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PRE AND POST MARKET QUALITY ASSESSMENT OF COMMERCIAL LAYERS' RATION IN BISHOFTU AND ADDIS ABABA, ETHIOPIA.

MSc THESIS

By

ADDIS ASEGID ADMASU

Addis Ababa University, College of Veterinary Medicine and Agriculture
Department of Animal Production Studies
MSc Program in Animal Production

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Addis Ababa University

College of Veterinary Medicine and Agriculture

Department of Animal Production studies

PRE AND POST MARKET QUALITY ASSESSMENT OF COMMERCIAL LAYERS' RATION IN BISHOFTU AND ADDIS ABEBA, ETHIOPIA

Submitted by

Addis Asegid Student name	____________ Signature	____________ Date

Approved for submittal to thesis assessment committee

Ashenafi Mengistu (PhD, Assoc. Prof) Major Advisor	____________ Signature	____________ Date
Prof Gebeyehu Goshu (PhD, Professor) Department Chairperson	____________ Signature	____________ Date

College of Veterinary Medicine and Agriculture

Department of Animal Production studies

As members of the Examining Board of the final MSc open defense, we certify that we have read and evaluated the thesis prepared by Addis Asegid Admassu titled: **Pre and post market quality assessment of commercial layers' ration in Bishoftu and Addis Ababa, Ethiopia** and recommend that it be accepted as fulfilling the Thesis requirement for the Master of Science in Animal Production.

Chairman	________________ Signature	__________________ Date
Internal Examiner	________________ Signature	__________________ Date
External Examiner	________________ Signature	__________________ Date

DEDICATION

This thesis is dedicated to my late Grandmother Bogalch H/ Mekael and my mother Luladey Kidanu for nursing me with affection and love and for their dedicated scarifies for the success of my life.

BIOGRAPHICAL SKETCH

The author of this MSc Thesis was born in September 1980 in East Hrargehe Zone, Gursum district, Ethiopia. He attended his Elementary School and High School Education at Fugnanbira Elementary and Gursum Secondary Schools, respectively. After completion of his High School Education, he joined Chiro ATVET College and graduated with Diploma in Animal Sciences in 2005. Soon after graduation, he was employed by Gursum Agricultural and Rural Development Office. After serving two years, he joined Ambo University in 2007 to pursue his BSc degree in Agriculture (Animal Production) and graduated in 2009. Up on completion he continued working as an expert at Gursum Agriculture and Rural Development Office till 2011. He was then employed by Veterinary Drug and Animal Feed Administration and Control Authority as a Junior Feed Analyst in 2015 and is now working as a Senior Animal Feed Inspector at the Ethiopian Agricultural Authority. In February 2021, he has got a chance to join Addis Ababa University, College of Veterinary Medicine and Agriculture to pursue his MSc study in Animal Production.

STATEMENT OF AUTHOR

I proclaim that this Thesis is my original work and that all sources of materials used for this dissertation have been duly acknowledged. This Thesis has been submitted in partial fulfillment of the requirements for an MSc degree at the Addis Ababa University, College of Veterinary Medicine and Agriculture and is deposited at the University Library to be made available to borrowers under rules of the Library. I solemnly declare that this Thesis is not submitted to any other academic institution anywhere for the award of any academic degree, diploma or certificate. Brief quotations from this Thesis are allowable without special permission provided that accurate acknowledgement of source is made. Requests for permission for extended quotation from or reproduction of this manuscript in whole or in part may be granted by the head of the major department or the Dean of the School of Graduate Studies when in his or her judgment the proposed use of the material is in the interests of scholarship. In all other instances, however, permission must be obtained from the author.

Name: Addis Asegid Signature________________

Place: College of Veterinary Medicine and Agriculture

Date of Submission:_______________________

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ACRONYMS AND ABBREVIATION

AIB	Apo lipoprotein A-I binding protein
ASABE	American Society of Agricultural Enginers.
AvP	Available Phosphorus
CF	Crude Fiber
CFDF	Cumulative Frequency Distribution Functions
Cl	Chlorine
CP	Crude Protein
CV	Coefficient of variations
CSA	Central Statistical Authority
DA	Development Agent
DM	Dry Matter
DEFRA	Department for Environment, Food and Rural Affair's
EAA	Ethiopian Agriculture Authority
EIAR	Ethiopian Institute of Agricultural Research
ESAP	Ethiopian Society of Animal Production
ESA	Ethiopian Standard Institute
FAO	Food and Agriculture Organization
FCR	Feed Conversion Ratio
FQAS	Feed Quality Assurance Scheme
GTP	Growth transformation plan
ILRI	International Livestock Research Institute
ISO	International Standards Organization
K	Potassium
LC	Lest Cost
LIN	linoleic acid
LMP	Livestock Master Plan
MAXL	Maximum Limit Value
MC	Moisture content
ME	Metabolizable Energy
MINL	Minimum Limit Value

MoUDHC	Ministry of Urban Development and Contraction
MT	Metric Tone
Na	Sodium
Na Cl	Sodium Chloride
NFE	nitrogen free extract
NIRS	Near Infrared Spectrophotometer
NRC	National Research Council
OSM	Osmotic Pressure
P	Phosphors
SBM	Soya bean Meal
SD	Standard Deviation
SS	Shortage Severity
TBT	Technical Barriers to trade World Trade Organization
TMR	Total mixed ratio
USAD	United States Agency for International Development
VDFACA	Veterinary Drug and Animal Feed Administration and Control Authority
WTO	World Trade Organization

ABSTRACT

Addis Asegid (2023). Pre and post market quality assessment of commercial layers' ration in Bishoftu and Addis Ababa, Ethiopia

This study was undertaken to determine the proximate composition and variations of nutrient in commercial layer's feeds produced and sold in Addis Ababa and Bishoftu. A total of 438 feed samples classified into two sampling categories were collected in 2022. The first category referred as premarket feed and comprises 240 samples collected from 12 licensed commercial feed producers, while the second referred as post market feed consist of 198 samples collected from 198 commercial layer farms who totally depend on feed produced by these commercial feed producers. The samples were subjected to proximate analysis using non distractive method. This research suggests that the nutrient composition of layers feed is highly variable among manufacturers, but also among the similar batches of the same manufacturers. Among analyte in focus, available phosphorus, calcium and sodium contents portray poor mix uniformity between similar production batches, though their concentration was predominantly close to the maximum-to-middle compared to Ethiopian standard (ESI) requirements. The noncompliance frequencies in crude protein and metabolizable energy, calcium, and available phosphorus content range from39.3 to 43.8%,33.8% to 48.3 %, 18.1 to 43.5%and 6.3to11.3 %, with average total deficiency of 1.3 and1.7%,62.5 and 112.4kcal/kg, 1.15% and 2.09% respectively. The moisture and crude fiber contents in 5 to 10 % and 2 to7 % of the total feed samples surpass the maximum limit respectively, while all crude fat values were higher than the maximum recommended requirement. This may lead to under or over-feeding of essential nutrients which eventually turn into reduced bird performance, added input costs, and increased environmental pollution. Statically significant ($P \leq 0.05$) association between out of compliance frequencies and feed sample categories or study locations were apparent, which in part attributed to differences in ingredient source, quality, and feed compounding practices across the study locations. To ensure quality and standardization of feeds, frequent monitoring, and enforcement of standards in the preparation of feed is cardinal, this will ensure that nutritional feeds are formulated to meet production needs of poultry birds.

Key words: *premarket: post market, proximate analysis, feed quality, feed evaluation, and feed standard.*

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1. INTRODUCTION

- **Background**

Despite improvements over the past two decades, food insecurity and malnutrition remain major issues in Ethiopia. Climate change is exacerbating pre-existing pressures on food security, and 37 per cent of young children still suffer from chronic malnutrition (Lucie,v and Samir, 2022). Poor human nutrition has continued due to lack of sufficient energy and protein in the food or due to insufficient availability of food (Abedullah *et al.,* 2007). According to (Yusuf *et al.*, 2016) the minimum intake of protein by an average person's should be 65g per day; of this, 36g (that is, 55.4%) should come from animal sources. Poultry which has a short generation interval and higher feed conversion efficiency thus provides a cheap source of animal protein, eggs and meat, occupies a pivotal position in alleviating protein deficiency in Ethiopia (Melkamu, 2013).

In addition, as is the case in many developing countries, poultry production in Ethiopia can stimulate local economic development of urban centers through the development of related micro-enterprises that are responsible in whole or in part for the provision of inputs and the processing, packaging and marketing of the outputs Provision of services to the sector (Melkamu, 2013 and Mutami, 2015). In addition, it can contribute to poverty alleviation and socio-economic inclusion of vulnerable groups such as the urban poor, women, the disabled, orphans and the unemployed to enable them to earn a decent livelihood (Abubakar *et al.*, 2007, Gororo and Mabel, 2016).

Further, it needs low capital investment and assures quick returns (Rajendran and Samarendu, 2003). Thus, poultry in Ethiopia is increasingly identified by the government, development partners, and commercial stakeholders as a value chain with potential to deliver high growth, employment, social inclusiveness, and nutritional benefits. The total poultry population in Ethiopia is estimated to be about 60.5 million of which 94.3%, 3.2% and 2.5 % were reported to be indigenous, cross and exotic, respectively in backyard, small-scale, and large-scale commercial production systems respectively (CSA, 2016). Despite the huge poultry population, the annual output is only 60,000 metric tons of meat and 40,000 metric tons of egg (FAO, 2013) and the per capita egg and poultry meat consumption in Ethiopia is one of the lowest in the world: 0.4 kg eggs and 0.6 kg of chicken meat per annum (FAO, 2013) .The country's chicken industry, which is still in its infancy, holds considerable potential for growth especially when considering the low average per capita poultry consumption, population growth of 2.6 percent, urbanization growth of 3.8 percent, and continued per capita income growth (USAD, 2017).

Between 2015 and 2020 Ethiopian has planned to invest ETB 2.4 billion to develop the chicken industry (ELMP, 2015) mainly to upgrade the family backyard poultry production to improved breed backyard systems (Akililu *et al.,* 2008 , Tadesse *et al.,* 2013, and Haftu, 2016) and small-scale commercial systems which almost exclusively depend on compound poultry feeds from commercial system (Toddle, 2013). The intervention also gives equal attention to increase meat and egg production from large commercial system (Shapiro *et al.,* 2017). These expected to raise chicken meat production to 164,000 tons and eggs to 3.9 billion by the year 2020, which is 247 and 828 percent increase, respectively compared to the base 2015 (Shapiro *et al.,* 2017). That means the potential of the poultry industry in Ethiopia to reduce the meat production–consumption deficit, enhance food and nutritional security and contribute to household and national economic growth is enormous. Also, at global and regional levels the demand for livestock products is projected to increase by 60-70 percent by 2050 from the current level (Makkar, 2016).

