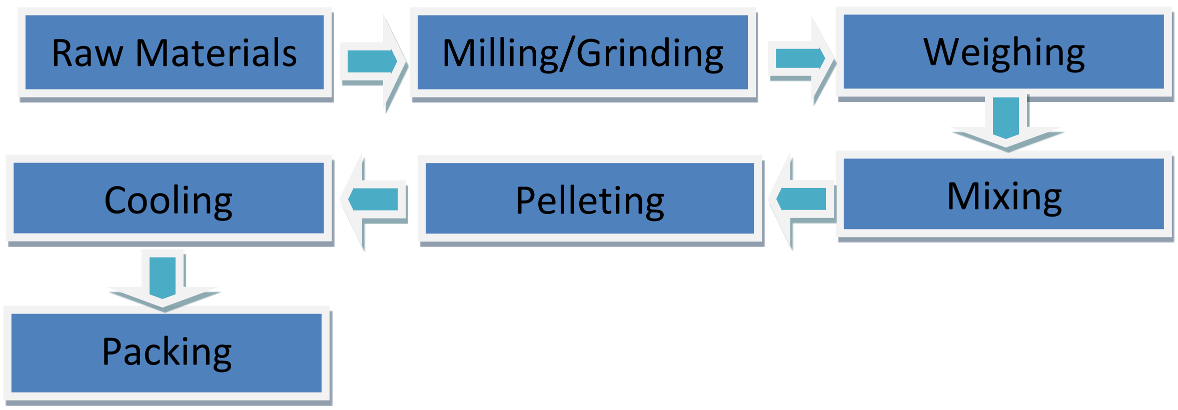

Figure 1. The process flow of animal feed production

Pelleting

Pelleting is the most commonly used thermal processing method in the animal feed industry. The aim of pelleting processing is to agglomerate ingredient particles by mechanical action, in combination with moisture, pressure and temperature. Several factors affect the quality of pellet, such as the nutritional composition of feed, the size of the feeds, the time and temperature applied, the moisture content, compression rate of pellet die and gap between the pellet press roll and die (Muramatsu *et al.*, 2015).

Pellet form of feed improves animal performance and feed conversion than a meal form of a diet. Livestock that are fed pellets show higher weight gain and better feed conversion than those that are fed meals. The improvements in performance are achieved by decreasing feed wastage, reducing selective feeding, decreasing ingredient segregation, minimizing time and energy expended for prehension, destroying of pathogenic organisms, thermally modifying of starch and protein and improving palatability (Thomas *et al.*, 1997).

2.2.3. Animal feed production in Ethiopia

Demand for Animal Source Foods and Feeds in Ethiopia

Driven by population growth, increasing urbanization and incomes, the demand for livestock commodities in Ethiopia is rapidly growing. Compared to the production base year of 2014/15 with estimated 167million liters of milk, 1.3 million tones of red meat and 419 million eggs, the projected demand is expected to be 1490 million liters of milk, 1.9 million tones of red meat and 3.9 billion eggs by 2020 (LMP, 2015). Also, at global and regional levels the demand for livestock products is projected to increase by 60-70% by 2050 from the current level. Thus, Ethiopia should take advantage of the opportunity to benefit from the global and the country's economic development and the better future of animal source food consumption (Makkar, 2016).

Ethiopia is working on a strategy to achieve food security and to provide income for its population from the livestock sector which requires a lot of research and development in the area. The country is planning to benefit largely from the livestock and fisheries sectors in order to develop its economy. The livestock and fisheries sectors present opportunities for business and increasing the availability of livestock sourced products and can address food and nutrition security challenges in Ethiopia (Tegegne *et al*., 2010).

The demand for compound feeds is affected by the supply, quality and cost of feed ingredients. The higher cost of compound feeds has led for livestock producers to use other resources of natural pastures, improved pastures and crop residues. There is a varying demand for animal feeds across the country where Addis Ababa shows the highest demand due to the availability of different feed factories (Demissie, 2018).

Feed ingredients commonly used in Ethiopia

Among the various available animal feeds, the ones that are utilized in Ethiopia include green fodder, crop residues that are harvested byproducts, improved feeds such as alfalfa, hay and industrial by-products (CSA, 2014). Natural pasture and crop residues contribute the largest share. The quality of these feed resources varies in time and ecological change, rainfall, soil type and cropping intensity. Crop residues have limited feeding value due to high fiber. In recent years, many improved forages have been developed and are utilized in different areas of the country. Industrial by-products are mainly used in urban and peri-urban livestock production and for production of animals with a relatively high nutrient supply (Mengistu *et al*., 2017).

In central high lands of Ethiopia, although natural pasture and crop residues are produced in large amounts, their full and efficient utilization for livestock feeding has been hindered partly by economic problems and inadequate knowledge of the farmers. The major constraints for not applying different roughage treatment techniques were lack of knowledge about the methods used, shortage of money and ease of access to the methods (Hassen *et al*., 2010).

Feed industries in Ethiopia

There are several private and union commercial feed manufacturing industries in Ethiopia which mainly produce feeds for poultry production. Currently the feed industries are operating below their capacity due mainly to low demand, high cost and low quality of feeds produced (Tolera *et al*., 2012). The animal feeds produced in Ethiopia are mainly composed of the ingredients corn, bone and meal, soya bean cake, noug cake, rapeseed cake, limestone, salt, vitamin, lysine and methionine. Most ingredients are found locally as the byproducts of factories but some are imported (VDFACA, 2016).

There are a total of 81 feed enterprises found in the Ethiopian commercial feed sub-sector as shown in Table 1. The feed industry includes feed processing plants, farmer unions, supplement manufacturers, feed processing machinery and forage seed producers. Most of these enterprises are found in Addis Ababa (Bediye *et al.*, 2018).

Table 1. Industry structure and regional distribution of enterprises engaged in feed industry

	Number of enterprises in each category					
Region	Feed processing plants	Farmer unions	Supplement importers /manufacturers	Feed processing machinery	Forage seeds	Total enterprises
Addis Ababa	10	1	10	4	1	26
Oromia	12	6	4	1	0	23
Amhara	4	7	0	0	0	11
SNNPRS	4	6	1	0	0	11
Tigray	2	8	0	0	0	10
Total	32	28	15	5	1	81

(Bediye *et al.*, 2018)

Price trends of feed ingredients in Ethiopia

Price trends of feed ingredients taking base year of 2010/11 and average price of 2015/16 suggest an average increase of 52% across five years and at an annual increase of 11% (Table 2).

Table 2. Price trends of major feed ingredients (Birr per ton)

Ingredient	2010/11 Price	2015/2016 Price	Percentage change
Maize	4000	5100	28
Wheat bran	2800	4170	49
Wheat middling	3000	4200	40
Niggerseed cake	3000	4800	60
Rapeseed cake	1300	2900	123
Soybean meal	7500	12000	60
Cottonseed cake	4550	5000	10
Percentage change on the overall period		52	
Percentage change per annum		11	

(Bediye *et al.*, 2018)

Price trends of feeds in Ethiopia

Price trends of feeds taking base year of 2010/11 and average price of 2015/16 show a more than double price increase for all feeds (Table 3). The lowest increase was for chick starter ration (63%) and the highest increase for heifer ration (130%).

Table 3. Price trends of major compound feeds (Birr per ton)

Ingredient	2010/11	2015/16	% Change
Layers ration	5,030	8,340	66
Growers ration	5,520	10,270	86
Chick starter ration	6,550	10,676	63
Dairy ration	3,340	6,110	83
Calves ration	4,280	8,560	100
Heifer ration	2,800	6,440	130
Beef cattle ration	3,520	6,090	73
Sheep ration	3,540	6,440	82

(Bediye *et al.*, 2018)

2.2.4. Animal feed requirements

Animal feed requirements are determined by defining the animal's requirements and the ability of feed stuffs to meet those requirements. The determination considers the complex digestive system of livestock species and the availability of various potential feedstuffs that can be provided. The nutrient requirements are defined by understanding and modeling fermentation, digestion, absorption, and retention of nutrients by animals and defining how these factors are influenced by numerous physiological, environmental, and management factors (Galyean, 2014).

Specification for dairy cattle

Dairy cattle require nutrients for maintenance, growth, production and reproduction. These nutrients are expressed in terms of water, energy, minerals and vitamins. Feeds should primarily supply the energy and the digestibility required for the animal to be fed. Energy content of the feed directly determines nutritional content of milk. Thus the energy required should be proportional to the composition of the milk (fat and protein content) (Streeter, 2006). The existing Ethiopian standard for animal feed protein for cattle is 15-25 % by mass (table 4).

Table 4. Requirements for compounded cattle feeds

Item	Constituents	Levels
1	Moisture, percent by mass,max	12
2	Crude protein, percent by mass	15-25
3	Non protein nitrogen, percent by mass,max	6
4	Crude fiber, percent by mass,max	12
5	Acid insoluble ash, percent by mass,max	4
6	Crude fat, percent by mass,max	10
7	TDN, percent by mass, min	72
8	Common salt, percent by mass,max	1
9	Calcium, percent by mass,min	0.8
10	Phosphorus, percent by mass,min	0.5
11	Magnesium, mg/kg, min	700
12	Sulphur , percent by mass,min	0.2
13	Manganese, ppm, min	20
14	Zinc, ppm, min	40
15	Cobalt , ppm, min	0.1
16	Copper, ppm, min	10
17	Iodine , ppm, min	0.8
18	Vitamin A, IU/kg, min	6000
19	Vitamin D, IU/kg, min	600

ESA (2019)

Specification for poultry

Poultry require nutrients to maintain their current state and to enable body growth (weight gain) or egg production. Birds need a steady supply of energy, protein, essential amino acids and fatty acids, minerals, vitamins and, most important, water. Poultry obtain energy and required nutrients from natural feeds but their feeds can be fortified by supplements. The different classes of poultry, layers and broilers have different demand for energy, proteins and minerals (Leeson and Caston, 2008). The Ethiopian standard for crude protein is 16.5 % for poultry layers and 20% for poultry broilers (Table 5).

Table 5. Requirements for compounded poultry feeds

Item	Constituents	Chick starter	Grower	Layer	Broiler starter	Broiler finisher	Layer breeder	Broiler breeder
1	Moisture, percent by mass,max	12	12	12	12	12	12	12
2	Crude protein, percent by mass	19	15	16.5	22	20	17.5	17.5
3	Non protein nitrogen, percent by mass,max	5	7	7	5	6	7	7
4	Crude fiber, percent by mass,max	8	9	14	8	9	14	14
5	Acid insoluble ash, percent by mass,max	3	4	4	3	3	4	4
6	Salt as NaCl , percent by mass, max	0.6	0.6	0.6	0.6	0.6	0.6	0.6
7	Calcium as Ca , percent by mass, max	1-1.4	1-1.4	3-4	1-1.4	1-1.4	3-4	3-4
8	Available phosphorus , percent by mass, min	0.4	0.4	0.4	0.45	0.45	0.4	0.4
9	Lysine, percent by mass, min	1	0.7	0.6	1.2	1	0.6	0.6
10	Methionine,percent by mass, min	0.35	0.27	0.3	0.5	0.4	0.3	0.3
11	Methionine + Cystine, g/100g	0.6	0.5	0.55	0.55	0.7	0.55	0.55
12	Metabolisable energy (kcal/kg) , min	2600	2500	2600	2800	2900	2600	2600

ESA (2019)

The feeds must also provide minerals as part of a feed formulation or in form of supplements and premixes in amounts as stated in table 6.

Table 6. Minimum requirements for minerals, fatty acids and vitamins in poultry feeds

Item	Constituents	Chick starter	Grower	Layer	Broiler starter	Broiler finisher	Layer breeder	Broiler breeder
1	Manganese, mg/kg	75	50	55	75	75	75	75
2	Iodine, mg/kg	1	1	1	1	1	1	1
3	Iron, mg/kg	110	96	90	110	110	90	90
4	Copper, mg/kg	8	7	7	8	8	8	8
5	Selenium, ppm	0.1-4	0.1-4	0.1-4	0.1-4	0.1-4	0.1-4	0.1-4
6	Zinc, mg/kg	60	60	60	60	60	60	60
7	Vitamin A, IU/Kg	8000	7000	8000	10000	9000	9000	9000
8	VitaminD3, IU/Kg	2000	1500	2000	2000	2000	2000	2000

ESA (2019)

2.3. The role of nutrition on animal productivity

Animal performance is defined based on feed quality. The intake of available nutrients determines animal productivity. Quality of milk produced by dairy cows is majorly affected by nutrition and feeding management. Supplying the right amount and variety of feed that meets the energy and protein requirement of cattle is essential to get a maximum yield and quality of milk. Energy and protein levels of poultry layer feeds have effects on egg production while egg shell quality is mainly controlled by the contents of minerals and vitamins in the diets. The dietary energy supply of birds directly affects fatness of carcasses (Ajantha *et al.,* 2017).

2.4. Ensuring safety and quality of animal Feeds

Ensuring feed safety and quality is has recently become major area of improvement in the commercial feed sector. Livestock producers and consumers of animal source foods are also deeply concerned with this issue. The animal feed industry, including the ingredient suppliers, as part of the food chain, has the mandate to produce safe and healthy products in order for livestock producers to provide safe and quality foods up to standard (Aung and Chang, 2014).