- **Statement of the problem**

Commercial feed sector in Ethiopia should take advantage of the global and domestic feed demand increased in parallel with increased future animal source food consumption. In 2015 compound feed demand gap for feed was over 120,000 metric tons for poultry meat alone, $157 million opportunity in feed (Negash, 2018). If Ethiopia achieves even 10% of Livestock Master Plan targets to increase meat production to 1.93 million MT and egg production to 3.9 billion by 2020, the demand will grow significantly faster than over the past few years (Negash, 2018). Furthermore, Ethiopia is well-positioned to serve the

~$2.9 billion animal feed imports market in North and East Africa. Egypt, Morocco, and Algeria alone comprise 79% of this market, presenting particularly promising target markets (Negash, 2018).

The growth in the demand for poultry product industry is having an intense effect on the demand for raw materials and feed. Experience elsewhere showed that the increasing demand for eggs has generated challenges to the layer industry including food security, food safety, feed ingredient shortages, disease problems, and increasing productions costs (Wang *et al.,* 2017). The provision of diets closely matching optimum requirements is a key strategy to overcome these challenges by optimizing raw material usages, lowering production costs, and attenuating the loss of nutrients in effluent, including nitrogen and phosphorus, released into the environment. Recent survey study made on small-scale commercial chickens in Ethiopia revealed that feed accounts 73, 57, 55 percent production costs in table egg, broiler and pullet respectively (USAD, 2017).

Quality feed enables farms to reduce production costs, maintain or increase food quality and consistency, and improve animal health and welfare through balanced nutrition. A balanced diet meets the animals nutritional needs based on its physiological stage and target production level, so nothing is wasted (Crump *et al.,* 2002). It can also reduce the potential for pollution from animal waste by providing only the necessary amounts of highly bioavailable dietary nutrients (Crump *et al.,* 2002). Feed quality is generally the responsibility of both raw material suppliers and feed manufacturers and is influenced by factors such as handling, storage and use

Different scholars have defined quality in different ways. Chandrupatla (2009) defined quality as meeting a specification or conformance to specifications. Juran (1988) defined quality as fitness to use, while Crosby (1995) defined quality as the conformance to requirements. From Crosby’s definition, it can directly be seen that standards monitors quality. In contemporary era, consumers are increasingly becoming health conscious, hence sensitive to the quality of what they eat. As quality of food is related to the quality of what animals eat, thus the quality of animal feeds is of paramount importance (Nielson, 2015). To attain and sustainably maintain the required quality of animal feeds, there should be standards that are known and adhered to by farmers and feed processors (Geerts, 2014).

Ethiopia has a concrete and very well elaborated, mandatory poultry feed quality standard since 2002, titled, “Compounded Poultry Feeds Specification” and coded as ES 28:2002(E) by the Ethiopian Standards Agency (ES, 2019). However, formal feed quality control in Ethiopia is uncommon both at the production site and at the selling point, a situation (Nagesh, 2018). However, there is general perception that layers feed compliance to Ethiopian feed standard specification is very low, though research evidence is very scanty.

Qualities of Agro-Industrial By-Products (AIBPs) and locally available supplementary feed resources are highly dynamic and subjected to variations depending on the type of raw material, processing method, season, handling, storage, transportation, and utilization. The feeds quality variations between batches of production due to uneven supply of quality raw material from the primary producers are a major problem. In his recent study Negash (2020) reported that from 64 feed samples formulated for dairy, poultry, and beef animal all have a crude protein contain below the national feed quality standard.

This study aims to fill this information gaps through assessing the feed mix uniformity and the extent to which the pre and post market commercial layers feed in Addis Ababa and Bishoftu compliance to Ethiopian layers feed standard requirements. Addis Ababa-Bishoftu routes account about 69% and 50 % of the total poultry commercial farms (Wondmeneh *et al.,* 2017) and compound feed processors in the country are concentrated (Negash, 2020) respectively.

- **Research questions**
  - ✓ Is there a difference in mix uniformity out comes between similar production batches produced by different producers?
  - ✓ Is variation in analytes in focus between similar productions batches exceeds feed industry limits?
  - ✓ Is there a difference between pre and post market feeds in compliance out comes?

- ✓ Is there a significant relationship between pre and post market feeds and compliance outcomes?
- ✓ How do the Addis Ababa and Bishoftu compare in pre and post market feeds compliance outcomes?

Objectives of the Study:

The study was aimed at addressing the following general and specific objectives.

General objective:

- ❖ To assess commercial layers feed mix uniformity between similar production batches and their degree of compliance to Ethiopian feed standard requirements.

Specific objectives:

- to assess commercial layers feed mix uniformity between similar batches produced by feed producers in the study area
- To evaluate premarket commercial ration of layer feed quality in relation to the Ethiopian Standards.
- To evaluate post market commercial ration of layer feed quality in relation to the Ethiopian Standards.
- To assess the relationships between feed quality and feed sample categories and/or study locations

- **Significance of the study**

Our expectations based on previous studies and scanty evidence are that compliance is low both at the feed producer and chicken farm level. If the expectations are proven to be right, the findings can contribute to how to enhance awareness and foster compliance with chicken feed standards among actors in the value chain, hence promote growth of the subsector in a systematic and more informed way.

- **Scope of the study**

Feed samples from commercial feed produced and marketed in Addis Ababa and Bishoftu were collected in 2022. The sample population comprises 12 feed producers and 198 commercial layer farms which account about 80 % the total population of feed producers and 60 % of chicken famers in the study region participated in sampling scheme. The feed samples were subjected to chemical analysis using nondestructive methods and results compared to Ethiopian layer feed specifications. In addition, descriptive statistics were applied to evaluate mix uniformity between similar production batches as measured by the concentration of main analytes in focus. The association between compliance out comes and feed sample categories and study regions tested statistically.

- **Limitations of the study**

Locally available feed resources are highly dynamic and subjected to variations depending on the type of raw material, processing method, season, handling, storage, transportation, and utilization. Thus, to arrive at comprehensive understanding unlike the current study, necessitates periodical assessment and laboratory analysis to generate up-to-date information on nutritional qualities of the feeds, which in turn helps to sensitize farmers and the concerned institutions in charge of monitoring and regulating qualities of feedstuffs in relation to the standards set for the different groups/species of animals in the country.

- **Structure of the thesis**

The thesis is consists of eight sections namely, abstract, introduction, literature review, material and methods, results, discussion, conclusion, recommendation and reference.

2. LITERATURE REVIEW

2.1. World poultry production

The poultry sector, which plays an extremely important role in terms of food safety and nutrition, is the fastest growing agricultural sub-sector, especially in developing countries (FAO, 2020). The total poultry population in the world (chicken, duck, goose, guinea fowl and turkey) is about 27.9 billion head in 2019 (FAO, 2020). Chickens have the largest share with around 93 per cent. The number of chickens worldwide has more than doubled since 1990, from 14.38 billion in 2000 to 25.9 billion in 2019 (FAO, 2020), due to population growth, increased income and urbanization (FAO, 2020) World poultry meat production, which reached 115 million tons in 2018, reached 118 million tons in 2019, of which Africa's share is only 6.2 million tons (FAO, 2020). Global egg production totalled 1.528 billion eggs in 2018. In 2019, this figure reached 1.577 billion, of which 73 billion are in Africa (FAO, 2020). Egg production by the laying hen industry has increased significantly worldwide, with the volume of egg production increasing by 119% (35.5 versus 76.8 million tons) from 1990 to 2018 (http://www.fao.org) (Food and Agriculture Organization of the United Nations, 2018). Eggs are a balanced source of nutrients as they contain 457 g/kg protein on a dry matter basis (Lunven *et al.*, 1973) with all essential amino acids, omega-3 fatty acids and important vitamins (A, D, E, B12), minerals and antioxidant(Browning and Cowieson, 2014).

2.2. Poultry production systems in Ethiopia

The world's most important poultry production systems are the extensive system, the semi-intensive system and the intensive system (FAO, 1996). The choice of system is largely determined by the availability of resources and inputs; such as housing, cages, food, medication, time/attention and vaccinations (Guye, 2004). Four poultry production systems can be described in developing countries. These are the free range system or the traditional village system; the backyard or subsistence system; the semi-intensive system and the small-scale intensive system (Sonaiya and Swan 2004). Guye (2004) also reported that there are typically four management systems in developing countries have been recognized: the free range or unimproved backyard, the improved backyard, the semi-intensive and the intensive systems. According to Sonaiya and Swan (2004), 80% of farmers in Africa, Asia and Latin America keep poultry either in free-range extensive system or in backyard extensive system.

Based on factors like breed, flock size, housing, feed, health, technology, and biosecurity (Bush, 2006) the poultry industry in the nation can be divided into three main production systems: traditional poultry production system, small-scale market-oriented poultry production system, and commercial poultry production system (Emebet and Kidane, 2016).

2.2.1. Traditional poultry production system

Traditional poultry is the dominant system in Ethiopia, accounting for almost 98% of the poultry population (CSA, 2020). Breeds are mostly native chickens, although some hybrids and exotic breeds (<50 birds) can be kept under this system and managed by individual farm households with minimal labour (Dawit *et al.*, 2008). When birds are kept in a scavenger system; little or no funding is provided for housing, food or health care. Depending on the conditions, this is usually enough for survival and a small level of production. However, inadequate nutrition, compounded by marked seasonal variability, is a major predisposing factor to disease and high mortality (FOA, 2008). As investments are made in improving animal health, housing and particularly in the introduction of improved birds, attention must be paid to nutritional supplementation. The system is not business-oriented and is rather intended to satisfy the different needs of agricultural households

2.2.2. Small-scale market-oriented poultry production system

The medium level of feed, water, and veterinary service inputs as well as little to no biosecurity are characteristics of the small-scale market-oriented chicken production system (Alemu and Tadelle, 1997). The majority of small-scale commercial poultry farms buy their feed and starting stock from large-scale farms (Nzietchueng, 2008). For more economic reasons, small flocks of 50 to 1000 crossbred or exotic varieties are typically managed. It is prominent in East Shewa and Addis Abeba's urban and peri-urban areas.

2.2.3. Commercial poultry production system

The large-scale commercial production system is a high-intensity production system involving 2,500 to 50,000 birds housed under indoor conditions with a moderate to high level of biosecurity (FAO, 2007). This system relies heavily on imported exotic breeds that require intensive inputs such as food, housing, health and modern management systems. It is estimated that this sector accounts for almost 2% of the national poultry population (Alemu and Tadelle, 1997). Medium and large intensive poultry producers are mainly based in and around towns and cities such as Addis Ababa, Bishoftu and Adama. Broiler production is concentrated in Adama, Modjo and Bishoftu; Pullet rearing is highly concentrated in Bishoftu. While egg production is mainly in Addis Ababa (FAO, 2019).

2.2.4. Small-scale commercial poultry production system

It is an emerging system in urban and peri-urban areas of Ethiopia where either broilers or egg-type exotic breeds of chickens are raised commercially using relatively modern management methods (Alemu and Tadelle, 1997). Small poultry farms maintain modest flock sizes of typically 50 to 500 exotic breeds to allow for greater commercial exploitation (Mekonnen, 2007). However, Solomon (2007) reports that under this production system a small number of exotic chicken breeds (501,000) are produced commercially and using relatively modern management methods.