Nutritional quality

The need for maintaining the desired level of nutritional and quality standards of feed ingredients and compound feeds is a challenge for commercial feed producers, the regulatory body and livestock producers. The quality of some of the produced compound feeds has been found to be unreliable and livestock owners tend to refrain from using such feeds. As one means of prevention, feed quality and safety standards have to be revised (Demissie, 2018).

Microbial quality

A wide range of microbes naturally occur on or as contaminants of forages, cereal grains, oilseed by products and compound feeds. Salmonella, listeria and E. coli are among the bacteria that could contaminate animal feeds. Cereal grains and oilseed by products are succeptible to fungi occurring as plant pathogens or developing during storage. Thus animal feeds must be stored in a controlled environment and should be monitored regularly for the growth of bacteria and fungi. Molds reduce the digestibility and palatability of feeds causing reduced growth, productivity and immunity of livestock (Adams *et al.*, 1993).

Mycotoxins

Among feed safety issues, is found the issue of high aflatoxin levels found in oilseed cakes and compound feeds that has raised serious concerns in ensuring the desired quality and safety of feed along the food value chain. Mycotoxins are found to cause reduced feed intake or feed acceptability. However, diseases caused by mycotoxins, known as mycotoxicoses, are the most important health problems caused by fungi contamination that cause lesion of organs. Mycotoxicoses can cause significant losses to the animal industry worldwide and must be prevented (Rodrigues and Naehrer, 2012).

2.5. Feed formulation

Feed formulation is the process of quantifying the number of feed ingredients that need to be combined to form a single uniform mixture for livestock and animal industry. The formulated feeds provide various nutrients that are needed for the growth of livestock. A good animal yield is highly dependent on the quality and safety of feeds supplied. Therefore the formulated feed should provide a balanced diet for the animal with high-quality ingredients and adequate amount to provide healthier growth (Poultry Hub, 2015).

One of the criteria for feed formulation is to make sure that all ingredients included in the recipe are safe from physical, chemical and biological contaminants. There should be a determination of contaminants such as mycotoxins especially aflatoxins before mixing of raw materials. And dilution of contaminated feed ingredients should be prohibited as it still poses a risk on public health (Grace *et al*., 2015).

Feed formulation is done based on the class of the animal, feed ingredient types and constraints and cost and availability of ingredients. Formulation of animal ration is a complicated problem as, the requirement of animals varies with species, the stages of growth, body weight and physiological needs such as pregnancies, milk yield at certain level with different fat percentages (Fox *et al.,* 2004).

Feed cost directly determines the profitability of animal farming since it accounts for most of the industry's expenses. In an attempt to economize the ration formulation, several mathematical models have been used with varying success. Some of the conventional methods available are Pearson's square method, trial and error method, two by two matrix method, simultaneous equation method and linear programming method (Pratiksha, 2012).

1. **Pearson square method**: is a simple method of balancing rations better used only when two ingredients and one nutritional requirement are used. It is mostly used for protein content. It works by making use of a square. The number that represents nutrient requirement is written at the center of the square. The ingredients to be used are listed and balanced on the side of the square. This method can't be applied for complex feed mixes (Wagner & Stanton, 2012).
2. **Trial and error method:** is a way of calculating formulations until the nutritional requirements are fulfilled. It can be done manually on paper or on a computer. However it is a time and money consuming method and difficult to apply to a larger number of ingredients (Afolayan, 2008).

3. **Two by two matrix method:** is a method of using an equation to balance two ingredients to fulfill two nutritional requirements. It can't be applied to more number of ingredients and requirements (Ghosh *et al.*, 2014).
4. **Simultaneous equation method**: is an advanced mathematics that utilizes algebraic equations to fulfill nutritional requirements by combining two or more ingredients. It is not practical, can be applied for only two nutrients at a time (Saxena, 2010).
5. **Linear programming:** is a method used effectively for least-cost ration or economic concentrate mixture formulation for many years. It allows a rapid formulation of rations that meet nutrient specifications by selecting optimal solutions. It has been evolved to consider the nutrient variability of the feed stuff in the model for ration formulation (Ghosh *et al.*, 2014).

There are different linear programming mathematical methods and softwares that are used to formulate profitable animal feeds by incorporating various ingredients. Some of the options that are available include least cost formulation, Win Feed 2.8, Feed MU2, Eco-MIX, AFSO, Feed-Mixer, Feed Formulation and Feed Assist. These soft wares and mathematical models allow for formulating feeds in a shorter time with less human error of calculation (Patil *et al.*, 2017).

The following are possible formulated diets for dairy cattle and poultry layers and broilers given by Yami (2015).

Table 7. Dairy feed ration

Ingredient	Maize	Soybean meal	Bone meal	Barley	Salt	Premix	Wheat bran	Limestone
Percent	60	10	3	12	0.5	0.5	10	4

Table 8. Poultry layer feed ration

Ingredient	Maize	Soybean meal	Bone meal	Limestone	Meat and bone meal	Salt	Premix	Wheat reject
Percent	63.5	20	2	6	4.5	0.5	0.5	3

Table 9. Poultry broiler feed ration

Ingredient	Maize	Soybean meal	Animal fat	Bone meal	DL-methionine	Salt	Premix	L– lysine
Percent	60	30	4	4.6	0.2	0.5	0.5	0.2

3. MATERIALS AND METHODS

3.1. Description of the study area

Addis Ababa has the highest number of animal feed enterprises in Ethiopia (26 out of 81). The study was conducted in Addis Ababa University, center for food science and nutrition laboratory.

3.2. Sample collection and preparation

Animal feed samples were collected from animal feed producers found in Addis Ababa. There are seven feed manufacturers in and around the study area. A total of 42 samples were taken of which 25 were feed ingredients (5 maize, 5 wheat bran, 5 wheat middling, 5 niger seed cake and 5 soya bean cake), 17 were compound feeds (5 dairy feeds and 12 poultry feeds). Samples were collected aseptically to avoid contamination. Samples were ground and crushed and kept in a controlled temperature and moisture prior to analysis.

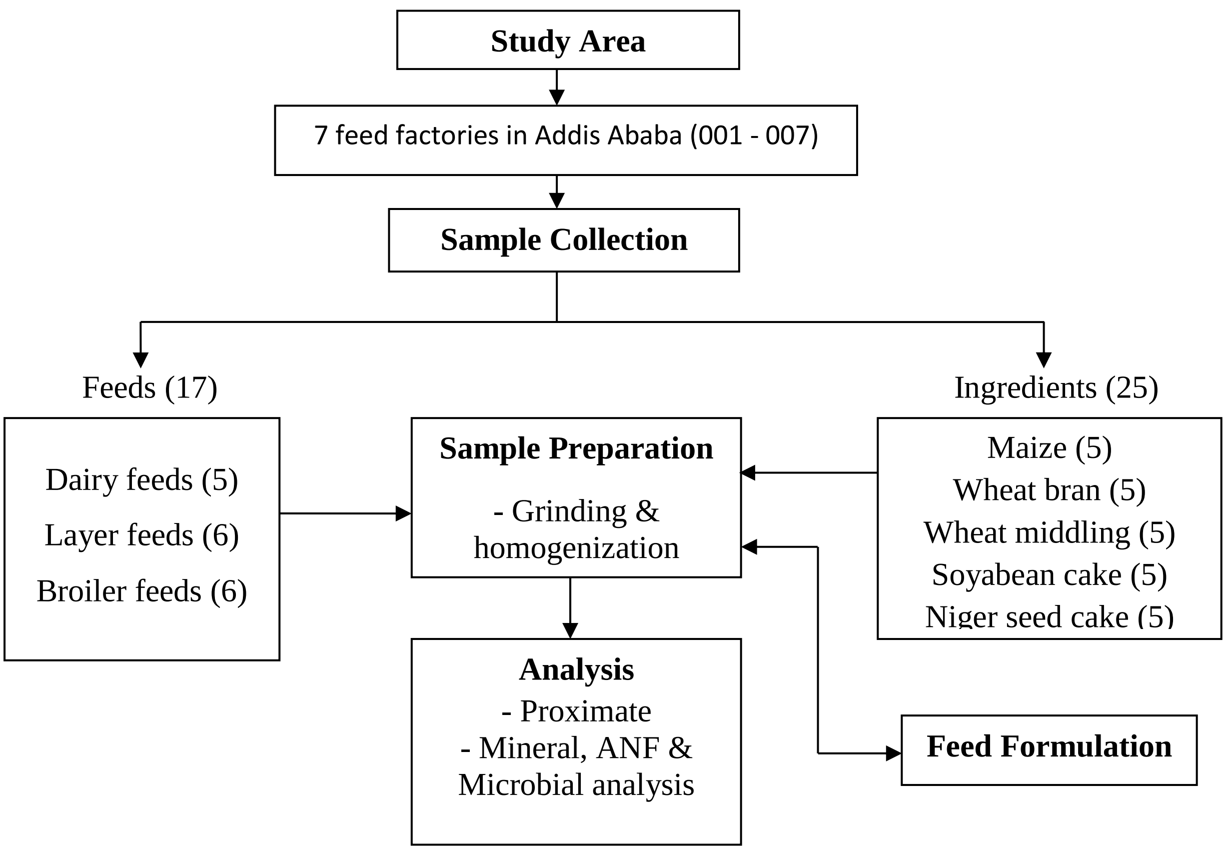

Figure 2. Flow chart of study design

3.3. Feed formulation by least cost formulation

Feed formulation was done by using least cost formulation application that uses linear programming. The formulation functions by utilizing Microsoft excel solver add in option. Excel is preferable since it is popular and widely available. It allows developing a feed from different ingredients that have various nutrient compositions in order to produce nutritious and affordable feeds (Radhika and Rao, 2010).

Least cost formulation is a way of balancing rations in a simple procedure that enables formulating feeds by entering the nutritional requirement of an animal for a specific nutrient. Feed combinations that can give the required nutritional value with the least possible cost values are selected. This is done by relating the food content of the ingredients with their cost. The spreadsheet has an alterable integrated list of common ingredients used in feed formulation with their respective average nutrient composition (Thomson and Nolan, 2001).

In the formulation process, the inputs for the formulation were entered accordingly. First the ingredients to be used in the formulation were selected. The ingredients selected based on nutrient content, availability and cost were wheat bran, wheat middling, soya bean meal, maize, molasses, rapeseed cake, limestone, salt, premix and dicalcium phosphate. Since the list of the ingredients was already available in the spreadsheet only the nutritional compositions were altered. Thus the average values obtained from the ingredient analysis in the study were filled in the feed analysis section of the worksheet. Then the cost of the ingredients in birr/quintal was filled as given in table 10.

Table 10. Cost of the ingredients used for formulation

Ingredient	Birr/quintal
Wheat bran	800
Wheat middling	800
Soybean meal	2000
Maize	750
Molasses	500
Rapeseed cake	550
Limestone	250
Salt	1000
Premix	12000
Dicalcium phosphate	900

The feed constraints, the minimum and maximum amount of the ingredients that is allowed in the feed were entered. After that the nutrient constraints, the minimum and maximum amount of the required nutrients were filled. Finally the feeds were formulated and a price was calculated. After formulation, the formulated diets were analyzed. The nutritional constraints are obtained from ESA standards while the feed constraints were obtained from Yami (2015). Feed constraints are put in order to mitigate possible side effects such as antinutritional factors that come from some of the feed ingredients.