This activity is pursued as a source of income in and around major cities and communities with relatively improved nutrition, housing and healthcare (Mekonnen, 2007; Simeamelak *et al.*, 2011). Most small poultry farms are located around the city of Debre-Zeit in the region of Oromia and Addis Ababa (Solomon, 2007). This production system is characterized by moderate levels of feed, water and veterinary services and minimal to low biosecurity. Most small poultry farms obtain their feed and basic supplies from large commercial farms and occasionally from nearby government breeding and propagation centre’s (Solomon, 2007 and Wondu *et al.*, 2013). This system is involved in the delivery of table eggs to various supermarkets, kiosks and hotels through intermediaries (Nzietcheung, 2008).

The total number of small intensive poultry producers and their specific contribution to national poultry production is not known. However, they provide the growing urban population with the largest share of poultry eggs and meat (Boere *et al.,* 2015). Their distribution is similar to that of medium and large intensive poultry producers. The semi-intensive family poultry producers, on the other hand, are also widespread in rural areas connected to urban markets.

2.2.5. Constraints of small-scale commercial poultry production

Despite the poultry industry's contribution to the economy, the sub-sector faces a challenge to grow as fast as possible. Poultry feed and nutrition is one of the most critical constraints in poultry production for both rural smallholders and large farms in Ethiopia (Tadelle *et al.,* 2003). The problem is mainly related to the lack of processing facilities, inconsistent availability and distribution, and inferior quality of processed feed when available (Tadelle *et al.,* 2003 and Emebet and Kidane, 2016). The lack of feed quality regulations and laboratory facilities for chemical analysis also contribute significantly to the poor quality of processed feed. The Ethiopian Quality and Standardization Agency is aware of the issue and is collaborating with the Ethiopian Animal Production Society (ESAP) on feed quality standards and legislation (Dessie *et al.,* 2013). According to Solomon (2007), the availability, quality and cost of feed are the major barriers to poultry production in Ethiopia, which cannot support itself with grain grains, which make up the bulk of poultry concentrate feed. The country experiences a shortage of protein supplements and micronutrients (vitamins and minerals) needed to prepare balanced rations (EIAR, 2016). Aromolaran *et al*. (2013) also reported that the lack of quality feed formulation ingredients and high feed costs were a major barrier preventing small commercial poultry farms from increasing layers production in Nigeria.

Likewise, Rajendran and Samarendu (2003) showed that high feed costs, high costs of medicines and vaccines, and poor quality of feed and feed ingredients were the main obstacles to intensive poultry production in India. The high production costs resulting from the cost of medicines and feed, as well as inefficient production methods, have contributed to the dire situation of the poultry industry (Lawrence *et al.,* 2015). Protein and carbohydrates are by far the two most important nutrients in poultry diets, not only because they have a significant impact on birds' voluntary feed intake, but also because they account for about 90% of the total cost of ingredients in a ration (summer; 1974) Cereals make up a large proportion (>50%) of poultry diets, providing mainly carbohydrates and some protein. They are primarily dietary energy sources, but can vary widely depending on the grain and animal species (Black, 2001). The most common feed grains for poultry are maize or maize (*Zea mays*), wheat (*Triticum aestivum*), barley (*Hordeum vulgare*) and sorghum or millet (*Sorghum bicolor*). Feed represents the largest cost factor in poultry production and accounts for up to 70 per cent of the total costs. About 95 per cent of the total feed costs are used to cover the energy and protein requirements, about 3 to 4 per cent for the main requirement of minerals, trace elements and vitamins and 1 to 2 per cent for various feed additives.

2.3. Layers production

Layer production represents one of the most economic and easiest means of bridging the supply demand gap of animal protein, due to their rapid growth rate and superior feed conversion ratio. More so, compared to other livestock species, layers enjoy a relative advantage of easy management, quick returns to capital investments and wide acceptance of its egg for human consumption (Joni, 2009). Layers have emerged today as the fastest growing segment for poultry industry with the increased acceptance of chicken eggs and meat in city, town and villages. Birds usually begin laying at around five months (20–21 weeks) of age and continue to lay for an average of 12 months (52 weeks), laying fewer eggs as they approach the molting period. The typical production cycle lasts about 17 months (72 weeks) and includes three distinct phases namely brooders, breeders and layers lasting about 0-2, 2-3 and 3-17 months respectively (NCR, 1994)

2.4. Layers nutrition

Nutritional science is about providing a nutrient balance that best meets laying hens' needs for optimal growth, development, egg production and egg quality. Successful laying hen production depends on providing the birds with feed of the highest quality, in terms of the ingredients used, the processing methods used and the form in which the feed is presented to the laying hens (NRC, 1994). NRC (1994) reported that poultry feed consists mainly of a mixture of different feeds such as cereal grains, soybean meal, animal by-product meals, fats and vitamin and mineral premixes. These feeds, along with water, provide vital nutrients for birds. The feed rations of laying hens should be formulated to provide the right balance of energy, protein and amino acids, minerals, vitamins and essential fatty acids to enable optimal growth and performance. When formulating laying hen feed, the focus is on crude protein (CP) as protein is the crucial component of poultry nutrition and is vital to life along with the other essential nutrients such as carbohydrates, fat, water, vitamins and minerals (Cheeke, 2005).

2.5. Nutrient requirements of layers

Applegate and Angel (2014) stated that nutrient requirements are the amount of nutrients animals need to sustain their activities, to maximize growth and feed conversion efficiency, and to improve laying capacity and hatchability. The nutrient requirements of commercial laying hens vary according to age, genetic strain, environmental conditions, management practices, amino acid and energy levels in the diet, among others. Therefore, the nutritional requirements of laying hens need to be regularly assessed and updated to formulate appropriate diets for each production situation (Costa *et al.*, 2004).

The diet of laying hens can be accurately divided into different types, depending on the needs of phase feeding and the characteristics of birds in different periods of production. It is obvious that the beginning of the laying period is the crucial turning point in laying hen nutrition, since the biological characteristics and the production purpose of these two phases are completely different: In pullets, the aim of nutrition is to create a solid basis for laying hen nutrition future production and can be described in sufficient detail to ensure the lowest mortality, optimal health status, adequate time to sexual maturity and controllable herd uniformity; With laying hens, on the other hand, optimal performance, the longest possible peak phase and optimal immune functions are important. Accordingly, the studies and recommendations for these two phases differ significantly

Pullet stage is the fastest growth phase in a hen's life. During this period, birds exhibit polytropic developmental traits that require a corresponding change in requirement parameters. NRC (1994) divided the growth period of pullets into four periods: 0 to 6 weeks, 6 to 12 weeks, 12 to 18 weeks and 18 weeks to age at first egg. However, different countries and companies have their own timing standards. For example, the Ethiopian feeding standard for chickens (Ethiopian Standard Institute, 2019) recommends a strategy of 0 to 8 weeks, 9 to 18 weeks and 19 weeks to onset of lay.

2.5.1. Carbohydrate

Feed represents 65 to 75% of the total Egg production cost with energy representing at least 60% of total cost for feed. Hence, accurate estimates of the real available amount of feedstuff energy are necessary to meet nutrient requirements and performance objectives at optimal efficiency.(Barzegar *et al.*, 2019) .In recent years, there has been a significant increase in research output surrounding Fiber in poultry diets, and the postulation that dietary fiber may have beneficial effects. Both insoluble and soluble fibers have been shown to support various parameters of poultry production and improvements in performance, egg production, and nutrient digestibility. (Desbruslais *et al.*, 2021;Panaite *et al.*, 2021) also states That dietary fibre have beneficial impact on intestinal morphologie, origan développement and modulation of intestinal micro flora, dépite It négative effets on feed intake and nutrient digestibility.

Sozcu and Ipek (2020) also examined egg quality parameters and found that the supplementation of 1 kg/t lignocellulose in turn resulted in significantly increased eggshell fracture strength, eggshell thickness, increased yolk index percentage and increased yolk ratio. However; DeArruda *et al*. (2018) reported lower egg weights with increasing insoluble fiber content, while (Kocer *et al*., 2021) reported mixed results when supplementing laying diets with different fibre content. Reported body weight, egg production rate, and shell mass were all linearly significantly increased by increasing fibre intake. In addition, the fraction of shell less eggs and the fraction of cracked/broken eggs were reduced numerically linearly, with the fibre fraction being increased to 3-5%. The latest research precisely determines the crude fibre content in poultry; the crude fibre content could be in a range of 3-4% for a longer period of time, while it could be used at 5% for layers. In general, poultry feed manufacturers and poultry producers believe that the fibre content in poultry feed must be kept below 7% (Varastegani*., et al* 2018), however, caution should be exercised in pigs and poultry when crude fibre is incorporated.

2.5.2. Fat

Fats are high in energy, providing about 2.25 times more energy than the same amount of carbohydrates, thus acting as a useful source of stored energy. Fat-soluble vitamins are contained in the lipid content of feed and must therefore be present in the feed. However, excess fat reduces feed intake. Essential fatty acids in the oil fraction of feed ingredients are necessary for chick growth and egg production with sufficient fat content. Stored fat also acts as a heat insulator, maintaining body temperature (McDonald *et al.,* 2011).

Due to the continuous improvement of laying hen production performance, the demands on the feed energy of laying hens are increasing. Oils are the most commonly used energy source in forage nutrition of laying hens and have multiple effects such as: improving palatability, feed intake, animal immunity and reducing morbidity; Production performance, fat metabolism, egg quality, increasing FCR and improving poultry health, egg weight, egg mass and eggshell thickness. The unique aroma of oils can improve the palatability of feeds and enhance their flavour, leading to increased animal intake. (Gao *et al.*, 2021: Ding *et al.*, 2017)

2.5.3. Protein and amino acid

Proteins are among the most important feed components and are an essential nutrient. Proteins are necessary for various functions in the animal body and are a major component of most body tissues. Proteins are made up of amino acids that contain nitrogen (N). Protein is required daily for growth and development, maintenance and production. Several studies have shown that increasing dietary CP levels can improve egg content (Novak *et al.,* 2006). The main benefits were found for egg yolk (Gunawardena *et al.,* 2008), protein content in egg yolk (Ding *et al.,* 2016), eggshell (Novak *et al.,* 2012), feed conversion ratio, egg weight and egg mass (Ding *et al.*, 2012 and Alagawany *et al.,* 2020) and protein (Ding *et al.,* 2016)

A recent study aimed to determine the effects of dietary crude protein (CP) and total sulfur amino acid (TSAA, Met+Cys) levels on production performance, egg quality and egg components in Lohmann Brown laying hens aged 18 to 34 weeks to investigate, Alagawany *et al.* (2020) found that a dietary CP of up to 18% was associated with the best feed conversion ratio, egg weight, and egg mass. On the other hand(Viana *et al.*, 2017) indicated that nutrition and breeding system influence egg quality. For laying hens, the level of protein in the diet is important for the formation of the yolk and especially of the albumen. Since the ability of laying hens to store protein is limited, the protein concentration in the feed should be equated to achieve the desired egg production.

Protein requirements tend to decline with age, nonetheless, requirements for amino acids are generally high. Essential amino acids (e.g. lysine and methionine) cannot be adequately synthesized within the body and deficiencies limit the synthesis of proteins, which is why pre- mixes are commonly used in compounded feeds. (Lukuyu *et al.*, 2009). Main sources are oilseed by-products fish meal.

For maximum performance, ten amino acids classified as essential: lysine, methionine, tryptophan, threonine, arginine, isoleucine, leucine, histidine, phenylalanine, and valine must be obtained from the diet. Of these 10 essential amino acids, lysine and methionine are the first two limiting amino acids for layers, while threonine is the third limiting amino acid. Glycine is considered vital for young birds. Glycine and serine are the limiting nonessential amino acids in the poultry diet. Cysteine and tyrosine are considered semi-essential amino acids because they can be synthesized from methionine and phenylalanine, respectively. (Alagawany *et al.*, 2020).

Methionine plays an important role in optimal growth performance in poultry and is involved in feather synthesis, important biochemical processes (as a methyl group donor) and muscle building. Threonine is very important for the synthesis and maintenance of proteins in the body and, as an essential component of mucin, plays an important role in intestinal health and is involved in an important metabolic process such as uric acid formation. Lysine has been found to improve carcass quality and growth performance in broilers. Finally, lysine's main role is to participate in protein synthesis as well as cell growth and maintenance, and it is considered a reference amino acid in the ideal protein diet (Alagawany *et al.,* 2020).

2.5.4. Mineral

Calcium (Ca) is a key mineral in laying hens, particularly during the laying period (Araujo *et al.,*2011) Calcium (Ca) and phosphorus (P) are important nutrients in poultry diet formulations, especially for bone formation and as enzyme cofactors. Calcium is important in eggshell formation; inadequate levels in the diet of laying hens may affect shell quality and egg production .Eggshell quality is important in poultry production because a large number of eggs with defective shells cause great economic loss. (Castillo *et al.,* 2004) .

An early study was published by Gilbert *et al.,* (1981), who suggested that a 3.00% Ca level was insufficient, and 4.50% Ca was recommended to maintain reasonable eggshell quality. A more recent study by Vieira *et al*., (2011) recommended that 3.41% Ca was the minimum required level in the diet of laying hens. Castillo *et al.,* (2004) reported that 4.38% and 4.64% were the optimum Ca levels for maximum egg production in the diet of laying hen. Several studies have investigated the effect of dietary Ca levels on internal egg quality characteristics.

Wu *et al* (2007) indicated an increase in albumen and yolk weights with an increasing Ca level, resulting in an increase of egg weight, when the Haugh unit significantly decreased. The authors ascribed these improvements to higher egg weights detected at a higher Ca level. An et al. (2016), however, found no significant influence of Ca content on the Haugh unit. Chang *et al*. (2019) reported a significant influence of different dietary Ca values (0.60, 0.90, 1.20, 1.80, 2.40 and 3.00%) on the egg quality of pigeon eggs. They pointed out that protein percentage, protein level, and Haugh unit all increased linearly with increasing dietary Ca levels.

However, (Ketta *et al.,* 2019) reported no significant effects of dietary Ca on egg production and no significant impact on feed consumption. Phosphorus plays an important role in nerve function and is an essential component of eggshells, phospholipids, and nucleic acids. It is a key mediator of energy metabolism through ATP.(Li *et al.*, 2017). It is usually supplied as calcium carbonate in the form of limestone or oyster shell, or from other sources, such as marine shells.

2.5.5 Vitamins

Numerous studies have shown that trace elements affect the performance of livestock significantly, including that of birds. Although vitamins are required in relatively small quantities, they are very important in maintaining good animal health. Vitamins are nutrients required in small amounts (milligrams or micrograms) which may or may not be synthesized by the animal´s organism.

They are classified according to their physiological functions in the body and how they contribute to the maintenance of health. Vitamins are essential for the different development phases of a bird, and their absence in the diet, or low absorption, may induce signs of metabolic deficiency (Barroeta *et al.*, 2012).

A general classification of vitamins is based on their solubility, as fat- or water-soluble vitamins. The fat-soluble vitamins are vitamin A, vitamin D, vitamin E, and vitamin K. The water-soluble vitamins include members of the B-complex group and vitamin C. Vitamins have different function for laying hens. For example; Fat soluble-vitamins like A and E positively influence egg production (i.e., number, weight or egg quality) , hatchability, improve the immune stats and promote the normal metabolism in order to defend against disease and stress., while vitamin E is often associated with the synthesis of various hormones, and in livestock species, it was a direct effect on gonadal function was reported (Yaripour *et al.*,2018)

Vitamin E is an important fat-soluble nutrient. Its role in domestic animal production is essential since animals are unable to synthesize vitamin E. Vitamin E has been reported to have beneficial effects on antioxidant status, anti-inflammatory activity, and hatchability and fertility. In addition, vitamin E has been shown to improve meat and egg quality, as well as carcass characteristics and egg quality.

Vitamin D nutrition plays a critical role in calcium (Ca) and phosphorus (P) metabolism, bone mineralization, and other physiological processes related to performance and immunity against infections in broiler chickens. (Oikeh *et al.*, 2019) the deficiency of vitamin D Couse thinning of the eggshells, reduced shell quantity. If the diet is completely devoid of vitamin D3, egg production decreases rapidly and eggs with very thin shells or no shell will be produced. Vitamin D is a fat-soluble vitamin essential for the proper metabolism of calcium (Ca) and phosphorus (P), and the maintenance of normal skeletal integrity in animals (Adhikari *et al.*, 2003)

2.5.6. Water

Water is the most important nutrient as it has a central role in all aspects of metabolism and critical for bird welfare. It is difficult to access water requirements, as water intake is modulated by age, feed intake, and stage of production, ambient temperature, water temperature and quality. The intake of water and feed are directly related; hens that drink less water will also consume less feed, and, subsequently, egg production declines. Presumably, current high producing laying hens have higher metabolic demands for water than did earlier layer strains.

Water intake is a sensitive indicator of bird health and, therefore, monitoring water intake of a flock is a useful guide to changes in bird welfare. Hens must have access to water of high quality at all times. Water deprivation for ≥12 hr. has an adverse effect on growth of young poultry and egg production of layers; water deprivation for ≥36 hr. results in a marked increase in mortality of both young and mature poultry. Cool, clean water, uncontaminated by high levels of minerals or other potential toxic substances, must be available at all times. (Bryden *et al.*, 2021) .

2.6. Layers feed formulation

Feed formulation is crucial in meeting nutrient requirements of poultry. This aims at avoiding excess nutrient supply as much as nutrient deficiency. Poultry feed consists of many ingredients, which are broadly classified into energy suppliers (fats, oils and carbohydrates), proteins (amino acids), vitamins, minerals and to improve product quality. Typically, grains like wheat, barley, sorghum, and corn provide energy, while soybeans, lupins, canola, and peanuts provide protein. These ingredients are then combined to meet the energy, protein, vitamin and mineral needs of poultry in the feed formulation process. The basis of any commercial farming system is to formulate a diet combining ingredients with the least cost in order to give a better return on investment.

Nutrition is central in poultry production because of its direct influence on performance and production economics. Feed formulation is the applied side of nutrition where nutritionists apply their knowledge to meet the nutritional requirements by formulating more economical feeds for maximum performance. However, the nutritional content varies widely within and between crops depending upon the type of feedstuffs (Jha *et al.*, 2011a, Jha *et al.*, 2011b), within and between fibrous and starchy feedstuffs (Tiwari and Jha, 2016), and harvesting condition and processing method (Hernot ***et al.***, 2008).

One way to improve feed formulation is to improve feed quality by reducing nutrient variability. Considerable nutrient variability can result in under-feeding or over-feeding of essential nutrients, resulting in reduced bird performance, added input costs, and increased environmental pollution (Duncan, 1988). A few solutions have been proposed to deal with nutrient variability in feedstuffs since recognizing this problem in the 1960s. Margin of safety inclusion and non-linear "stochastic" feed formulation are the most important solutions proposed (Nott and Combs, 1967; Rahman and Bender, 1971).

2.7. Feed evaluation

The feed evaluation is the examination of the feed quality, which provides information about the composition of feed or feed components and their suitability for poultry. Feed quality can be assured by knowing the physical nature and actual composition of the feed, both in terms of nutritional and anti-nutritional components. (Chellapandian, 2020)
Feed evaluation concerns the use of methods to describe animal feedstuffs with respect to their ability to sustain different types and levels of animal performance. In feed evaluation, emphasis is placed on determining specific chemical entities, although the physical characteristics of the feed are also important. The practical goal of feed evaluation is to optimize the efficiency of feed utilization, animal output and, ultimately, financial return to the producer. (France *et al.,* 2000)**.**

Poultry diets are formulated based primarily using cereals and protein meals (corn, wheat and soybean meal (SBM)) as the main ingredients. The wide variation among the nutritional values of these co-products creates a necessity of developing routine evaluation techniques to detect these variations in order to formulate balanced diets and achieve optimal animal performance. In practice, however, variations in the nutritional quality of feeds can result in incorrectly balanced feeds being produced. Therefore, it is of paramount importance for the feed industry to understand both the nutritional needs of the animals and the nutritional value of the feeds available for formulating feeds

Ingredients can account for 70-90% of the cost of manufacturing feed (Jones, 1989). In addition, as feed mills grow larger, the share of ingredients in total costs will tend to increase. Not only does it make economic sense to pay attention to the quality of the ingredients, but also that a large part of the fluctuations in the nutrient content of compound feeds can be attributed to the ingredients. In fact, one poultry company was able to link ingredients to 40-70% of the variation in the nutrient content of the finished feeds (Jones, 1989).

Conventional feed ingredients such as corn, wheat and SBM used in poultry feeding programs may provide the best results in terms of performance but may not be cost effective. Therefore, the poultry industry is shifting to alternative feed ingredients, mainly agro-industrial by-products. The major limitation of using such by-products in poultry feed is the variation in their nutritional composition, even when obtained from the same source but in different batches. One of the possible ways to minimize the impact of such fluctuations is to routinely analyze each batch coming out of the processing industry. Before supplementing the animal diet, a nutrient assessment of such feeds must be carried out. This is because their nutrient content varies greatly within and between crops depending on the type of forage (Jha *et al.,* 2011a, Jha *et al.,* 2011b), within and between fibrous and starchy forages (Tiwari and Jha, 2016) and the crop condition and processing type. (Hernot *et al.,* 2008).

2.7.1. Feed evaluation methods.

Choosing the right feed is an essential factor in the poultry industry. Many feed rating systems can provide estimates of nutritional value, but each has shortcomings. The most reliable systems from a biological point of view (digestible or available amino acids) are also the most complex and expensive and therefore unsuitable for routine feed testing. Due to these problems in feed evaluation, feed manufacturers often carry out inadequate nutritional tests. In the past, feed assessment was a cumbersome process that took several days. However, newer devices and methods have been developed that allow rapid assessment of most materials.