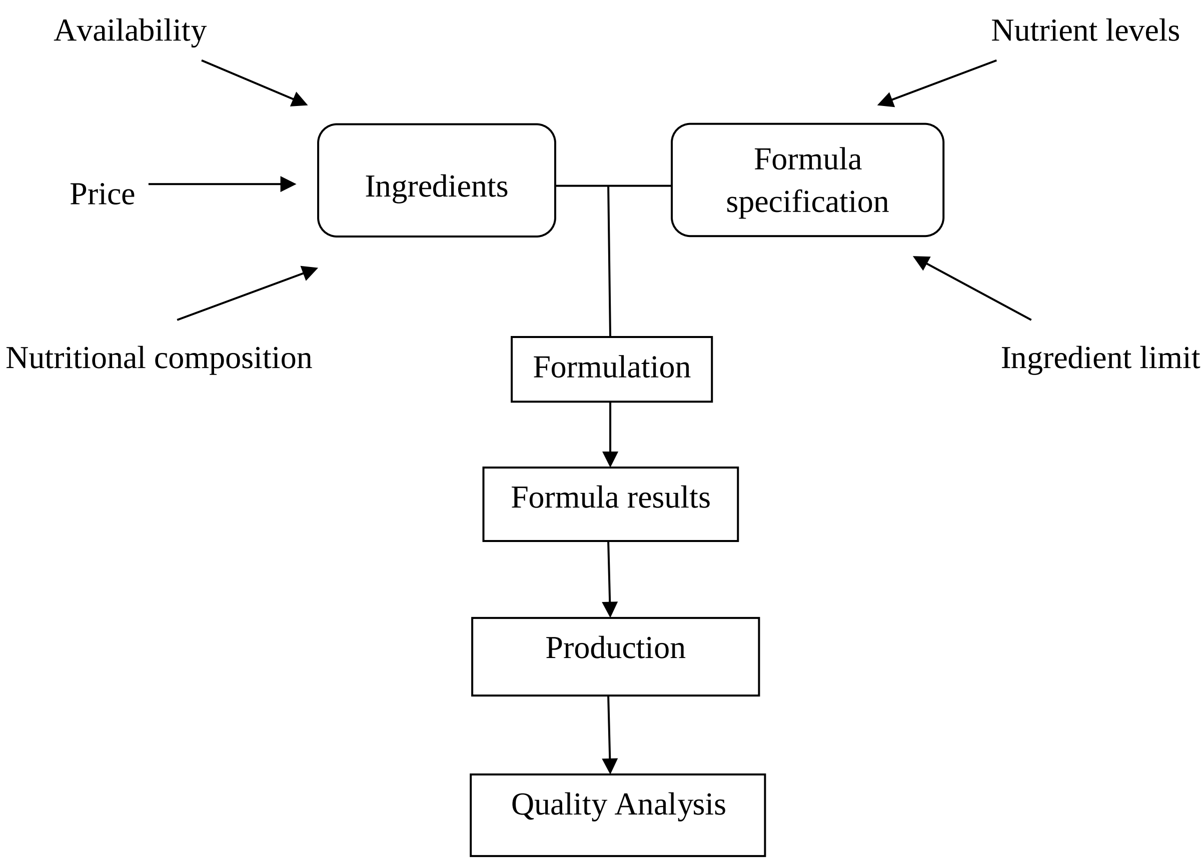

Figure 3. Flow chart of least cost formulation

(Rossi, 2004)

3.4. Proximate analysis of animal feeds and ingredients

Moisture analysis (AOAC 925.09, 2000), crude protein analysis (AOAC 970.09, 2000), crude fat analysis (AOAC 4.5.01, 2000), crude fiber analysis (AOAC 962.09, 2000) and ash analysis (AOAC 923.03, 2000) were done for the animal feeds and ingredients (AOAC, 2000).

Moisture analysis

First aluminum dishes were dried in an oven and were measured on analytical balance which gave mass 3 (W3). Then 5g of the sample was weighed on the dish which was recorded as mass 1 (W1). Then the sample was placed in an oven that was preheated to 105^0 c. It was left to dry for 3 hours measuring from the moment when the oven temperature had turned to 105 ^{0}C. Then it was left to cool for 20 minutes in a desiccator and was weighed which was recorded as mass 2 (W2). It was dried again until a constant weight.

Moisture content was calculated by:

$$\text{Moisture, Percent by weight} = \frac{(W1 - W2)}{W1 - W3} x\ 100$$

W1= Weight in g. of the dish and sample before drying

W2= Weight in g. of the dish and sample after drying

W3= Weight in g. of the empty dish

Crude protein analysis

The crude protein content of animal feed and ingredient samples were determined by using the AOAC (2000) official method 955.04 following the Kjeldahl procedure.

Digestion–0.5 g of the sample was weighed and placed in the Kjeldahl flask. 10 g of potassium sulfate, 1 g of copper sulfate and 25 ml of concentrated sulphuric acid was added and a few granules of pumice stone and the contents of the flask were mixed. The flask was placed on the Kjeldahl heater and heated moderately at first, shaking from time to time, until the mass carbonized and the foam disappeared; and then it was heated more intensively until it boiled steadily. When the solution became clear and light green it was left to boil for another hour and it was cooled.

Distillation - 25 ml of boric acid and a few drops of methyl red indicator were added in the collection flask (300 ml Erlenmeyer flask). The flask was placed under the condenser of the distillation apparatus so that the glass tube of the condenser was in the liquid of the Erlenmeyer flask. 300 ml of water was added in the Kjeldahl flask while continuously stirring until the sulfates dissolved completely. 100 ml of 40% sodium hydroxide was added slowly and the Kjeldahl flask was connected with the distillation apparatus. The Kjeldahl flask was heated gently until about 150 ml of liquid is distilled for about 30 minutes.

Titration - the ammonia present in the distillate was titrated with 0.1N sulphuric acid until the color changed from green to purple. The determinations were done in duplicates. A blank determination was done using all reagents in the same quantities and following the outlined procedures but without the material to be tested to correct for the readings.

Protein was calculated using the formula:

$$\%\text{N} = N\ HCl \times \frac{(\text{ml sample titer} - \text{ml blank titer})}{mg\ of\ sample} \times \frac{14\text{ g N}}{\text{mole}} \times 100$$

$$\%\ \text{Protein} = \%\ \text{N} \times 6.25$$

Crude fat analysis

Crude fat analysis was conducted by soxhlet method. 5g of the sample was weighed and placed in an extraction thimble. The thimble was placed in an extractor and was extracted for 6 hours with 150 ml petroleum ether. Heating was regulated such that petroleum ether was siphoned 15 times every hour. The ether extract was collected in a dry, weighed flask. After 6 hours, the petroleum ether was distilled off and then the residue was dried in an oven for 90 minutes. It was then cooled in a desiccator and weighed. It was dried again for 30 minutes and reweighed. Drying and weighing was repeated until the weight difference between consecutive weighings was less than 1 mg.

Calculation: $\text{Crude fat} = \frac{W2-W1}{W} X\ 100$

Where, W1 = Weight in g of extraction flask

W2 = Weight in g of extraction flask + dried crude fat

W = Weight in g of sample

Crude fiber analysis

2g of the sample was weighed on moisture and fat-free material into the beakers and 200 ml of dilute sulphuric acid was added and then was fitted to the refluxing apparatus. The contents were heated so that it began to boil within about 1 minute. The flask was rotated frequently and boiled for exactly 30 minutes. The contents of the flask were filtered through fine linen held in a funnel fitted to rubber Stoppard vacuum flasks. The residue on the linen was washed back into the beaker and 200 ml of dilute sodium hydroxide was added. The boiling and filtration procedure was repeated for sulphuric acid. The residue was washed thoroughly with boiling water and was transferred to a pre-weighed crucible. The residue was washed thoroughly and then ethanol three times while continuously filtering the contents of the crucible with the suction pressure of the vacuum flasks. Then the crucible and contents were dried at 105^0C to constant weight. Then it was cooled in a desiccator and weighed (W1). The contents of the crucible were ignited in a muffle and were cooled in a desiccator and weighed (W2).

Calculation: Crude fiber % $= \frac{W1-W2}{W}\ x\ 100$

Where, W1 = Crucible + Residue

W2 = Crucible + ash residue

W = Sample weight

Total ash determination

First porcelain dishes were cleaned and dried in a furnace for 30 minutes at 550^0c. Then the crucibles were cooled for 30 minutes in a desiccator and then weighed (W1). Then 2.5g of samples were weighed (W2). After that the samples were charred on a hot plate under a fume hood until the smoke ceased. Next the samples were ashed in a furnace for 5hrs at 550^0c until turned white and clear. Then the ashed samples were cooled for 30 minutes in a desiccator and weighed (W3).

The total ash was calculated as : $Ash\ \% = \left(\frac{W3-W1}{W2-W1}\right) \times 100$

Where, W2-W1 is samples mass in gram on dry base and

W3-W1 is mass of ash in gram.

3.5. Mineral analysis of animal feeds

Mineral analysis was done by using AOAC 942.05, 2002.The ash was dissolved by 5ml HCl at low temperature on a hot plate for about 2 hours. Then 7ml of 3M HCl was added and heated on a hot plate until the solution boiled. The digest was cooled and filtered through a filter paper into 50 ml volumetric flask. Then 5ml 3M HCl was added to the dishes and heated to dissolve the residue in the dishes and then transferred to volumetric flask. Then the filter paper was washed thoroughly and the washing was collected in the flask and made to the mark. Then the mineral concentration was determined by atomic absorption spectrophotometer. A blank solution was prepared. Blank solution and calibration solutions were run first.

Then the mineral was calculated as: $Mineral\ content\ (mg/100g) = \frac{(a-b)}{10\ \times w} \times v$

Where, a = concentration of sample solution in ppm

b = concentration of blank solution in ppm

v = volume in ml of extract

w = sample weight

3.6. Antinutritional factor analysis of poultry feeds

Phytate analysis

The phytate content of the samples was determined according to the method described in Oyaizu (1986). 100mg of sample was extracted with 10 ml of 2.4% HCl in a mechanical shaker for one hour at room temperature. The extract was centrifuged at 3000 rpm for 30 min. The clear supernatant was used for phytate estimation. 1ml of Wade reagent (containing 0.03% solution of $FeCl_3 \cdot 6H_2O$ and 0.3% of sulfosalicylic acid in water) was added to 3 ml of the sample solution (supernatant) and the mixture was vortexed for 5 s. Absorption readings at 500 nm were taken against a blank solution (3 ml extract solution mixed with 2 ml of 2.4% HCl). Sodium salt of phytic acid (4.5–36 mg/ml) was used as standard for construction of calibration curve.

Tannin analysis

Tannin was determined using method by Maxson and Rooney (1972). 1g of each sample was weighed and mixed with 10 ml of 1% HCl in methanol in a screw cap test tube. Then, the tube was shaken for 24 h at room temperature on a mechanical shaker. The solution was centrifuged at 1000 rpm for 5 min. 1ml of supernatant was transferred to another test tube and mixed with 5 ml of vanillin-HCl reagent (prepared by mixing equal volume of 8% concentrated HCl in methanol and 4% vanillin in methanol). A mixture of 1 ml of extract solution with 5 ml of 1% HCl without vanillin-HCl reagent was used as a blank. After 20 min, the absorbance of the solutions and the standard were measured at 500 nm. Catechin (0.5–12 mg/100 ml) was used as standard for construction of calibration curve.

3.7. Microbiological analysis of animal feeds and ingredients

Total mold count

Yeast and mold count was performed using the AOAC 2014.05 method. Accordingly, samples were serially diluted by blending 25 grams of each sample with 225 ml peptone water in a clean 500 ml sterile flask, shaken to make 10^{-1} dilution, and then serially diluted as needed (10^{-2}, 10^{-3}, 10^{-4}, 10^{-5}). Then, 0.1 ml aliquots from appropriate dilutions were spread-plated in duplicate on pre-dried surfaces of Potato Dextrose Agar (PDA) containing chloramphenicol (0.05 g/L). The plates were then incubated at 25^{o}C for 5 days and the count was done using colony counter.

3.8. Experimental design and data analysis

The experimental design used in this study was Completely Randomized Design (CRD) and data were analyzed by analysis of variance (ANOVA) using statistical software SPSS version 20 and significance differences were tested at ($p < 0.05$). All laboratory analysis was performed in duplicates, and averages were presented.

4. RESULTS AND DISCUSSION

4.1. Nutritional composition of animal feed ingredients

A total of 25 animal feed ingredients namely maize(5), wheat bran(5), wheat middling(5), soya bean cake(5) and niger seed cake(5) were analyzed to get values of moisture, crude protein, crude fat, crude fiber and total ash.

4.1.1. Nutritional composition of maize

The moisture content of maize ranged from 13.85% to 14.84% with an average value of 14.32%. The crude protein of maize ranged from 5.17% to 7.96% with an average value of 6.48%. The crude fat of maize ranged from 2.87% to 3.41% with an average value of 3.13%. The crude fiber of maize ranged from 1.48% to 3.04% with an average value of 2.3%.The total ash of maize ranged from 0.68% to 2.04% with an average value of 1.29% (Table 11).

Table 11. Nutritional composition of maize expressed as mean ± SD

Sample	Moisture (g/100g)	Crude Protein (g/100g)	Crude Fat (g/100g)	Crude Fiber (g/100g)	Total Ash (g/100g)	ME (kcal/kg)
Maize 001	$14.76^{b}\pm0.85$	$6.56^{a}\pm0.81$	$3.20^{a}\pm0.17$	$2.14^{a}\pm0.04$	$1.10^{a}\pm0.59$	3547.00
Maize 002	$14.42^{a}\pm0.85$	$6.47^{a}\pm1.32$	$3.16^{a}\pm0.23$	$2.61^{a}\pm0.61$	$1.20^{a}\pm0.13$	3525.00
Maize 003	$14.50^{a}\pm0.48$	$6.98^{a}\pm1.39$	$3.17^{a}\pm0.06$	$2.00^{a}\pm0.74$	$1.46^{a}\pm0.64$	3537.00
Maize 005	$13.91^{a}\pm0.85$	$6.30^{a}\pm1.29$	$3.16^{a}\pm0.35$	$2.44^{a}\pm1.19$	$1.52^{a}\pm0.74$	3513.00
Maize 006	$14.32^{a}\pm0.38$	$6.11^{a}\pm1.33$	$3.10^{a}\pm0.32$	$2.32^{a}\pm0.14$	$1.17^{a}\pm0.16$	3533.00
Mean	14.32	6.48	3.16	2.30	1.29	3531.00
Requirement	12	8	-	2	2	-

^{a,b,c} Means with different letters in a column are significantly different ($P<0.05$). – not available

According to the level set by ESA, for the moisture content of maize, all of the samples were above the limit 12%. The crude protein values of all the samples were below the limit 8%. The crude fiber limit is 2% and all the samples had crude fiber content above the limit. All the samples lied below the limit for ash which is 2%.