The approximation analysis is a scheme for routinely describing animal feeds, developed in 1865 by Henneberg and Stohmann at the Weendes experimental station in Germany (Oyinkansola and Sema, 2019). Often referred to as the Weendes Analysis System, the system's primary purpose is to break down carbohydrates into two broad categories: Crude Fiber and Nitrogen-Free Extract (NFE). The system consists of the determination of water, ash, crude fat (ether extract), crude protein and crude fiber (Oyinkansola and Sema, 2019

Near-infrared reflectance spectroscopy (NIRS) is one of the newest techniques that can be used to assess feed components with minimal sample preparation (Van Kempen and Simmon, 1997). NIRS provides the ability to quickly measure Crude Protein, Dietary Fiber, Fat, Total and Digestible Amino Acids, Calcium, Total and Available Phosphorus, and Energy Value (ME) of individual ingredients and the final feed product.

The NIRS has been adopted widely by the nutritionists and feed industry as a rapid feed evaluation technique and is becoming increasingly popular. The use of NIRS technology to determine basic nutrients such as moisture, protein, fat, and fiber of major feed ingredients and finished feeds has been around for many years. With advancement in technology, NIRS is being used for a range of measurements that are based on using laboratory methods to provide reference values for establishing calibration(Jha and Tiwari , 2016)

The main advantage of NIR is that it provides relatively very accurate prediction of nutritional value (given that high quality calibration and method is used). Also, it is economically more efficient than any other analytical methods and is able to determine multiple components of each sample in a single measurement. But it is costy and needs proper data base accumulation and calibration (Jha and Tiwari, 2016).

2.7.2. Feed ingredient quality

Because many of the key feed ingredients are by-products from other industries, feed manufacturers are often in an inferior position in terms of ingredients and their quality. As a result, feed manufacturers are often able to make something good out of other people's waste. Ingredients can account for 70-90% of the cost of manufacturing feed (Jones, 1989). In addition, as feed mills grow larger, the share of ingredients in total costs will tend to increase

Not only does it make economic sense to pay attention to the quality of the ingredients, but also that a large part of the fluctuations in the nutrient content of compound feeds can be attributed to the ingredients. In fact, one poultry company was able to link ingredients to 40-70% of the variation in the nutrient content of the finished feeds (Jones, 1989). Variations in nutrient content violate the primary goal of feed production and cost in terms of performance.

Quality has been defined by various people as fitness for purpose, or meeting an expectation, or a degree of excellence, or conformity to a standard. Although near-infrared spectrophotometry (NIRS) is used to quickly determine the moisture, fat, protein and fiber content of an ingredient sample, many feed manufacturers do not analyze ingredients prior to use. Therefore, predictability of feed ingredients is important and it must be concluded that high quality ingredients are predictable and of consistent quality.

2.7.3. Feed mix uniformity

The task of a feed mill consists of blending a set of raw materials and additive premixes in order to produce a feed according to a specific formula. Then, to ensure the compliance of this manufactured feed with legislation and the product label, the finished product and the raw materials that compose it must be submitted to a quality control plan. The right mix of ingredients, such as proteins, vitamins and minerals, has a strong influence on the growth and health of the animals on the one hand, and on the quality of the end products, such as meat and eggs, on the other (Mccoy *et al.*, 1994).

Therefore, mixing is probably the most critical step in any feed manufacturing situation. However, in a survey, Wicker and Poole (1991) found that more than half of the 145 mixers tested did not provide adequate mixing. The authors attributed the mixing inefficiency to insufficient mixing time, operating the mixers beyond design capacity, and worn, altered, or broken mixing equipment. Concerns about creating a consistent mix include the following nutrient oversupply by the dietitian (Wicker and Poole, 2003), regulatory issues (Jones, 1989), and animal performance (Mccoy *et al.*, 1994).

When considering mix uniformity, there are two distinct types of variation: variation among similar batches and variation within a single batch. Variation among batches is controlled by monitoring feedstuff characteristics and using proper formulation, accurate moisture information, and calibrated scales for accurate weighing by diligent mixer operators (Buckmaster, 2009). Within batch variation is controlled with proper mixer operation which includes factors such as fill order (sequence of putting feedstuffs into the mixer), mixing time, and mixing protocol (Rippel *et al.*, 1998) and mixer maintenance (Oelberg, 2013).

The variability in the crude protein concentration of the delivered TMRs was reported by James and Cox (2008). With mean values close to 17.2%, the standard deviations were 1.4% to 2.1% and the maximum to minimum range was up to 12%. They found significant differences between farms in terms of loading accuracy, driver skill and diligence, and equipment. Historically, commercial and integrated industries have aimed for a 10% coefficient of variation. Wicker and Poole (1991) found that of 100 commercial and integrated feed manufacturers surveyed, nearly 50% had a CV over 10% and one in five had a CV over 20%. These farms, of course, make grain-soy-based feeds where the physical properties of the ingredients are well controlled and more sophisticated mixing equipment is the norm.in a smaller study of on-farm pig feed producers, Herrmann and McClure (1995) found a mixed CV average of 13%, ranging from 4 to 34%.

According to Herrmann and McClure (I995), a coefficient of variation of less than 10% is considered as homogeneous mix while a coefficient of variation between 10 and 25% and greater than 25% indicates opportunities for improvement and cause for concern. Nutritional value variability of a compound feed may be explained in three ways: the nutrient composition of the ingredients (Fairbairn *et al.,* 1999), the formula characteristics, and the feed-manufacturing process (Groesbeck *et al.*,2007; Bunzel 2008). Assuming that, in current feed manufacturing industry, milling and mixing of the main ingredients (materials with inclusion >2%) is highly accurate (Bunzel 2004; Groesbeck *et al*., 2007) the most important and unpredictable source of variation should be the nutrient composition of the ingredients.

The process by which high-quality ingredients are turned into high-quality feed involves three components within the feed mill: people, machinery and processes. If there is a lack of quality in any of these three components, the continuous production of high-quality feed is unlikely. However, it is equally important to ensure that people, machines and processes are coordinated to achieve the goal of efficiently producing high-quality feed (Bunzel 2004; Groesbeck *et al.,* 2007). In addition, finished feed analyzes are necessary and important as they provide the mill with a final report on how well the quality has been controlled.

2.7.4. Finished feed quality

In many cases, feeds are ingested by animal’s right after they are manufactured, before any tests can be carried out. To give the mill a "final report card" on how well quality was controlled, finished-feed analyses are essential and crucial. How much finished feed should be sampled and analyzed. The reply to that question will depend on a variety of factors, but as a general rule of thumb, one sample of each formula should be taken once a week or once for every 100 tons of production, whichever is higher (Frank ;2008).

2.8. The compliance theory

Compliance means conformity with the law or policy objectives (Coombs, 1980; Hutter, 1997). Of importance with compliance and noncompliance is goal orientation (Mitchell, 1996; Brehm and Hamilton 1996). Whoever does either of the two does so with a particular purpose (Coombs, 1980). To facilitate the study of complex compliance behavior, a taxonomic approach in addressing regulates' goals must be adopted (Etienne, 2010). This taxonomy indicates categories of goals that actors intend to achieve through compliance or noncompliance with certain rules or regulations.

Lindenberg and Linda (2007) proposed three broad categories of goals: the hedonic goal, the profit goal, and the normative goal. Practically every specific goal pursued in a given situation can be linked to one of the three categories and can therefore be understood as a particular form of the hedonic goal, the profit goal or the normative goal. As it is with compliance of any other rules, compliance with standards is grounded in these goals. Actors will comply with standards for the sake of either, avoiding some penalties taking advantage of some economic gains that accrues as a result of complying with certain standards or abiding with social norms (Nadvi and Wältring, 2001).

More specifically, the hedonic goal is based on the actor's motivation to find pleasure in completing a task. It is associated with positive emotions such as happiness, fun, comfort and their negative counterparts such as guilt, anger, shame or uneasiness (Etienne, 2010). In relation to this hedonic goal, if compliance with certain rules results in positive emotional rewards, regulators are likely to comply with these regulations. Interestingly, the hedonic goal is present in almost everything human beings do. Whatever people do has elements of pleasure seeking or pain avoidance (Singhal and Greiner, 2009)

The profit goal, on the other hand, refers to the motivation to maintain or increase one's own resources. An actor operating in a win framework is primarily concerned with the prospect of a reward or gain in the form of money, power, influence, leisure, etc. (Etienne, 2010). Finally, the normative goal is based on the regulators' motive to act appropriately or to do the right thing. This goal is based on compliance with social norms, which is a rule shared within a group and controlled and sanctioned by its members or relevant authority. The normative goal is related to identity and the way individuals categorize themselves (Wenzel, 2007)

In this respect, actors will comply with regulations intending to precisely fit in their respective societies. Of the three mentioned categories of goals that underlie compliance or noncompliance with regulations, the gain goal carries more weight (Etienne, 2010). This study makes use of diffusion and compliance theories because standards are innovations that should diffuse from their points of formulation to intended users. Further, compliance is the ultimate goal of any standard setter. Without compliance, there is no need of having standards. While much effort has gone into the setting of poultry feed standards, less is done in the area of awareness creation and compliance enhancement, a fact which necessitated this study.

2.9. Quality standards

The term "standard" is defined by the World Trade Organization (WTO) under the Agreement on Technical Barriers to Trade (TBT) as a document approved by a recognized body that provides guidelines or characteristics for products or related processes for common and repeated use and production methods, compliance with which is not mandatory. Food safety and compliance with the standards established by law can also be considered as elements of food quality, as they contribute to the acceptance of a food product by consumers and can be used as a marketing tool to trade products in countries with high food safety standards

The rules and practices in place to guarantee that the product attributes and production methods agreed upon in a contract are regularly met are known as quality standards. Standards are essential for control, monitoring, and auditing because they encourage uniformity and serve as a benchmark for assessing whether compliance has been attained. Regulations, customers, and organizations all have different criteria for quality.

Nevertheless, their main objective is to locate and fulfill these needs. Technical specifications, product standards, process standards, official requirements, and contractual agreements can all be used to determine the needs for the product and any associated processes. While some organizations adopt governmental and private food safety and quality standards, others have created their own quality management system standards

There is consensus in the development of standards, as they are the result of the joint work of experts in the field. Standards indicate what can be agreed upon at an international level as they are created through consensus and a variety of stakeholders. Therefore, a published standard is the harmonized synthesis of what the group is prepared to publish. Because of the numerous and diverse stakeholders and diverse needs, consensus on international and regional standards is even more important than at national level. Standardization organizations such as ISO and IEC do not always produce standards. Standards can be created by any organization for internal or external use. This includes, for example, consumer standards in relation to consumer information, the product description must meet a certain standard, such as nutritional and health claims, such as low fat. An established industry group sets industry standards, commonly referred to as commodity standards or identity standards. They define a trusted identifier for a specific product, such as wheat, that meets a minimum standard set by the industry

2.9.1. Use of quality standards

Standards play a crucial role in ensuring that goods and services are provided in a uniform and consistent manner, and in giving customers and user's confidence that the goods and services they consume meet their needs. Many of the standards mentioned ensure, for example, that the properties of a component are measured, calculated or evaluated in a uniform manner. Typically, this involves determining the chemical and physical properties of the components.