The results are different from a study conducted in India with moisture, crude protein, crude fat and total ash values of 7.27, 10.28, 5.39 and 2.3% respectively (Das *et al.*, 2014). But the results are similar to a study by Enysisi *et al* (2014) with 11.6 - 20 .0% (moisture), 4.50 – 9.87% (crude protein), 2.17- 4.43 (crude fat), 2.10 - 26.70% (crude fiber) and 1.10 – 2.95% (Ash) .The high moisture of the samples can be attributed to the storage of the samples while the crude protein values were not far from the standard.

4.1.2. Nutritional composition of wheat bran

The nutritional content of wheat bran is given in Table 12. The moisture content of wheat bran ranged from 9.9% to 12.81% with an average value of 11.75%. The crude protein of wheat bran ranged from 9.85% to 13.57% with an average value of 11.83%. The crude fat of wheat bran ranged from 2.76% to 3.60% with an average value of 3.24%. The crude fiber of wheat bran ranged from 6.06% to 8.96% with an average value of 7.89%. The ash of wheat bran ranged from 2.18% to 4.46% with an average value of 3.27%.

Table 12. Nutritional composition of wheat bran expressed as mean ± SD

Sample	Moisture (g/100g)	Crude Protein (g/100g)	Crude Fat (g/100g)	Crude Fiber (g/100g)	Total Ash (g/100g)	ME (kcal/kg)
Wheat bran001	11.92^{c}±0.57	12.12^{b}±0.18	3.45^{a}±0.00	7.36^{a}±1.80	3.56^{a}±1.12	3238.00
Wheat bran002	11.54^{b}±0.57	10.03^{a}±0.25	3.25^{a}±0.49	7.59^{a}±0.74	3.09^{a}±0.81	3181.00
Wheatbran 003	12.76^{d}±0.71	10.78^{a}±0.93	2.99^{a}±0.17	8.49^{a}±0.68	2.57^{a}±0.55	3204.00
Wheatbran 005	12.40^{d}±0.57	12.94^{c}±0.58	3.34^{a}±0.08	7.88^{a}±1.07	3.14^{a}±0.13	3308.00
Wheat bran006	10.11^{a}±0.30	13.26^{c}±0.44	3.16^{a}±0.57	8.11^{a}±1.16	4.00^{a}±0.65	3212.00
Mean	11.75	11.83	3.24	7.89	3.27	3229.00
Requirement	11.00	15.50	-	11.00	7.5	-

^{a,b,c} Means with different letters in a column are significantly different (P<0.05).- not available

The moisture content of the wheat brans was found to be higher than the ESA limit 11% in four of the wheat brans while one was below the limit. All of the samples had crude protein value below the limit 15.5%. All of the wheat brans were found to be below the crude fiber limit of 11%. All samples were lower than the ash limit of 7.5%. The high moisture reported in the study might be attributed to improper storage conditions.

The results found in this study were different from the study conducted in the highlands and central valley of Ethiopia (Zewdu, 2010) with moisture 13.47%, crude protein 16.87% and total ash 4.42%. The results were similar to a study conducted in India except for the crude protein value which was 15.68% (Das *et al.,* 2014). It is also similar to the study by (Onipe *et al.,* 2015) with results of moisture 8.1- 12.7%, crude protein 9.6- 18.6% and total ash 3.9- 8.1%.

4.1.3. Nutritional composition of wheat middling

The moisture content of wheat middling ranged from 9.94% to 11.89% with an average value of 10.79%. The crude protein of wheat middling ranged from 11.04% to 14.19% with an average value of 13.05%. The crude fat of wheat middling ranged from 1.90% to 3.17% with an average value of 2.63%. The crude fiber of wheat middling ranged from 2.82% to 8.25% with an average value of 5.96%. The ash of wheat middling ranged from 1.15% to 3.63% with an average value of 2.13% as given in Table 13.

Table 13. Nutritional composition of wheat middling expressed as mean ± SD

Sample	Moisture (g/100g)	Crude Protein (g/100g)	Crude Fat (g/100g)	Crude Fiber (g/100g)	Total Ash (g/100g)	ME (kcal/kg)
Wheat middling001	$10.13^{a}\pm0.24$	$13.61^{a}\pm0.74$	$3.06^{c}\pm0.06$	$6.33^{b}\pm0.79$	$2.87^{a}\pm1.07$	3383.00
Wheat middling002	$11.78^{b}\pm0.16$	$13.12^{a}\pm0.17$	$3.17^{c}\pm0.07$	$7.61^{b}\pm0.91$	$2.30^{a}\pm0.31$	3417.00
Wheat middling003	$11.24^{b}\pm0.07$	$12.44^{a}\pm0.48$	$1.98^{a}\pm0.11$	$3.11^{a}\pm0.41$	$1.50^{a}\pm0.49$	3496.00
Wheat middling005	$10.20^{a}\pm0.37$	$12.18^{a}\pm1.61$	$2.25^{a}\pm0.21$	$5.75^{b}\pm0.79$	$1.94^{a}\pm0.11$	3317.00
Wheat middling006	$10.62^{a}\pm0.57$	$13.90^{a}\pm0.41$	$2.74^{b}\pm0.35$	$7.02^{b}\pm1.30$	$2.22^{a}\pm0.74$	3336.00
Mean	10.79	13.05	2.63	5.96	2.13	3390.00
Requirement	11.00	16.50	-	9.50	5	-

[a,b,c] Means with different letters in a column are significantly different (P<0.05). – not available

Only two of the wheat middling samples had a moisture value above the limit 11% . All the samples had a crude protein value less than the limit 16.5%. The crude fiber content of all of the wheat middlings was below the limit of 9.5%. All samples were less than the limit for ash 5%.

The results of wheat middling are similar to a study by (Slominski *et al.*, 2004) with crude protein 14% but different in moisture content and crude fat which were 7.9 and 10.2 % respectively. The reason for a low crude protein found in this study could be due to the fact that the wheat middling samples contained high amount of bran.

4.1.4. Nutritional composition of soya bean cake

Table 14 shows the nutrient content of soya bean cake. The moisture content of soya bean cake ranged from 4.03% to 7.99% with an average value of 5.75%. The crude protein of soya bean cake ranged from 44.28% to 48.59% with an average value of 46.70%. The crude fat of soya bean cake ranged from 3.34% to 6.15% with an average value of 5.49%. The crude fiber of soya bean cake ranged from 6.56% to 9.13% with an average value of 7.92%. The ash of soya bean cake ranged from 5.06% to 7.56% with an average value of 6.29%.

Table 14. Nutritional composition of soya bean cake expressed as mean ± SD

Sample	Moisture (g/100g)	Crude Protein (g/100g)	Crude Fat (g/100g)	Crude Fiber (g/100g)	Crude Ash (g/100g)	ME (kcal/kg)
Soyabean cake 001	$7.94^{d}\pm0.71$	$44.45^{a}\pm0.24$	$6.00^{b}\pm0.10$	$8.40^{a}\pm1.03$	$6.00^{a}\pm0.11$	3296.00
Soyabean cake 002	$6.64^{c}\pm0.16$	$45.15^{a}\pm0.96$	$3.50^{a}\pm0.16$	$8.33^{a}\pm0.87$	$6.00^{a}\pm0.49$	3174.00
Soyabean cake 005	$5.25^{b}\pm0.28$	$47.60^{b}\pm0.98$	$6.00^{b}\pm0.17$	$7.48^{a}\pm0.66$	$6.40^{a}\pm0.38$	2964.00
Soyabean cake 006	$4.10^{a}\pm0.99$	$48.02^{b}\pm0.51$	$5.96^{b}\pm0.49$	$7.22^{a}\pm0.93$	$7.06^{a}\pm0.71$	3298.00
Soyabean cake007	$4.80^{b}\pm0.35$	$48.30^{b}\pm0.41$	$6.00^{b}\pm0.21$	$8.15^{a}\pm0.25$	$6.00^{a}\pm1.33$	3305.00
Mean	5.75	46.70	5.49	7.92	6.29	3207.00
Requirement	10.00	44.00	6.00	9.00	-	-

^{a,b,c} means with different letters in a column are significantly different (P<0.05)

According to the limit set by ESA, all the soya bean cakes had moisture content below the limit, 10%. All of the samples had a crude protein value above the limit 44%. Three of the samples had a crude fat content above the limit 6% while two lied below the limit. Four of the samples had crude fiber content below the limit 9%.

The results found in the study are similar in crude protein, crude fiber and crude ash but different in crude fat results of Banaszkiewicz (2011) which were 44, 4.3-7.2, 5.6-7.2 and 0.55-3.0% respectively. But the results of the study differ from results reported in Nigeria (Oladimeji and Kolapo, 2008) with crude protein 41%, crude fat 5.7%, crude fiber 7.1% and ash 5.1%. The variation of crude protein among the soya been cake samples could have resulted from different processing of the cakes.

4.1.5. Nutritional composition of niger seed cake

The moisture content of noug cake ranged from 5.32% to 9.6% with mean value 7.54%. The crude protein ranged from 35% to 38.97% with mean value 37.36%. The crude fat ranged from 7.61%

to 9.74% with a mean value of 8.60%. The crude fiber of the cake ranged from 13.1% to 18% with a mean value of 15.62%. The ash ranged from 5.73% to 8.84% with a mean value of 6.99% (Table 15).

Table 15. Nutritional composition of niger seed cake expressed as mean ± SD

Sample	Moisture (g/100g)	Crude Protein (g/100g)	Crude Fat (g/100g)	Crude Fiber (g/100g)	Total Ash (g/100g)	ME (kcal/kg)
Niger seed cake 001	7.16^{b}±0.40	38.14^{b}±0.37	7.65^{a}±0.06	13.61^{a}±0.72	7.63^{a}±0.85	3139.00
Niger seed cake 002	8.84^{c}±1.09	37.76^{b}±0.89	8.20^{b}±0.21	15.65^{a}±0.44	6.30^{a}±0.49	3142.00
Niger seed cake 003	8.66^{c}±0.08	37.66^{b}±0.62	9.65^{d}±0.13	17.00^{b}±0.71	8.05^{a}±1.12	3106.00
Niger seed cake 005	7.72^{b}±0.08	38.01^{b}±1.36	8.42^{b}±0.02	15.80^{a}±0.51	6.51^{a}±0.74	3140.00
Niger seed cake006	5.34^{a}±0.03	35.22^{a}±0.31	9.07^{c}±0.24	16.04^{b}±1.53	6.48^{a}±1.06	3165.00
Mean	7.54	37.36	8.60	15.62	6.99	3138.00
Requirement	10	32	7	20	-	-

^{a,b,c} means with different letters in a column are significantly different (P<0.05)

According to the limit set by ESA, all samples had moisture content below the limit 10%. While all contained crude protein above the limit32%. All the samples had a crude fat content higher than the limit 7%. All samples of niger seed cake had crude fiber content lower than the limit 20%.

The results of niger seed cake were similar to a study by Zewdu (2010) with moisture 6.59%, crude protein 34.5% and total ash 10.94%. The results of this study were also similar to a study by (Kassahun *et al*., 2012) except for crude protein (30.3), crude fiber (27.3) and ash (11.3). The high protein and fat content of the niger seed samples makes them suitable for production of feeds that meet standards.

4.1.6. Comparison of nutritional composition of animal feed ingredients

There is a significant difference among animal feed ingredients in moisture with soya bean cake having the lowest value and maize the highest value. There is also a significant difference in total ash value with maize the lowest value and niger seed cake the highest value. There is a significant difference in crude fat with niger seed cake having the highest value. There is a significant difference in crude protein with maize having the lowest value and soya bean cake the highest value. There is a significant difference in crude fiber with maize having the lowest value and niger seed cake having the highest value.

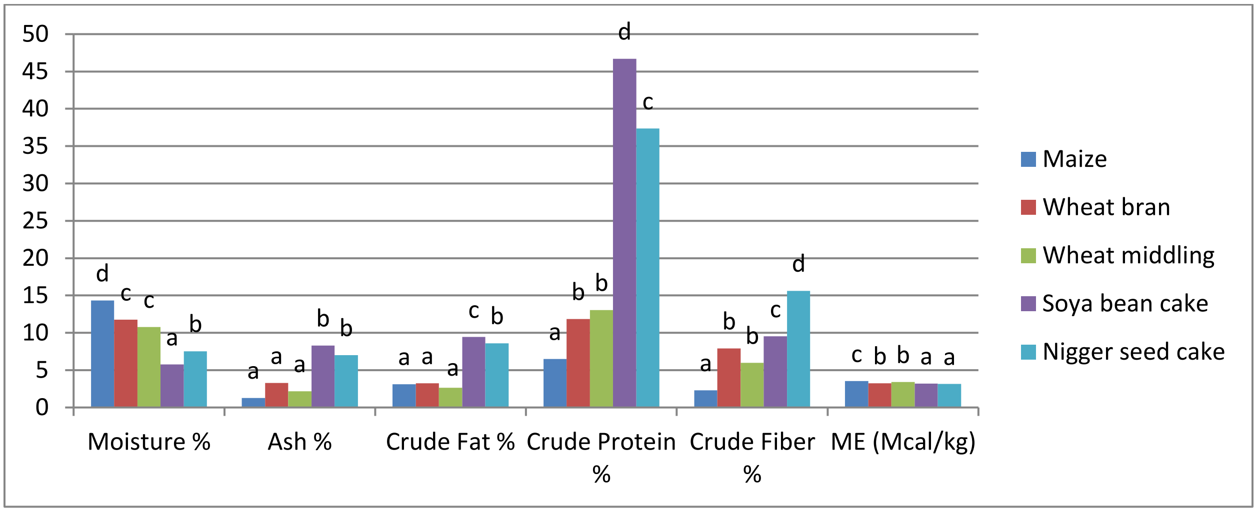

Figure 4. Mean values of nutritional composition of animal feed ingredients

4.2. Nutritional composition of animal feeds

A total of 17 feed samples were analyzed namely dairy feed (5), poultry layer feed (6) and poultry broiler feed (6). The samples were analyzed for values of moisture content, crude protein, crude fat, crude fiber and ash.

4.2.1. Nutritional composition of dairy feeds

The moisture content of dairy feed as shown in Table 16, ranged between 9.47% and 12.76% with a mean value of 10.79%. The crude protein of dairy feed ranged between 15.15% and 20.75% with a mean value of 18.3%.The crude fat of dairy feed ranged between 1.88% and 6.11% with a mean value of 4.14%. The crude fiber of dairy feed ranged between 5.62% and 23.69% with a mean value of 12.68%.The ash of dairy feed ranged between 6.58% and 16.11% with a mean value of 10.38%.

According to the standard set by ESA, only one of the samples had moisture content above the limit 12%. While all of the samples had crude protein value that lied in the set range of 15% to 25%, all the samples had a crude fat value below the limit 10%. Only one of the samples was above the crude fiber limit 12%.

The results found in this study were similar to a study conducted in and around Addis Ababa by Feyissa *et al.*, (2015) with moisture 11.1%, crude protein 19.08% and total ash 9.25%. The crude fat found in the study was very much lower than the standard. This might have occurred due to utilization of oil seed cakes with a lower fat value. This can be corrected by using ingredients such as roasted full fat soya bean.

Table 16. Nutritional composition of dairy feeds expressed as mean ± SD

Sample	Moisture (g/100g)	Crude Protein (g/100g)	Crude Fat (g/100g)	Crude Fiber (g/100g)	Total Ash (g/100g)	ME (kcal/kg)
Dairy Feed 001	12.38^{c}±0.54	17.15^{a}±0.20	3.75^{b}±0.01	7.03^{a}±1.98	8.00^{a}±0.82	3162.00
Dairy Feed 002	11.20^{b}±0.13	15.75^{a}±0.85	4.50^{c}±0.34	23.58^{c}±0.16	14.00^{b}±0.28	2410.00
Dairy Feed 003	9.82^{a}±0.08	19.66^{c}±0.76	2.26^{a}±0.08	10.64^{b}±1.12	7.25^{a}±0.94	2987.00
Dairy Feed 004	11.02^{b}±0.68	18.65^{b}±0.20	4.31^{c}±0.08	10.79^{b}±1.00	15.01^{b}±1.56	2813.00
Dairy Feed 006	9.51^{a}±0.06	20.27^{d}±0.68	5.90^{d}±0.21	11.38^{b}±0.89	7.63^{a}±0.65	3130.00
Mean	10.79	18.30	4.14	12.68	10.38	2900
Requirement	12	15-25	10	12	-	-

^{a,b,c}means with different letters in a column are significantly different (P<0.05)

4.2.2. Nutritional composition of poultry layer feeds

The nutritional content of poultry layer feeds is given in Table 17. The moisture content of layer feed ranged between 7.93% and 10.15% with a mean value of 9.33%. The crude protein of layer feed ranged between 14.88% and 21.59% with a mean value of 19.05%. The crude fat of layer feed ranged between 3.50% and 7.22% with a mean value of 4.58%. The crude fiber of layer feed ranged between 9.66% and 17.98% with a mean value of 12.98%. The ash of layer feed ranged between 10.45% and 22.68% with a mean value of 15.67%.

According to ESA, the moisture content of all the layer feeds was below the limit 12%. And only one of the samples was below the limit for crude protein, 16.5%. All the samples were above the limit for crude fiber, 7%. Two of the samples had total ash below the limit 14% while four were above the limit.

The results of this study were similar to a study in Japan (Sittiya and Yamauchi, 2014) with crude protein 18.11%, crude fat 5.68% and total ash 11.95%. The low result of crude protein for one of the samples might have come from the use of high proportion of the low protein ingredients.

Table 17. Nutritional composition of layer feeds expressed as mean ± SD

Sample	Moisture (g/100g)	Crude Protein (g/100g)	Crude Fat (g/100g)	Crude Fiber (g/100g)	Total Ash (g/100g)	ME (kcal/kg)
Layer Feed 001-1	9.42^{b}±0.01	19.78^{c}±0.96	5.25^{d}±0.20	10.20^{a}±0.42	17.20^{b}±1.15	2803.00
Layer Feed 001-2	8.48^{a}±0.21	20.65^{c}±0.76	4.50^{c}±0.37	10.92^{a}±0.45	12.00^{a}±2.19	2923.00
Layer Feed 002	9.96^{b}±0.06	20.12^{c}±0.10	4.25^{b}±0.04	17.88^{c}±0.15	15.60^{b}±0.75	2541.00
Layer Feed 004	10.04^{b}±0.16	17.33^{b}±0.17	3.75^{a}±0.06	15.29^{b}±0.58	15.14^{a}±1.00	2622.00
Layer Feed 005	9.72^{b}±0.57	15.40^{a}±0.74	3.50^{a}±0.00	9.76^{a}±0.14	22.00^{c}±0.96	2564.00
Layer Feed 006	8.33^{a}±0.58	21.00^{c}±0.83	6.22^{e}±0.98	13.82^{b}±1.19	12.05^{a}±1.10	2906.00
Mean	9.33	19.05	4.58	12.98	15.67	2726.00
Requirement	12.00	16.50	-	7.00	14.00	2300.00

^{a,b,c} means with different letters in a column are significantly different (P<0.05). – not available

4.2.3. Nutritional composition of poultry broiler Feeds

The moisture content of broiler feeds ranged between 8.8% and 11.53% with a mean value of 9.92%. The crude protein of broiler feeds ranged between 16.77% and 25.08% with a mean value of 21.23%. The crude fat of broiler feeds ranged between 3.88% and 8.04% with a mean value of 4.98%. The crude fiber of broiler feeds ranged between 7.11% and 26.51% with a mean value of 11.81%. The ash of broiler feeds ranged between 15.34% and 21.57% with a mean value of 18.60% (Table 18).

The entire broiler feed samples had moisture content less than the limit set by ESA, 12%. Only one of the samples had a crude protein value less than the limit, 20%. All the samples were above the crude fiber limit 6%. All the samples' total ash was above the limit 9%.

The results of the poultry broiler feeds found in this study were similar to a study by (Diarra *et al.*, 2015) with 20.2% crude protein and 5.3% crude fat but different in crude fiber (4%) and ash (5.7%). The crude protein result was also similar to a study by (Sanusi *et al.*, 2015) 20.28% but the results of crude fat (9.56%) and crude fiber (7.7%) were different. The low protein content of one of the feeds might have resulted from using too much of the low protein raw materials of wheat brans and middlings.

Table 18. Nutritional composition of broiler feeds expressed as mean ± SD

Sample	Moisture (g/100g)	Crude Protein (g/100g)	Crude Fat (g/100g)	Crude Fiber (g/100g)	Total Ash (g/100g)	ME (kcal/kg)
Broiler Feed 002-1	9.55^{a}±0.71	20.76^{a}±0.25	4.16^{a}±0.23	8.45^{a}±1.00	19.92^{b}±1.94	2715.00
Broiler Feed 005-1	9.73^{a}±0.31	22.23^{b}±0.49	4.50^{a}±0.30	10.26^{a}±0.98	20.80^{b}±0.82	2638.00
Broiler Feed 004	11.09^{c}±0.62	18.20^{a}±2.02	4.00^{a}±0.17	7.93^{a}±1.17	15.30^{a}±0.27	2887.00
Broiler Feed 005-2	9.02^{a}±0.30	25.03^{c}±0.07	8.00^{c}±0.06	8.76^{a}±0.80	16.00^{a}±0.93	3033.00
Broiler Feed 002-2	9.40^{a}±0.71	21.00^{b}±1.07	4.24^{a}±0.30	9.08^{a}±1.16	18.77^{b}±0.66	2737.00
Broiler Feed 005-3	10.65^{b}±0.06	20.14^{a}±2.31	5.00^{b}±0.27	26.37^{b}±0.19	20.80^{b}±1.09	2099.00
Mean	9.92	21.23	4.98	11.81	18.60	2685.00
Requirement	12.00	20.00	-	6.00	9.00	2900.00

^{a,b,c}means with different letters in a column are significantly different (P<0.05). – not available

4.2.4. Comparison of nutritional composition of animal feeds

There is a significant difference in moisture among animal feeds with dairy feed having the highest moisture. There is a significant difference among animal feeds' total ash value with broiler feed having the highest value. There is no significant difference in crude fat value of the feeds. There is a significant difference in the crude protein value of feeds with broiler feed having the highest value. There is no significant difference among the crude fiber of the animal feeds.

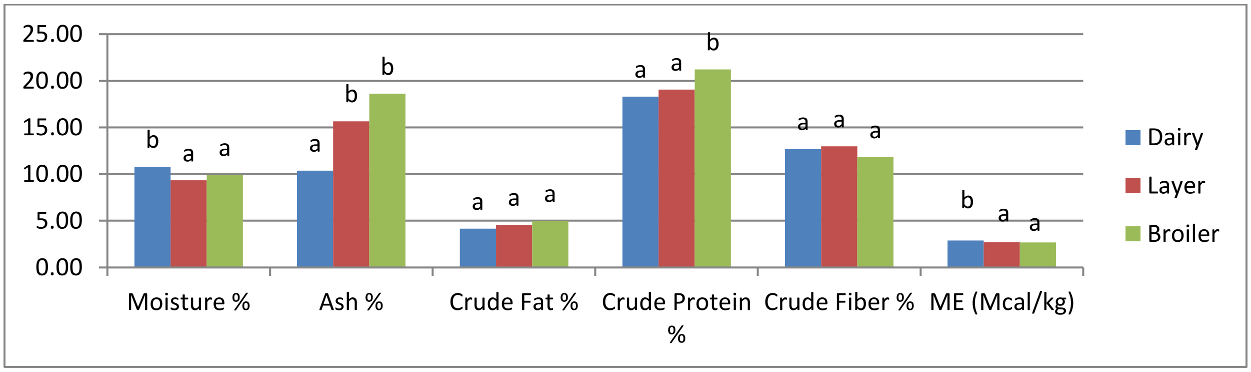

Figure 5. Mean values of nutritional composition of animal feeds

4.3. Mineral content of animal feeds

Mineral content of dairy feeds

The calcium and phosphorus content of dairy feeds is given in Table 19. Two of the dairy feeds have calcium content above the limit while three of the feeds have calcium content below the limit. All of the dairy feeds have phosphorus content below the limit set by ESA. Calcium limit for dairy feeds is 0.8% and the limit for phosphorus is 0.5%.

Table 19. Mineral content of dairy feeds expressed as Mean ± SD

Sample	Calcium (g/100g)	Phosphorus(g/100g)
Dairy Feed 001	$0.73^{a} \pm 0.06$	$0.06^{b} \pm 0.00$
Dairy Feed 002	$3.47^{b} \pm 0.66$	$0.08^{c} \pm 0.00$
Dairy Feed 003	$0.62^{a} \pm 0.03$	$0.06^{b} \pm 0.00$
Dairy Feed 004	$0.66^{a} \pm 0.03$	$0.04^{a} \pm 0.00$
Dairy Feed 006	$5.23^{c} \pm 0.16$	$0.09^{c} \pm 0.01$
Mean	2.14	0.06
Requirement	0.8	0.5

^{a,b,c}means with different letters in a column are significantly different ($P<0.05$)

The results found in this study were different from a study by Bhanderi *et al*., 2016 with mineral content of dairy feed of calcium 0.99 ± 0.1 and phosphorus 1.41± 0.06. The low content of calcium and phosphorus in the feeds shows that there is an imbalance of minerals in the dairy rations due to low mineral containing ingredients. Thus the feeds need to be improved with addition of ingredients such as limestone and dicalcium phosphate.

Mineral content of layer feeds

Calcium and phosphorus content of poultry layer feeds is given in Table 20. Only two of the layer feeds have calcium value in the specification range while four have calcium content less than the specification. All the layer feeds have phosphorus content below the limit set by ESA which is 0.4% respectively.