It is possible to demonstrate the performance of the product, e.g. a finished feed or feed ingredients, based on a defined measurement protocol or criteria. Sampling and sample reduction is done in the same repeatable way, e.g. sampling alternative feed sources that have historically varied widely in quality, even though the products appear to have been manufactured to specific tolerances. However, other standards are used to facilitate trade or enable compliance with regulations and laws by ensuring that any declaration or certificate provided for a product or service is communicated and accepted as providing a consistent and harmonized quality or specification exhibit.

In addition, there are standards that provide a unified and harmonized approach to management systems, environmental management, energy management, conformity assessment and certification. While product and service standards do not require independent third-party certification or conformance assessment, many standards are used to demonstrate conformance within certification schemes. This regulatory and legislative approach is increasingly being used by governments looking for consistency in the implementation of policies, particularly when those policies support fiscal stimulus.

2.9.2. Legal standards

Legal standards typically relate to safety and are set by national governments. They are binding and represent minimum standards for quality and safety, they are authentic and contain no dangerous impurities. In principle, product standards play a variety of useful roles in overcoming market failures (Stephenson, 1997). For example, emission standards oblige companies to internalize the costs of maintaining an acceptably low level of environmental damage. Food safety standards ensure consumers are protected from health risks and fraudulent practices about which information would not normally be available in private markets.

For consumers, efficient and non-discriminatory standards allow products to be compared on a common basis in terms of regulatory characteristics, thereby enabling increased competition. From the manufacturer's point of view, economies of scale and overall costs could be reduced by producing goods subject to recognized standards. Because standards themselves contain information about technical knowledge, conforming to efficient standards encourages companies to improve the quality and reliability of their products

2.9.3. International Standards

In order to improve global tradability and interoperability of products and services, it is important that standards are harmonized globally whenever possible to ensure they are truly cross-border. International standards set by an international body. When there is no multilateral consensus on the appropriate level or setting of standards, international standards also provide common reference points for countries to reference in order to reduce transaction costs. International standards developed by the International Standards Organization (ISO) provide developing countries in particular with a basis for selecting standards that are recognized in foreign markets.

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In this regard, compliance with global standards can increase export opportunities. Despite their potential to increase competition and trade, standards can be set that do the opposite. In general, the choice of standards could increase the compliance costs of some companies (e.g. new entrants) compared to other companies (e.g. incumbents), thereby reducing competition (Fischer and Serra, 2000). This outcome is likely to be most likely in the context of international trade, where governments could adopt technical regulations to favor domestic companies over foreign competitors, thereby restricting trade. This problem could be particularly problematic for small exporting companies from developing countries, as they would have to incur the fixed costs of complying with numerous international regulations without enjoying national economies of scale.

2.10. Feed quality regulation in Ethiopia

Feed quality is defined as “any of the features in the feed that makes it what it is” and “the degree of excellence which the feed possesses.” A good quality feed will supply all the nutrients in adequate quantity with high palatability and digestibility(Chellapandian , 2020) on the other hand feed quality is the degree to which the seat of inherent characteristic fulfills the requirements. The requirement comes from customers or regulatory authority. (VDFACA, 2019).

Feed quality control deals within plant process measurement that ensure quality parameters are met during receiving, manufacturing, delivery and marketing so that the feed maintain the quality at levels and tolerances acceptable to the buyer while minimizing the cost of processing.

The objective of quality control of feeds is to ensure that a consumer obtains feeds that are unadulterated, true to their nature, provide the intended nutrients, involve less processing and produce desired results in animal production. To achieve this control in quality, the feeds have to necessarily undergo various steps of quality evaluation.

Ensuring feed quality, as elsewhere in world, is one of the key challenges in the commercial feed sector in Ethiopian (Seyoum *et al,*. 2018). Several factors may affect both feed quality and feed mill feed manufacturing parameters (Loar and Corzo, 2011). The nutritional value of grains for poultry varies as a function of grain cultivar, its chemical characteristics and non-starch polysaccharide content, diet physical form, and bird category (Gutiérrez-Alamo *et al.*, 2008).

Feed mills usually produce large quantities of feed during a short time frame and reliable values for the nutrient content of feed components are essential for precise diet formulation. Feed costs accounts for the largest share of live production costs (Donohue and Cunningham, 2009) and therefore, any mistake in formulation can negatively affect company profits as well as animal production.

In Ethiopia the Feed quality control is regulated by a statuary body Veterinary Drug and Animal Feed Administration and Control Authority. It was established under 728/20 Act, Year (2012). The Ethiopian Standards Agency (ESA) is the national standards body of Ethiopia established in 2010 based on regulation No. 193/2010, develop compound livestock and poultry feed standards that specify compound feed requirements, and establish a system that enable to check in compliance.

The ESA which was established in 2010 based on regulation NO. 193/2010. ESI is established due to the restructuring of Quality and Standard Authority of Ethiopia which was established in 1970 and Based on this; in 2019, Veterinary Drug and Animal Feed Administration and Control Authority (VDAFCA) partnered to develop the Animal Feed Regulatory Program Standards (referred to as the feed standards).

The feed standards establish a uniform foundation for the design and management of country programs responsible for the regulation of animal feed. Through implementing the feed standards, it is better able to maintain and ensure the safety and quality animal feed supply. The implementation of the feed standards also helps to ensure a uniform and consistent approach to animal feed regulation among jurisdictions.

The goal of the standards is to leverage resources and share common successes to build systems within state regulatory feed programs. The standards are approved by the National Standardization Council and are continuously reviewed after publication and regularly updated to reflect the latest scientific and technological changes. The standards currently in use was published in 2019. Today there are 32 approved compound feed and feed ingredient standards that are ready for implementations and enforcement act by the regulatory body.

This standard sets out the key requirements for those who wish to participate in the Feed Quality Assurance Scheme (FQAS). To help ensure the safety of the food produced (i.e. meat, eggs and dairy products), both feed business operators and farmers have a regulatory obligation to control the safety of feed offered to food producing animals. Participants are required to remain compliant with the relevant legislation.

Providing safe, high quality feed requires process and procedural controls throughout the feed chain and mechanisms to certify such controls as effective. The requirements and recommendations contained in the Ethiopian Standards are based on a consensus that reflects the interest of the representatives of the technical committee as well as comments from the public and other forms. The Ethiopian Standards are approved by the National Standardization Council and are continuously reviewed after publication to reflect the latest scientific and technological changes.

The public sector has played a key role in the development, implementation and enforcement of food and feed safety regulations, contaminant monitoring, consumer education, training and research. While the private sector Trade associations or agribusinesses, implement quality management procedures to assess and manage elements of food quality and safety in response to customer and regulatory requirements.

3. METHODS AND MATRAILS

3.1. Study locations

The study was conducted in and around the Municipalities of Addis Ababa and Bishoftu in the East Shewa Zone in the Oromia Regional States. Addis Ababa, the political capital and the most important commercial and cultural center of Ethiopia, is geographically located in the heart of the country, $9^{o}2'$N latitude and $38^{o}45'$E longitude. Its average elevation is 2,400 meters above sea level, with the highest elevation reaching 3,200 meters at Entoto Hill in the north. Addis Ababa is one of the fastest growing cities in Africa and a primate city in Ethiopia with an estimated population of around four million, which is about 25% of the total city population (MoUDHC, 2015 and Erena *et al.*, 2017)

Bishoftu is located 47.9 kms southeast of Addis Ababa. The town is located at 9^{0}N latitude and 40^{0}E longitudes at an altitude of 1850 meters above sea level in the central highlands of Ethiopia. It is a resort town, known for its several lakes and pioneering commercial poultry keeping in the country. The 2007 national census reported a total population for Bishoftu of 99,928, of whom 47,860 were men and 52,068 were women (CSA, 2007). According to Wondmeneh *et al.*, (2017) of the total commercial farms in the country about 69% are concentrated close to the consumption centers around Addis and Oromia, Bishoftu- Adama rout (34.5% each). This imply, more than 50 % of the total compound feed processors in the country are located in these regions and their total production is dominated by poultry feed products (Negash, 2020).

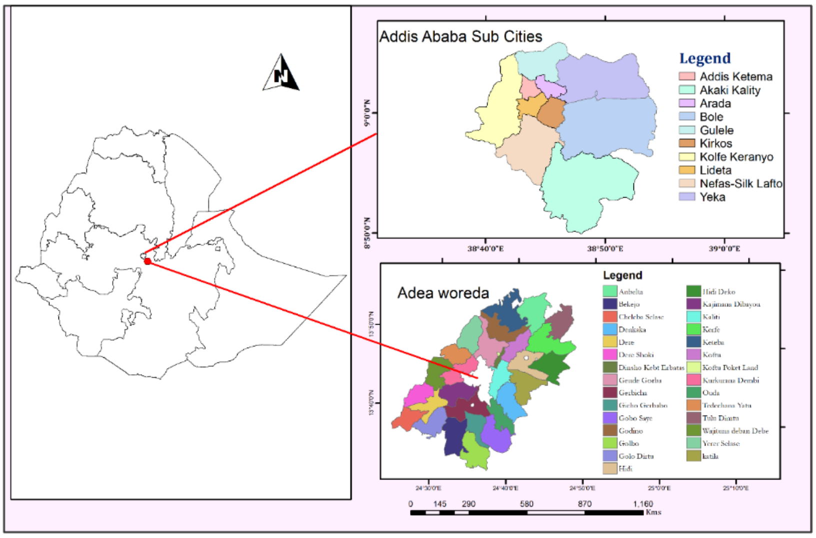

Figure 1:Map showing the study regions

3.2. Sample size

Commercial layer farms and compound layer feed retailor shops, are supposed to be the two main source of post market feed samples which used to assess the quality of commercially manufactured feeds once they have entered the marketing channel. Nevertheless, the pretest assessment and analysis of secondary data from agriculture office authorities revealed that the number of feed retailor shops in respective study regions were too small to make meaningful inference and subsequently dropped from the sampling scheme. Thus, the post market feed quality assessment study was limited to feed samples collected from small, medium, and large commercial farms which according to the secondary data sources make up 81.7%, 12.5%, 5.7% and 57.4%, 26.6% and 16.0% of the total commercial farms in Addis Ababa and Bishoftu respectively, operational at the time of sample collection.

In the contrary premarket feed samples were collected directly at point of commercial layer feed production and hence represent feed quality before dispatched to the market. Accordingly, the samples for premarket feed quality assessment study were drawn from 12 commercial feed producers (8 in and around the Addis Ababa city and 4 in and around Bishoftu town out of 10 and 5 commercial feed producers operational at the time respectively. Feed samples from commercial feed producer and commercial farms marketed in Addis Ababa and Bishoftu were collected from January-April 2022.

The total sample size was determined using the sample size determination formula proposed by Yemane (1967). In this formula the sample size is determined is as:

$$\mathbf{n}= \frac{Z^2pq}{(e)^2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(Eq 1)}$$

Where n= is the sample size,

Z^2= is 1 - α equals the desired confidence level,

e = is the desired level of precision,

p = is the estimated proportion of an attribute that is present in the population, and

q = is 1-p.

To capture the maximum possible variability within the population size that comply with Ethiopian standard with the desire a 95% confidence interval and ±5% precision the p value in Eq 1 set was0.05 (p= 0.5) and Eq 1 rewritten as Eq 2 to determine the total sample size.

$$\text{n}= \frac{\boldsymbol{Z^2} * pq}{(e)^2} = \frac{(\mathbf{1.96})^2 * (\mathbf{0.5}(\mathbf{1-0.5})}{(\mathbf{0.05})^2} = 384.16 \approx 384 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (Eq2)$$

Then it follows that a minimum number of samples required to capture the maximum possible variability within feed sample population was estimated at of 384, which proportionally divided among the four sampling subgroups to accommodate a comparative analysis of subgroups as suggested by (Sudman, 1976).

With this assumption, two hundred forty premarket feeds sample (160 from Addis and 80 from Bishoftu) were collected from 8 and 4 feed producers respectively, to quantify the variations between and within the sample population. Likewise, the post market feed samples collected from one hundred ninety-eight commercial farms (104 from Addis Ababa Region and 94 from Bishoftu. The small, medium, and large commercial farms make up 81.7%, 12.5%, 5.7% and 57.4%, 26.6% and 16.0% of total post market feed sample collected.

3.3. Feed sampling scheme

Stepwise purposive sampling process was followed by proportional random sampling procedure to collect the feed sample from the commercial feed producers and commercial layers farms. Addis Ababa and Bishoftu are purposively selected as study locations since the two regions represent most significant population of commercial layers chicken keeping centers in the country. Further, most of the feed mills and standard regulatory authorities are reside in and around the two regions (Seyoum *et al.*, 2018). From the eleven sub-cities of Addis Ababa City Administration, again seven sub-cities were selected purposively based on the commercial layers farm and feed millers' populations as suggested by the authorities of the Bureau of Urban Agriculture.

Pre and post market feed samples in and around Addis Ababa were collected from 8 compound feed millers (80%) and 104 commercial farms (60%) using proportional random sampling technique (Kish, 1965), respectively. While from Bishoftu town, which has fifteen kebeles, seven kebeles were selected purposively based on the above-mentioned criteria. Four commercial layer feed millers (80%) and 94 commercial layer farms (60%) selected using methods described above. The selected commercial farms has flock size < 1000 birds, between: 1001-2500 birds and above 2500 birds.

The sampling was done carefully using a method described by Fahrenholz and Stark (2014) and Ethiopian standard feed sampling procedure (ES: 1029:2019). Two hundred forty compound commercial layer feed samples from 12 feed producers were collected proportionately from the total population of feed millers in respective study locations. From each miller, twenty 1kgs composite samples were collected from ten individual batches, 10 composite samples directly from the mixer (or at the mixer gate during discharge, whichever method is accessible and safe for the operator) and the remaining 10 composite samples 1kg each were collected after bagging from randomly selected bags using a Seedburo grain probe (Chicago, Ill.). In both case four subsamples of 0.5 kg each make one composite sample.

The sub samples per each batch were bulked on clean plastic sheet, mixed thoroughly to make up 1kg composite sample ready for final feed composition analysis. The composite sample were put in clean plastic bag labeled with permanent ink the company name code, date of sampling/manufacturing, sealed and closed in box transported to the laboratory. At the same, time pertinent information associated with feed ingredient, processing capacity and types of feed and feed manufacturing processes recorded.

Similarly, one hundred ninety-eight compound commercial layer feed samples were collected proportionately from 198 commercial layer farms operational at the time of sample collection. Five subsamples of 0.5kg each were taken randomly from five to ten bags depending the stock, bulked on clean plastic sheet, mixed thoroughly to make up 1 kg composite sample ready for final feed composition analysis. Composite feed samples put in clean plastic bag labeled with farm code, date of sampling, code of company supplying the feed sealed and closed in box transported to the laboratory. In addition, data on farm characteristics such as breed, flock size and housing conditions were collected.

3.4. Determination of nutriment concentration

Each sample was scanned in a closed 3.5 cm diameter ring cup, using a Foss model DA 7250 NIR scanning monochromator device, equipped with a spinning module (Lidén and Eremina, 2021). The instrument works in reflectance mode in the spectral range 11002500 nm and measures every 2 nm (spectral bandpass 10 nm to 61 nm). Spectral absorbance values were obtained as log (1/R), where R represents the percent of energy reflected, which must then be related to the amount of the component as determined by reference or standard method (Lidén and Eremina, 2021). The spectra were exported to the WinISI software version 4.4 and were combined with the chemical reference data. The relationship between the log (1/R) values and the reference method values is expressed as an approximation and always involves some form of regression equation to determine the moisture content, crude fiber, crude fat, crude protein, metabolizable energy, available P, Ca, Na , the feed samples.

Before running the sample, the instrument was checked with check sample for verification of the wavelength. The feed was homogenized or mixed well to make sure the sample is representative. Appropriate sample cup designed for the analysis of dry, ground products, were employed in conjunction with the Foss NIR spectrometer, equipped with internal standards for control of light intensity, bandwidth and wavelength position.

3.5. Determination of mix uniformity

Mix uniformity between similar production batches was measured using the method of (Fan *et al*., 1970). In this method calls for at least 10 samples per each feed producers taken and uses CV as the primary uniformity measure.

3.6. Data analysis

Descriptive statistics, including the mean, standard deviation, coefficient of variation, maximum, mini-mum, Kurtosis and Skewness, were performed to describe the basic features of the data using the R software package, version 4.5 (R Core Team, 2020).

Frequency analysis was used to estimate the frequency of out of compliance of, crude fiber, crude fat, crude protein, metabolizable energy, moisture content, calcium, available P and sodium content. Cumulative Frequency Distribution Functions (CFDF) were used with quantitative continuous variables, such as the nutrient content of pre and post market compound feed samples. The CFDF is used to establish the frequency of occurrences relative to a reference point; the reference point used in the analysis of nutrient content compliance is Ethiopian base mark commercial layers feed quality s standard requirement (ES 1027: 2019) established for a nutrient by the regulators.

The CFDF is represented, as the case may be, by a solid ascending or descending line in a coordinate system in which the nutrient levels resulting from chemical analysis are on the abscissa and the cumulative frequencies of occurrence (percentage) are on the ordinate. The solid line on the CFDF indicates the minimum or maximum cut-off point, and the projection of the dotted lines on to the Y-axis indicates the frequency or percentage of samples associated with nutrient levels below the standard.

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The out-of-compliance frequency for a particular feed category and nutrient is established determining the frequency associated with crude protein, metabolizable energy, available P, Ca and Na determined by the lab values lower than the standard specification minimum limit (MINL)value while the frequency associated with moisture content, total ash, crude fiber, crude fat determined by the lab values greater than the standard specification maximum limit value (MAXL) using CFDF equation Eq3 and Eq4 respectively.

$$F(X < MINL) = f \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (Eq\ 3)$$

Where F is the CFDF.

$$F(X > MAXL) = f \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (Eq\ 4)$$

X is moisture content, crude protein, sodium, crude fiber, crude fat, metabolizable energy, calcium, available phosphorus content of the feeds determined by the lab

The shortage severity (SS) is calculated as follows:

$$SS = \sum_{P}^{i=1} \left[\frac{X_I}{P}\right] \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (Eq\ 5)$$

Where Xi is the nutrient shortages lower than standard requirement and P is the number of values lower or greater than the standard requirement.

Expected nutrient requirements, recommended allowances, and ultimately feed specifications are available from many sources like sets of tables published by the American National Research Council (NRC) in 1994. For this study we adopted data shown Appendix 1 published by ESI (2019) to specify nutrient requirements of commercial layers feed.

In addition, the Chi-square independence test was employed to evaluate the relationship between observed frequencies of compliance and the two feed sample categories and study regions. Specifically, to test whether the frequencies of one categorical variable differ across levels of another categorical variable. In other words, whether or not a statistically significant ($P \leq 0.05$) relationship exists between the two variables. Since the number of categories is two, the expectations are calculated using the Ei, j formula for frequency of counts for (i,j) pair of factors) (R Core Team, 2020).The value of X [2] statistic is computed as shown below

$$X^2 = \sum_{i=1}^{r} \sum_{j=1}^{c} \frac{[O_{ij}-E_{ij}]}{E_{ij}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(Eq 6)}$$

Where X2= Chi-Square test of Independence

Oij = Observed value of two nominal variables

Eij = Expected value of two nominal variables

Degree of freedom is calculated by using the following formula:

$$Df = (r-1)(c-1) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (Eq\ 7)$$

Where

Df = Degree of freedom

r = number of rows

c = number of columns

3.7 Ethical consideration

Ethical clearance certificate for this study with certificate Ref.no: VM/ERC/02/14022, 01/03/2022 was obtained from the animal research Ethics Review Committee of the College of Veterinary Medicine and Agriculture (CVMA) at Addis Ababa University (AAU) evidencing that no animal is used for the research or no any harm act was done during sample analysis.

4. RESULTS

4.1. General features of the study population

4.1.1. Sample farm characteristics

In this study post market feed samples represent feed samples collected from commercially manufactured feeds once they have entered the marketing channels. More specifically, feed samples were collected from commercial layers farms which were identified to be the major consumers of feeds produced by feed manufacturing industries. Commercial layer farms comprising the small, medium and large-scale farms accounted about 70.02 %, 19.19% and 12.12% of the total post market feed sample population respectively (Table 1); while large scale commercial farms produce their own feed the small and medium scale farms entirely depend on commercial feed producers.

Table 1: Characteristics of commercial layer farms involved in post market feed sampling schemes.

Study Locations	Small scale (50-1000 birds)	Medium scale (1001-2500)	Large scale (> 2500 birds)	Total
Addis Ababa	85	13	6	104
Bishoftu	54	25	15	94
Total	**139**	**38**	**24**	**198**

4.1.2. Characteristics of feed producers

Pre market feed samples were collected from selected legally registered and licensed feed processing plants in Addis Ababa city administration and Bishoftu to characterize pre market feed quality. Feed processing plants have feed mill, mixer and storage places for ingredients and for processed feeds. In genera the level of awareness of feed producers about feed standards is low. The industry lacks statutory regulation and monitoring whilst a few of the producers label the nutrient contents of their feeds. Manufacturers seem to have no legal obligation to monitor the quality of their feeds either, an issue which is brought about by the lack of enforcement of regulations. It was often stressed that farmer feedback is the most important form of quality control as a result feed producers seldom analyze their compound feeds or raw materials. The reason Bing high cost of analysis and or unavailability of the service around feed compounders.

Most feed processing plants are currently operating below their installed capacity mainly due to low demand for the product and shortage of ingredients which highlight a phenomenon which is common in many developing countries. It was revealed that the compound feeds production in the study regions are dominated by poultry feed products. On the average combined poultry feed products (broiler and layer feeds), make up 66% of animal feed products, followed by dairy feeds which account about 22 (Figure 2).