Phosphorus is necessary for bone and teeth formation and milk and egg production. Calcium is one of the essential minerals in poultry layer nutrition. Other than being the main structure of bone structure, it is the main component of egg shell. Most of the poultry layer feeds in the study are lacking in calcium which could have resulted from the size of the limestone in the feeds which affects its solubility (Pelicia *et al.*, 2009).

Table 20. Mineral content of layer feeds expressed as Mean ± SD

Sample	Calcium (g/100g)	Phosphorus(g/100g)
Layer F001-1	3.53^{f} ± 0.35	0.08^{b}±0.00
Layer F001-2	0.57^{a} ± 0.28	0.08^{b}±0.00
Layer F002	3.44^{e} ± 0.06	0.08^{b}±0.01
Layer F004	0.63^{b} ± 0.03	0.07^{b}±0.01
Layer F005	1.09^{c} ± 0.06	0.07^{b}±0.00
Layer F006	2.85^{d} ± 0.35	0.04^{a}±0.00
Mean	2.02	0.07
Requirement	3-4	0.4

^{a,b,c} means with different letters a column are significantly different (P<0.05)

Mineral content of broiler feeds

Four of the broiler feeds have calcium content more than the ESA limit which is 1-1.14% while two of them have calcium content less than the limit. All the broiler feeds have phosphorus content less than the limit for phosphorus which is 0.45% (Table 21).

Only two of the poultry broiler feeds have a calcium value below the standard limit. This might have resulted from low calcium supplementation in the feed. The calcium supplementation can be maintained by providing calcium separately if not in the feed.

Table 21. Mineral content of broiler feeds expressed as Mean ± SD

Sample	Calcium (g/100g)	Phosphorus(g/100g)
Broiler F002-1	3.80^{c}± 0.03	0.07^{a}±0.02
Broiler F005-1	4.60^{d}± 0.28	0.05^{a}±0.00
Broiler F004	0.89^{b}± 0.06	0.07^{a}±0.00
Broiler F005-2	1.32^{b}± 0.03	0.05^{a}±0.00
Broiler F002-2	0.34^{a}± 0.06	0.06^{a}±0.00
Broiler F005-3	1.20^{b} ± 0.35	0.05^{a}±0.00
Mean	2.03	0.06
Requirement	1-1.4	0.45

^{a,b,c} means with different letters in a column are significantly different (P<0.05)

4.4. Antinutritional factors of poultry feeds

Antinutritional factors of layer feeds

The results for antinutritional factors of poultry layer feeds show high amount of phytate and tannin concentrations (Table 22). These antinutritional factors reduce feed intake, palatability, digestibility and nutrient utilization.

Table 22. Antinutritional factors of poultry layer feeds expressed as Mean ± SD

Sample	Phytate(mg/100g)	Tannin(mg/100g)
Layer F001-1	329.31^{e}±12.52	60.45^{b}±2.95
Layer F001-2	427.53^{f}±1.10	255.42^{e}±13.38
Layer F002	160.56^{b}±10.05	242.83^{e}±1.48
Layer F004	267.73^{d}±5.08	29.18^{a}±0.00
Layer F005	81.89^{a}±4.54	101.66^{d}±2.93
Layer F006	181.16^{c}±7.98	75.22^{c}±0.00
Mean	241.36	127.46

^{a,b,c} means with different letters in a column are significantly different (P<0.05)

Antinutritional factors of broiler feeds

The broiler feeds had high content of phytate and tannin as shown in Table 23. The negative impact of these antinutritional factors should be reduced by feed processing such as drying, soaking, grinding and pelleting and also by addition of enzymes such as phytase.

Table 23. Antinutritional factors of poultry broiler feeds expressed as mean ± SD

Sample	Phytate(mg/100g)	Tannin(mg/100g)
Broiler F002-1	323.02^{d}±5.61	8.39^{a}±0.00
Broiler F005-1	222.22^{b}±0.00	4.18^{a}±0.00
Broiler F004	199.47^{a}±10.45	138.90^{c}±8.80
Broiler F005-2	282.26^{c}±3.80	43.40^{b}±2.92
Broiler F002-2	179.53^{a}±8.84	330.26^{d}±8.81
Broiler F005-3	219.79^{b}±13.17	8.30^{a}±0.00
Mean	237.71	88.90

^{a,b,c} means with different letters in a column are significantly different (P<0.05)

4.5. Microbiological analysis of animal feeds and ingredients

The 42 samples of animal feeds and ingredients were analyzed for total mold count.

Fungal load in animal feed ingredients

The average fungal (Mold and Yeast) load recorded from all animal feed ingredients in the present study was found higher than the standard limit set for animal feed ingredients by ESA (2.0×10^4 CFU/g) (Table 24). In this study, a mean mold and yeast count that ranged between 2.60×10^6 CFU/g to 1.82×10^7 CFU/g were recorded from animal feed ingredients. The highest mold and yeast count (1.82×10^7 CFU/g) was noticed from niger seed cake samples whereas the lowest mold and yeast count (2.60×10^6 CFU/g) was recorded from maize samples.

A count similar to this study was reported on yeast and mold count for corn samples with a range of 1×10^5 to 1×10^6 CFU/g. But a higher count of 10^8 CFU/g was reported for cereal feed ingredients in Poland (Kukier *et al.*, 2013). However, a lower yeast and mold count than the current study was reported from Brazil (Valmorbida *et al.*, 2018) maize sample of 2×10^4 CFU/g .The high mold count found in this study could be attributed to the poor storage management applied in the present study.

Table 24. Total mold count of animal feed ingredients in CFU/g

Sample	Maize	Wheat bran	Wheat middling	Soya bean cake	Niger seed cake
001	7×10^6	1.25×10^7	4×10^6	4×10^6	2×10^6
002	0	3.4×10^7	2×10^6	2×10^6	7×10^6
003	0	8×10^6	1×10^6	-	2.2×10^7
005	1×10^6	6×10^6	8×10^6	1×10^6	0
006	5×10^6	1×10^6	3×10^6	8×10^6	6×10^7
007	-	-	-	1×10^6	-
Mean	2.6×10^6	1.27×10^7	3.6×10^6	3.2×10^6	1.82×10^7

Fungal load in animal feeds

All animal feeds had total mold count higher than the ESA limit, 2×10^4 CFU/g . The highest count was recorded for poultry layer feed (9.67×10^6 CFU/g) and the lowest count was recorded for poultry broiler feed (4.17×10^6 CFU/g) (Table 25).

Table 25. Total mold count of animal feeds in CFU/g

Sample	Dairy feed	Layer feed	Broiler feed
001-1	4×10^6	2×10^7	-
001-2	-	2×10^6	-
002-1	6×10^6	2×10^7	0
002-2	-	-	8×10^6
003	1.5×10^7	-	-
004	1×10^6	1.2×10^7	3×10^6
005-1	-	2×10^6	1×10^6
005-2	-	-	8×10^6
005-3	-	-	5×10^6
006	5×10^6	2×10^6	-
Mean	6.2×10^6	9.67×10^6	4.17×10^6

The results for dairy cattle feed are much higher than the results reported in Egypt (Mona *et al.*, 2016) which was a mean value of 5.58×10^4 CFU/g. The results for poultry feeds are much higher than the fungal load reported in poultry feeds from Nigeria (Kehinde *et al*, 2014) which contained 4×10^3 to 4.2×10^4 CFU/g. The higher counts might have resulted from improper storage conditions and handling of the feeds.

4.6. Nutritional analysis of feeds newly formulated by least cost formulation

Feeds for dairy cattle, poultry layers and poultry broilers have been formulated by using least cost formulation application. In the formulation, niger seed cake has been replaced with rape seed cake since it has been found in many studies unsafe due to contamination with aflatoxin. The production of rapeseed in Ethiopia is around 26,000 metric tons per annum. Rape seed cake is one of the oil seed cakes utilized for animal feed production. Similar to soya bean cake it is a good source of protein, carbohydrate and essential minerals which can serve various purposes. High water and oil absorption capacities, emulsion capacities and stabilities make it useful in the feed formulation (Rutkowska *et al.*, 2015).

Rapeseed cake has an average content of moisture 7.49 %, crude protein 31.96 %, crude fat 9.82 %, crude fiber 10.84 % and ash 8.56 %. Nega (2018) has pointed out that rapeseed meal can replace soya bean meal for the preparation of dairy and poultry feeds. A study by Rutkowska *et al.*, 2015 has showed that rapeseed meal can be used for dairy diet as an optional protein source. A study on broilers performance by feeding rapeseed meal in place of niger seed cake has been done by

Tadelle *et al.,* 2003 which revealed that rapeseed meal can be used up to 28% in broiler diets. Also the price of rapeseed cake is cheaper than the widely used soya bean cake and niger seed cakes.

The results for the formulation of the feeds are presented as follows. The feeds are prepared by using similar ingredients but different compositions.

1. Dairy cattle feed

Dairy cattle feed has been formulated by making use of the ingredients maize, wheat bran, wheat middling, soya bean cake, rape seed cake, molasses, limestone, salt, vitamin/mineral premix and dicalcium phosphate in the amount composition given in table 26. The feed costs one thousand thirty five birr per quintal.

Table 26. Composition of ingredients of newly formulated dairy feed

Ingredients	Amount (%)
Maize	40.00
Soya bean cake	21.00
Wheat bran	10.00
Wheat middling	10.00
Rapeseed cake	10.00
Molasses	03.00
Limestone	04.00
Salt	01.00
Vitamin/mineral premix	0.50
Dicalcium phosphate	0.50
Total	100

2. Poultry layer feed

The feed for poultry layers has been formulated by using the ingredients maize, wheat bran, wheat middling, soya bean cake, rape seed cake, molasses, limestone, salt and vitamin/mineral premix in the amount composition given in table 27. The feed costs one thousand ninety birr per quintal.

Table 27. Composition of ingredients of newly formulated layer feed

Ingredients	Amount (%)
Maize	40.00
Soya bean cake	20.00
Wheat bran	08.00
Wheat middling	08.00
Rapeseed cake	05.00
Molasses	03.00
Meat and bone meal	10.00
Limestone	5.00
Salt	0.50
Vitamin/mineral premix	0.50
Total	100

3. Poultry broiler feed

The feed for poultry broiler feed has been formulated by using maize, wheat bran, wheat middling, soya bean cake, rape seed cake, molasses, limestone, salt, vitamin/mineral premix and dicalcium phosphate in the amount composition given in table 28. The feed costs one thousand one hundred fifty birr per quintal.

Table 28. Composition of ingredients of newly formulated broiler feed

Ingredients	Amount (%)
Maize	40.00
Soya bean cake	27.00
Wheat bran	08.00
Wheat middling	08.00
Rapeseed cake	04.00
Molasses	03.00
Meat and bone meal	05.00
Limestone	04.00
Salt	0.50
Vitamin/mineral premix	0.50
Total	100

The newly formulated feeds were evaluated for proximate analysis (moisture, crude protein, crude fat, crude fiber and ash) and mineral analysis (calcium and phosphorus) and the results are given in tables 29 and 30.

Table 29. Nutritional composition of newly formulated feeds expressed as mean ± SD

Sample	Moisture (g/100g)	Crude Protein (g/100g)	Crude Fat (g/100g)	Crude Fiber (g/100g)	Total Ash (g/100g)	ME (kcal/kg)
Dairy Feed	7.46 ± 0.51	18.1 ± 0.30	9.88 ± 0.18	6.05 ± 0.07	3.74 ± 0.08	3651
Layer Feed	8.91 ± 0.58	19.33 ± 0.30	7.70 ± 0.96	5.83 ± 1.02	5.00 ± 0.13	3506
Broiler Feed	8.52 ± 0.65	21.2 ± 0.88	7.59 ± 0.82	5.11 ± 0.91	4.65 ± 0.06	3538

Table 30. Mineral content of newly formulated feeds expressed as mean ± SD

Sample	Calcium (g/100g)	Phosphorus (g/100g)
Dairy Feed	1.2 ± 0.42	0.55 ± 0.04
Layer Feed	3.41± 0.36	0.46 ± 0.05
Broiler Feed	1.24 ± 0.18	0.49 ± 0.04

The results of nutritional composition analysis evaluated for the newly formulated dairy, poultry layer and poultry broiler feeds show high nutritional value of the feeds. The feeds have improved results than the feeds that have been collected in the study area. Thus the formulated feeds can be used for the production of improved quality animal source foods.

Table 31. Comparison of nutritional composition of formulated dairy feed with factories

Dairy Feeds	Moisture (g/100g)	Crude Protein (g/100g)	Crude Fat (g/100g)	Crude Fiber (g/100g)	Total Ash (g/100g)	ME (kcal/kg)	Calcium (g/100g)	Phospho -rus (g/100g)
New Formula	7.46	18.10	9.88	6.05	3.74	3651	1.2	0.55
Factories	10.79	18.30	4.14	12.68	10.38	2900	2.14	0.06

Table 32. Comparison of nutritional composition of formulated layer feed with factories

Layer feeds	Moisture (g/100g)	Crude Protein (g/100g)	Crude Fat (g/100g)	Crude Fiber (g/100g)	Total Ash (g/100g)	ME (kcal/kg)	Calcium (g/100g)	Phospho-rus (g/100g)
New Formula	8.91	19.33	7.70	5.83	5.00	3506	3.41	0.46
Factories	9.33	19.05	4.58	12.98	15.67	2726	2.02	0.07

Table 33. Comparison of nutritional composition of formulated broiler feed with factories

Broiler feeds	Moisture (g/100g)	Crude Protein (g/100g)	Crude Fat (g/100g)	Crude Fiber (g/100g)	Total Ash (g/100g)	ME (kcal/kg)	Calcium (g/100g)	Phospho-rus (g/100g)
New Formula	8.52	21.2	7.59	5.11	4.65	3538	1.24	0.49
Factories	9.92	21.23	4.98	11.81	18.60	2685	2.03	0.06

The newly formulated feeds are better from the feeds collected from the study area in the results of crude protein, crude fat, crude fiber, calcium and phosphorus. This was achieved by the use of the suitable ingredients that fulfill these requirements. The crude protein of the newly formulated poultry feeds is up to standard. The crude fat of the newly formulated dairy feeds has an increased value. The crude fiber of poultry feeds is in range and also the phosphorus and calcium content of all feeds is improved.

5. CONCLUSION AND RECOMMENDATION

5.1. Conclusion

This study was done to evaluate the proximate, mineral, antinutritional and microbiological composition of animal feeds and ingredients. The proximate analysis results for the feed ingredients show that there is a significant difference among the feed producers. All the maize samples had moisture higher than the limit and crude protein less than the limit. Four out of the five wheat bran samples had moisture above the limit and all of the wheat brans had crude protein composition lower than the limit. Two out of five wheat middlings had moisture above the limit and all the wheat middling samples had crude protein below the limit. All soya bean cake and niger seed cake samples had nutritional composition within the limits.

The results for the dairy feeds showed that there is a significant difference among the feed manufacturers. Most of the results were in the set standard but 100% of the dairy feeds had crude fat value below the set limit. There was a significant difference among the manufacturers for poultry layer feeds. One out of the six poultry layer feeds (17%) had a crude protein less than the specification. There was also a significant difference among the poultry broiler feeds in all the proximate analysis and there was a deviation from the standard of crude protein in one of the samples out of a total of six samples (17%).

All of the poultry layer and broiler feeds had crude fiber above the limits. The mineral analysis of the animal feeds showed that 100% of the feeds contained a low amount of phosphorus. Three out of the five dairy feeds (60%), four out of the six layer feeds (67%) and two out of the six broiler feeds (33%) had low calcium value. The antinutritional factor analysis results showed that all the poultry feeds have a high amount of the antinutritional factors phytate and tannin. The microbiological analysis of the feeds and ingredients showed that 100% of the feeds and ingredients were highly contaminated by moulds far beyond the specified limits.

The results show that there is a need for improvement on some of the parameters of the nutritional requirement. From the feed formulations done in this study, it can be concluded that feeds can be produced by using a formulation that incorporates rapeseed cake. Rape seed cake is suitable to use as an alternative and additional ingredient for protein source with its high nutritional quality, availability and low cost.

5.2. Recommendation

- According to the result of the assessment of the nutritional status of the available animal feeds and ingredients used for animal feed manufacturing, it is recommended to store the ingredients and feeds in a controlled environment in order to keep the moisture at the set value.
- It is recommended for feed manufacturers to analyze the nutritional composition of raw materials that are used to make feeds in order to meet the required standards which can enable the producers to produce feeds with a higher protein and energy.
- It is recommendable to focus on mineral contents and analysis of calcium and phosphorus of the feeds since they are essential minerals required for quality nutrition that directly affect productivity.
- It is recommended for regulatory bodies such as VDFACA to monitor the nutritional quality of the animal feeds and ingredients in a regular manner in order to have consistent products.
- It is recommended to also check the safety of the raw materials used since unsafe raw materials result in unsafe feeds. It is advisable to avoid using niger seed cake since it has been found by several researches highly contaminated with aflatoxins. It can be replaced with uncontaminated and less susceptible ingredients with similar nutritional value like rape seed cake.
- Since all the feeds and ingredients analyzed in this study were found to be highly contaminated with molds far beyond the specified limit, it is advised to check the feed ingredients for mold infestation before purchasing and utilizing for feed manufacturing. Also ingredients free of mold should be kept in a conditioned environment and be monitored for mold growth prior to production. Researchers should focus on studying pathogenic microorganisms found in feeds and ways of producing healthier animal feeds .

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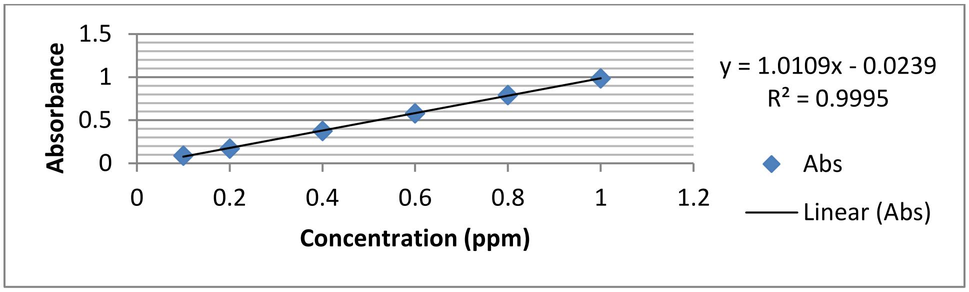
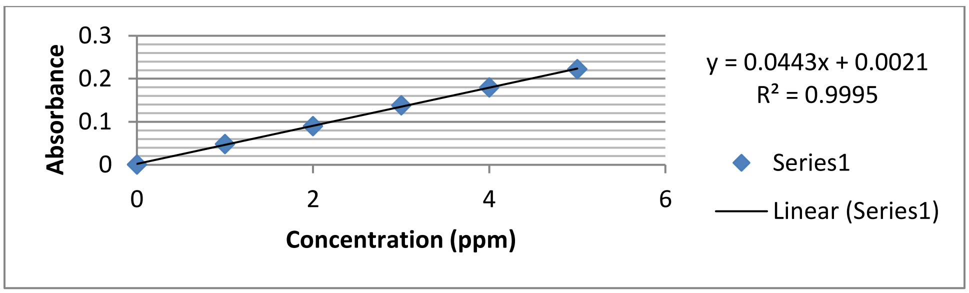
Annex

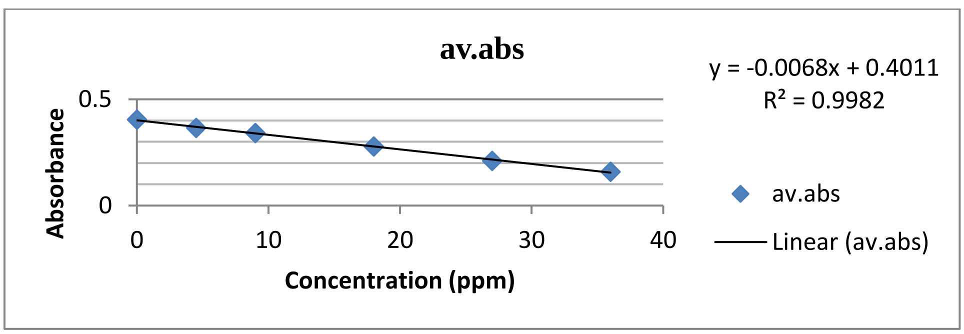
Annex 1. Calibration curve for phosphorus analysis



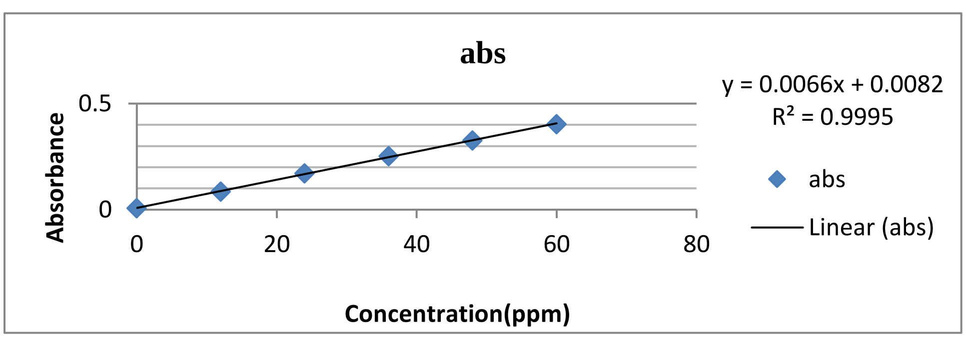
Annex 2. Calibration curve for calcium analysis



Annex 3. Calibration curve for phytate analysis



Annex 4. Calibration curve for tannin analysis



Annex 5. ANOVA

Moisture results

Moisture

	Maize	N	Subset for alpha = 0.05	
			1	2
Duncan[a]	Maize005	2	13.9100	
	Maize006	2	14.0000	
	Maize002	2	14.4200	14.4200
	Maize003	2	14.5000	14.5000
	Maize001	2		14.7600
	Sig.		.061	.219

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.

Moisture

	Wheat bran	N	Subset for alpha = 0.05			
			1	2	3	4
Duncan[a]	Wheat bran 006	2	10.1100			
	Wheat bran 002	2		11.5400		
	Wheat bran 001	2			11.9200	
	Wheat bran 005	2				12.4000
	Wheat bran 003	2				12.7600
	Sig.		1.000	1.000	1.000	.054

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.

Moisture

	Wheat middling	N	Subset for alpha = 0.05	
			1	2
Duncan[a]	Wheat middling 001	2	10.1300	
	Wheat middling 005	2	10.2000	
	Wheat middling 006	2	10.6200	
	Wheat middling 003	2		11.2400
	Wheat middling 002	2		11.7800
	Sig.		.075	.052

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.

Moisture

	Soya bean cake	N	Subset for alpha = 0.05			
			1	2	3	4
Duncan[a]	soya bean cake 006	2	4.1000			
	Soya bean cake 007	2		4.8000		
	Soya bean cake 005	2		5.2500		
	Soya bean cake 002	2			6.6400	
	soya bean cake 001	2				7.9400
	Sig.		1.000	.097	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.

Moisture

	nigger seed cake	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	nigger seed cake 006	2	5.3400		
	nigger seed cake 001	2		7.1600	
	nigger seed cake 005	2		7.7200	7.7200
	nigger seed cake 003	2			8.6600
	nigger seed cake 002	2			8.8400
	Sig.		1.000	.332	.091

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.

Moisture

	Dairy Feed	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Dairy Feed 006	2	9.5100		
	Dairy Feed 003	2	9.8200		
	Dairy Feed 004	2		11.0200	
	Dairy Feed 002	2		11.2000	
	Dairy Feed 001	2			12.3800
	Sig.		.467	.667	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.

Moisture

	Layer Feed	N	Subset for alpha = 0.05	
			1	2
Duncan[a]	Layer Feed 006	2	8.3300	
	Layer Feed 012	2	8.4800	
	Layer Feed 011	2		9.4200
	Layer Feed 005	2		9.7200
	Layer Feed 002	2		9.9600
	Layer Feed 004	2		10.0400
	Sig.		.588	.066

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.

Moisture

	Broiler Feed	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Broiler Feed 005	2	9.0200		
	Broiler Feed 02-2	2	9.4000		
	Broiler Feed 02-1	2	9.5500		
	Broiler Feed 05-1	2	9.7900	9.7900	
	Broiler Feed 05-2	2		10.6500	10.6500
	Broiler Feed 004	2			11.0900
	Sig.		.135	.089	.340

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.

Crude Protein results

Crude protein

	Maize	N	Subset for alpha = 0.05
			1
Duncan[a]	Maize 006	2	6.1100
	Maize 005	2	6.3000
	Maize 002	2	6.4700
	Maize 001	2	6.5600
	Maize 003	2	6.9800
	Sig.		.522

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.

Crude protein

	Wheat bran	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Wheat bran 002	2	10.0300		
	Wheat bran 003	2	10.7800	10.7800	
	Wheat bran 001	2		12.1200	12.1200
	Wheat bran 005	2			12.9400
	Wheat bran 006	2			13.2600
	Sig.		.229	.058	.099

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.

Crude protein

	Wheat middling	N	Subset for alpha = 0.05
			1
Duncan[a]	Wheat middling 005	2	12.1800
	Wheat middling 003	2	12.4400
	Wheat middling 002	2	13.1200
	Wheat middling 001	2	13.6100
	Wheat middling 006	2	13.9000
	Sig.		.108

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.

Crude protein

	Soya bean cake	N	Subset for alpha = 0.05	
			1	2
Duncan[a]	Soya bean cake 001	2	44.4500	
	Soya bean cake 002	2	45.1500	
	Soya bean cake 005	2		47.6000
	Soya bean cake 006	2		48.0200
	Soya bean cake 007	2		48.3000
	Sig.		.355	.366

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.

Crude protein

	Niger seed cake	N	Subset for alpha = 0.05	
			1	2
Duncan[a]	Niger seed cake 006	2	35.2200	
	Niger seed cake 003	2		37.6600
	Niger seed cake 002	2		37.7600
	Niger seed cake 005	2		38.0100
	Niger seed cake 001	2		38.1400
	Sig.		1.000	.587

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.

Crude Protein

	Dairy	N	Subset for alpha = 0.05			
			1	2	3	4
Duncan[a]	Dairy F002	2	15.7500			
	Dairy F001	2	17.1500	17.1500		
	Dairy F004	2		18.6500	18.6500	
	Dairy F003	2			19.6600	19.6600
	Dairy F006	2				20.2700
	Sig.		.069	.056	.157	.361

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.

Crude Protein

	Layer	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Layer F005	2	15.4000		
	Layer F004	2		17.3300	
	Layer F0011	2			19.7800
	Layer F002	2			20.1200
	Layer F0012	2			20.6500
	Layer F006	2			21.0000
	Sig.		1.000	1.000	.139

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.

Crude Protein

	Broiler	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Broiler GF004	2	18.2000		
	Broiler FF005	2	20.1400	20.1400	
	Broiler S002	2	20.7600	20.7600	
	Broiler FF002	2		21.0000	
	Broiler SF005	2		22.2300	
	Broiler GF005	2			25.0300
	Sig.		.055	.104	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.

Crude fat results

Crude Fat

	Maize	N	Subset for alpha = 0.05
			1
Duncan[a]	Maize 006	2	3.1000
	Maize 002	2	3.1600
	Maize 005	2	3.1600
	Maize 003	2	3.1700
	Maize 001	2	3.2000
	Sig.		.710

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.

Crude Fat

	Wheat bran	N	Subset for alpha = 0.05
			1
Duncan[a]	Wheat bran 003	2	2.9900
	Wheat bran 006	2	3.1600
	Wheat bran 002	2	3.2500
	Wheat bran 005	2	3.3350
	Wheat bran 001	2	3.4500
	Sig.		.253

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.

Crude Fat

	Wheat middling	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Wheat middling 003	2	1.9800		
	Wheat middling 005	2	2.2450	2.2450	
	Wheat middling 006	2		2.7400	2.7400
	Wheat middling 001	2			3.0600
	Wheat middling 002	2			3.1200
	Sig.		.230	.051	.115

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.

Crude fat

	Soyabean cake	N	Subset for alpha = 0.05	
			1	2
Duncan[a]	Soyabean cake 002	2	3.5000	
	Soyabean cake 007	2		5.9400
	Soyabean cake 006	2		5.9600
	Soyabean cake 001	2		6.0000
	Soyabean cake 005	2		6.0000
	Sig.		1.000	.876

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.

Crude Fat

	Nigger seed cake	N	Subset for alpha = 0.05			
			1	2	3	4
Duncan[a]	NSC 001	2	7.6500			
	NSC 002	2		8.2000		
	NSC 006	2		8.4250		
	NSC 007	2			9.0700	
	NSC 005	2				9.6500
	Sig.		1.000	.210	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.

Crude fat

	Dairy feed	N	Subset for alpha = 0.05			
			1	2	3	4
Duncan[a]	Dairy feed 003	2	2.2600			
	Dairy feed 001	2		3.7500		
	Dairy feed 004	2			4.3100	
	Dairy feed 002	2			4.5000	
	Dairy feed 006	2				5.9000
	Sig.		1.000	1.000	.356	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.

Crude fat

	Layer feeds	N	Subset for alpha = 0.05				
			1	2	3	4	5
Duncan[a]	Layer feed 005	2	3.5000				
	Layer feed 004	2	3.7500	3.7500			
	Layer feed 002	2		4.2500	4.2500		
	Layer feed 012	2			4.5000		
	Layer feed 011	2				5.2500	
	Layer feed 006	2					6.2200
	Sig.		.376	.105	.376	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.

Crude fat

	Broiler feeds	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Broiler feed 004	2	4.0000		
	Broiler feed 021	2	4.1600		
	Broiler feed 022	2	4.2350		
	Broiler feed 051	2	4.5000	4.5000	
	Broiler feed 053	2		5.0000	
	Broiler feed 052	2			8.0000
	Sig.		.091	.079	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.

Crude fiber results

Crude fiber

	Maize	N	Subset for alpha = 0.05
			1
Duncan[a]	Maize 003	2	2.0000
	Maize 001	2	2.1400
	Maize 006	2	2.3200
	Maize 005	2	2.4400
	Maize 002	2	2.6100
	Sig.		.419

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.

Crude Fiber

	Wheat bran	N	Subset for alpha = 0.05
			1
Duncan[a]	Wheat bran 001	2	7.3600
	wheat bran 002	2	7.5900
	Wheat bran 005	2	7.8800
	Wheat bran 006	2	8.1100
	wheat bran 003	2	8.4800
	Sig.		.393

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.

Crude Fiber

	Wheat middling	N	Subset for alpha = 0.05	
			1	2
Duncan[a]	wheat middling 003	2	3.1100	
	Wheat middling 005	2		5.7500
	Wheat middling 001	2		6.3300
	Wheat middling 006	2		7.0200
	wheat middling 002	2		7.6100
	Sig.		1.000	.100

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.

Crude fiber

	Soyabean cake	N	Subset for alpha = 0.05
			1
Duncan[a]	Soyabean cake 006	2	7.2200
	Soyabean cake 005	2	7.4850
	Soyabean cake 007	2	8.1500
	Soyabean cake 002	2	8.3250
	Soyabean cake 001	2	8.4000
	Sig.		.212

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.

Crude Fiber

	Nigerseed cake	N	Subset for alpha = 0.05	
			1	2
Duncan[a]	NSC 001	2	13.6100	
	NSC 002	2	15.6500	15.6500
	NSC 005	2	15.8000	15.8000
	NSC 006	2		16.0400
	NSC OO3	2		17.5000
	Sig.		.059	.097

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.

Crude Fiber

	Dairy	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Dairy F001	2	7.0200		
	Dairy F003	2		10.6400	
	Dairy F004	2		10.7900	
	Dairy F006	2		11.3800	
	Dairy F002	2			23.5800
	Sig.		1.000	.568	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.

Crude Fiber

	Poultry Layer	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Layer F005	2	9.7600		
	Layer F0011	2	10.2050		
	Layer F0012	2	11.2300		
	Layer F006	2		13.8200	
	Layer F004	2		15.2900	
	Layer F002	2			17.8750
	Sig.		.056	.050	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.

Crude Fiber

	Poultry Broiler	N	Subset for alpha = 0.05	
			1	2
Duncan[a]	Broiler G004	2	7.9350	
	Broiler F002	2	8.4500	
	Broiler G005	2	8.7550	
	Broiler F002	2	9.0800	
	Broiler F005	2	10.2650	
	Broiler F005	2		26.3750
	Sig.		.059	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.

Total ash results

Total ash

	Maize	N	Subset for alpha = 0.05
			1
Duncan[a]	Maize 001	2	1.1000
	Maize 006	2	1.1700
	Maize 002	2	1.2000
	Maize 003	2	1.4600
	Maize 005	2	1.5200
	Sig.		.462

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.

Total ash

	Wheat bran	N	Subset for alpha = 0.05
			1
Duncan[a]	Wheat bran 003	2	2.5700
	Wheat bran 002	2	3.0900
	Wheat bran 005	2	3.1400
	Wheat bran 001	2	3.5600
	Wheat bran 006	2	4.0000
	Sig.		.117

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.

Total ash

	Wheat middling	N	Subset for alpha = 0.05
			1
Duncan[a]	Wheat middling 003	2	1.5000
	Wheat middling 005	2	1.9400
	Wheat middling 006	2	2.2200
	Wheat middling 002	2	2.3000
	Wheat middling 001	2	2.8700
	Sig.		.095

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.

Total ash

	Soya bean cake	N	Subset for alpha = 0.05
			1
Duncan[a]	Soya bean cake 001	2	6.0000
	Soya bean cake 002	2	6.0000
	Soya bean cake 007	2	6.0000
	Soya bean cake 005	2	6.4000
	Soya bean cake 006	2	7.0600
	Sig.		.219

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.

Total ash

	Niger seed cake	N	Subset for alpha = 0.05
			1
Duncan[a]	Niger seed cake 002	2	6.3000
	Niger seed cake 006	2	6.4800
	Niger seed cake 005	2	6.5100
	Niger seed cake 001	2	7.6300
	Niger seed cake 003	2	8.0500
	Sig.		.114

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.

Total ash

	Dairy	N	Subset for alpha = 0.05	
			1	2
Duncan[a]	Dairy 003	2	7.2500	
	Dairy 006	2	7.6300	
	Dairy 001	2	8.0000	
	Dairy 002	2		14.0000
	Dairy 004	2		15.0100
	Sig.		.471	.332

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.

Total ash

	Layer	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Layer 012	2	12.0000		
	Layer 006	2	12.0500		
	Layer 004	2	15.1400	15.1400	
	Layer 002	2		15.6000	
	Layer 011	2		17.2000	
	Layer 005	2			22.0000
	Sig.		.056	.171	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.

Total ash

	Broiler feeds	N	Subset for alpha = 0.05	
			1	2
Duncan[a]	Broiler 004	2	15.3000	
	Broiler 052	2	16.0000	
	Broiler 022	2		18.7700
	Broiler 021	2		19.9200
	Broiler 051	2		20.8000
	Broiler 053	2		20.8000
	Sig.		.541	.124

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.

Minerals results

Calcium

	Dairy	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Dairy F003	2	.6200		
	Dairy F004	2	.6600		
	Dairy F001	2	.7300		
	Dairy F002	2		3.4700	
	Dairy F006	2			5.2300
	Sig.		.740	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.

Calcium

	layer feeds	N	Subset for alpha = 0.05					
			1	2	3	4	5	6
Duncan[a]	Layer feed 012	2	.5700					
	Layer feed 004	2		.6300				
	Layer feed 005	2			1.0900			
	Layer feed 006	2				2.8500		
	Layer feed 002	2					3.4400	
	Layer feed 011	2						3.5300
	Sig.		1.000	1.000	1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.

Calcium

	Broiler	N	Subset for alpha = 0.05			
			1	2	3	4
Duncan[a]	Broiler F002-2	2	.3400			
	Broiler F004	2		.8900		
	Broiler F005-3	2		1.2000		
	Broiler F005-2	2		1.3200		
	Broiler F002-1	2			3.8000	
	Broiler F005-1	2				4.6000
	Sig.		1.000	.070	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.

phosphorus

	Dayer feeds	N	Subset for alpha = 0.05		
			1	2	3
Duncan[a]	Dairy 004	2	.0400		
	Dairy 001	2		.0600	
	Dairy 003	2		.0600	
	Dairy 002	2			.0800
	Dairy 006	2			.0900
	Sig.		1.000	1.000	.175

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.

phosphorus

	Layer feeds	N	Subset for alpha = 0.05	
			1	2
Duncan[a]	Layer 006	2	.0400	
	Layer 004	2		.0650
	Layer 005	2		.0700
	Layer 012	2		.0750
	Layer 011	2		.0800
	Layer 002	2		.0800
	Sig.		1.000	.092

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.

phosphorus

	Broiler feeds	N	Subset for alpha = 0.05
			1
Duncan[a]	Broiler 051	2	.0500
	Broiler 052	2	.0500
	Broiler 053	2	.0500
	Broiler 022	2	.0600
	Broiler 021	2	.0650
	Broiler 004	2	.0700
	Sig.		.073

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.

Antinutritional factors results

Phytate

	Layer	N	Subset for alpha = 0.05					
			1	2	3	4	5	6
Duncan[a]	Layer F005	2	81.8882					
	Layer FOO2	2		160.5570				
	Layer F006	2			181.1594			
	Layer F004	2				267.7290		
	Layer F0011	2					329.3076	
	Layer F0012	2						427.5295
	Sig.		1.000	1.000	1.000	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.

Tannin

	Layer	N	Subset for alpha = 0.05				
			1	2	3	4	5
Duncan[a]	Layer F004	2	29.1800				
	Layer F0011	2		60.4550			
	Layer F006	2			75.2200		
	Layer F005	2				101.6550	
	Layer FOO2	2					242.8300
	Layer F0012	2					255.4200
	Sig.		1.000	1.000	1.000	1.000	.071

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.

Phytate

	Broiler Feed	N	Subset for alpha = 0.05			
			1	2	3	4
Duncan[a]	Broiler F002	2	179.5300			
	Broiler GOO4	2	199.4700			
	Broiler F005	2		219.7900		
	Broiler S005	2		222.2200		
	Broiler G005	2			282.2600	
	Broiler S002	2				323.0150
	Sig.		.052	.778	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.

Tanin

	Broiler Feed	N	Subset for alpha = 0.05			
			1	2	3	4
Duncan[a]	Broiler S005	2	4.1800			
	Broiler F005	2	8.3000			
	Broiler S002	2	8.3900			
	Broiler G005	2		43.3950		
	Broiler GOO4	2			138.8900	
	Broiler F002	2				330.2600
	Sig.		.464	1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.
a. Uses Harmonic Mean Sample Size = 2.000.