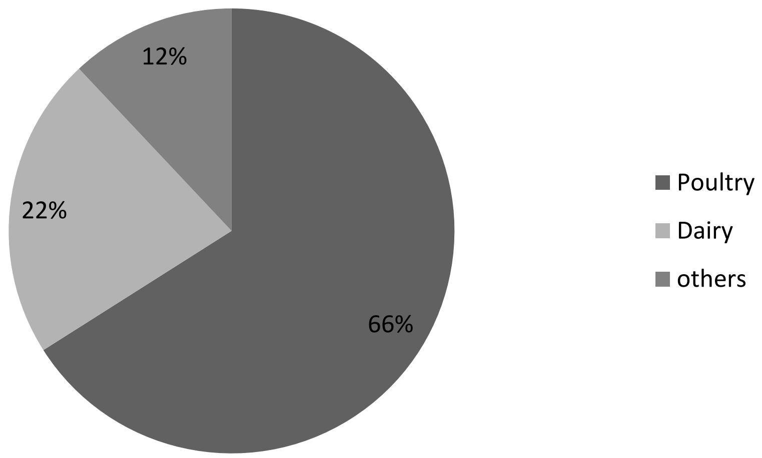


Figure 2: Feed types produced by feed producers in the study areas

4.1.3. Feed formulation and marketing

Chemical and physical properties of compound feed and storage conditions have a direct effect on feed quality. The feed mixer and millers engaged in compound commercial layers feed production using purchased grains (maize and same time wheat) Grain by-products (rice bran and wheat bran) industrial byproduct that includes (soybean meal, canola meal, cottonseed meal, sunflower meal, groundnut cake, Sesame meal, linseed meal and maize Gluten. And animal protein sources that include-meat meal, fish meal, blood meal, meat and bone meal and molasses) and Mineral Supplements: limestone, common salt, Bone Meal, fortified calcium and calcium carbonate. And also they use Vitamins (Vitamin, B complex, C, and D) and Amino acids (methionine and lysine) are the major one

They sell the finished feed directly to commercial poultry farms in urban and pre urban centers who buy quantities ranging from 1 to 2 ton per purchase. No traders as such are involved in the sells of compound feed. The fact that several feed producers are vertically integrating within the value chain and substantial volume of the produce goes to their own commercial farm consumption. Nevertheless, strong customer relationships are an important to establish loyal relationships with the client base.

4.2. Feed mix uniformity

Animal feed contains six main nutrients: water, protein, carbohydrates, fats, minerals and vitamins. These six nutrients are vital to animal survival. Therefore, there are differences in the nutritional needs of different farm animals, but the level of dietary energy and associated nutrients should be high enough to allow the animal's potential to be realized under specific environmental conditions, within economic limits. These feeds must be combined in such a proportion that the feed produced will meet the requirements of the different classes and ages of poultry without waste and at the most economical cost.

4.2. 1. Moisture content

The moisture content variation among similar production batches produced in the study area was presented in Table (2). The moisture contents among similar batches produced by feed producers in Addis Ababa and Bishoftu ranges between 6.2and 12.00 and 2.43 and 10.87 and with a mean for 8.66% and 7.95% respectively. The results further revealed that, the moisture content values were normally distributed with non-significant skewness irrespective of differences in feed producing plants. This may suggest that all feed producing plants achieved uniform mix uniformity in terms of feed moisture content. Moreover, moisture content values are sufficiently low which relates to freshness and stability for the storage of the feed over a long period of time.

Table 2: Descriptive statistics of moisture content (%) measured among similar batches of commercial layers feeds in Addis Ababa and Bishoftu

Regions	Feed producer	Min	Max	Mean	Kurtosis	Skewness	SD	CV (%)
Addis Ababa	01	7.89	11.07	9.64	-0.19	-0.65	0.92	9.54
	02	8.57	10.97	9.63	-1.01	0.27	0.78	8.1
	03	7.20	11.93	9.65	-0.93	-0.05	1.37	14.20
	04	6.20	8.70	7.60	-1.30	-0.50	0.90	11.84
	05	6.50	12.00	6.50	1.20	0.80	0.90	13.84
	06	7.70	11.20	9.60	0.00	-0.20	0.80	8.33
	07	7.10	11.60	8.05	0.60	0.30	0.93	11.08
	08	7.31	11.07	8.67	-0.23	0.00	0.94	10.99
	Mean	**7.30**	**11.06**	**8.66**	**-0.23**	**0.00**	**0.93**	**10.99**
Bishoftu	09	7.89	10.87	9.72	-0.19	-0.65	0.92	9.44
	10	4.21	9.92	7.51	-1.01	0.27	0.78	10.37
	11	2.43	7.25	4.91	-0.93	-0.05	1.37	27.91
	12	4.51	13.22	9.64	-1.29	-0.52	0.92	9.52
	Mean	**4.76**	**10.32**	**7.95**	**-0.86**	**-0.24**	**1.00**	**14.31**

4.2.2. Metabolizable energy content.

The result presented in Table 3 shows that the metabolizable energy values of similar batches produced ranges from 2321.60 kcal/kg to 3458.90 kcal/kg at Addis Ababa and 2443.45 kcal/kg to 3120.09 kcal/kg and at Bishoftu with a mean of 3017.9 and 2672.90 respectively. The results also revealed that the metabolizable energy values were normally distributed with non-significant skewness, though, kurtosis values as high as 2 may suggest in similar batches produced in feed processing plant 2 and 3 portray ME values characterized by distribution of long tail to the right suggesting presence of outlier values in some production batches.

However, the mixing uniformity, as estimated by coefficient of variation (CV) of metabolizable energy content showed that out of the total investigated feed processing plants in Addis, all had a mixer uniformity coefficient of variation of less than 10, while in Bishoftu all had CV's less than10%.

Table 3: Descriptive statistics of metabolic energy content (kcal/kg) measured among similar production batches of commercial layers feeds produced in and around Addis Ababa and Bishoftu.

Regions	Feed producers	Min	Max	Mean	Kurtosis	Skewness	SD	CV (%)
Addis Ababa	01	2433	3459	2688	-0.3	0.1	214	8.0
	02	2433	3459	2680	8.2	2.6	229	8.5
	03	2399	2890	2606	2.1	1.1	145	5.6
	04	2399	2811	2625	0.0	-0.1	150	5.7
	05	2322	2890	2606	-0.5	0.3	234	9.0
	06	2431	2819	2639	1.6	0.5	221	8.4
	07	2403	3055	2641	1.8	0.7	199	7.5
	08	2388	2853	2619	0.8	0.5	188	7.2
	Mean	**2401**	**3029.5**	**2638**	**1.71**	**0.23**	**0.47**	**9.8**
Bishoftu	09	2457	2890	2659	8.2	2.7	228	8.6
	10	2444	2997	2679	-0.3	0.1	150	5.6
	11	2457	3197	2754	2.1	1.1	268	9.8
	12	2443	3120	2673	0.0	-0.1	141	5.3
	Mean	**2450.3**	**3051.0**	**2691.3**	**2.5**	**1.0**	**0.0**	**10.01**

4.2.3. Fat content

The results indicated that crude fat content in similar batches produced in Addis Ababa and Bishoftu oscillates between 0.07% -6.9% and 2.8% -16. With a mean of 5.43% and 7.07% respectively. Coefficient of variation of fat content vary considerably between similar production batches across produced by feed processing plant in Addis, only 29% had a mixer uniformity coefficient of variation less than 15%, 42% were between 15-20%, and 25% were greater than 20% while in Bishoftu 50 % had CV's were between 10-15% and 50% greater than 20% (Table 4).

4.2.4. Crude protein content

The result shows that the crude protein content in similar batches produced by feed producers in Addis Ababa and Bishoftu ranges between 9.7 and 24.11 and 11.39 and 26.50 and with a mean of 16.70 % and 17.46% respectively (Table 5).

Table 4: Descriptive statistics of fat content (%) measured among similar batches commercial layers feeds in and around Addis Ababa and Bishoftu.

Regions	Feed producers	Min	Max	Mean	Kurtosis	Skewness	SD	CV (%)
Addis Ababa	01	0.07	6.32	4.78	0.55	-0.32	0.88	18.41
	02	4.31	6.19	5.29	-1.15	-0.03	0.61	11.53
	03	3.35	5.70	4.74	0.31	-0.18	0.58	12.24
	04	4.10	8.10	5.60	1.50	1.20	1.20	21.43
	05	2.40	6.50	2.40	0.30	-0.10	1.00	21.92
	06	4.10	6.90	5.70	-1.50	-0.10	0.90	15.79
	07	3.06	6.62	4.75	0.00	0.08	0.86	18.11
	08	2 .86	6.82	4.85	0.06	0.10	0.86	16.70
	Mean	**3.49**	**7.56**	**5.43**	**0.00**	**0.09**	**0.98**	**22.72**
Bishoftu	09	3.37	6.57	5.11	0.55	-0.32	0.88	18.34
	10	6.54	15.3	10.77	-1.15	-0.03	0.61	11.50
	11	4.21	9.92	7.51	0.31	-0.18	0.58	12.31
	12	2.80	6.05	4.89	1.49	1.23	1.17	20.94
	Mean	**4.23**	**9.54**	**7.07**	**0.30**	**0.18**	**0.81**	**15.77**

The results further elucidated that out of the total feed processing plant in Addis, 85.7% had coefficient of variation between 10-15%, 12.5% had CV greater than 20% while at Bishoftu 50 % had CVs between 10-15% and 25% were greater than 20% in crude protein content (Table 5).

Table 5: Descriptive statistics of crude protein content (%) measured among similar batches of commercial layers feeds in and around Addis Ababa and Bishoftu.

Regions	Feed producers	Min	Max	Mean	Kurtosis	Skewness	SD	CV (%)
Addis Ababa	01	9.7	24.1	16.5	0.0	0.2	4.0	24.0
	02	13.4	18.2	16.0	-1.3	-0.1	1.6	10.2
	03	14.7	24.1	17.6	2.1	1.6	2.6	14.9
	04	13.5	22.8	17.5	0.9	0.7	2.6	14.9
	05	12.3	18.6	15.6	-1.0	-0.1	1.9	12.1
	06	14.7	23.1	17.4	2.2	1.3	2.0	11.5
	07	13.0	21.8	16.2	0.5	0.6	2.5	15.1
	08	13.5	20.9	16.7	0.2	0.5	2.2	13.1
	Mean	**13.0**	**21.8**	**16.7**	**0.5**	**0.6**	**2.5**	**14.7**
Bishoftu	09	11.4	25.3	17.2	1.7	0.7	3.2	18.4
	10	12.2	22.3	17.0	-0.4	0.6	2.5	14.6
	11	14.9	26.5	19.3	-0.6	0.6	3.6	18.6
	12	12.2	20.2	16.3	2.3	0.2	1.5	9.3
	Mean	**12.7**	**23.6**	**17.5**	**0.7**	**0.5**	**2.7**	**15.2**

4.2. 5. Crude fiber content

Like moisture content values, crude fiber values were normally distributed with non-significant skewness. This indicates that crude fiber values among similar batches have low frequency of outliers of which in turn indicates the existence of comparable degree dispersion of ingredients throughout similar batches. (Table 6).The results further elucidated that out of the total feed processing plant mixed similar batches in Addis, only 14.23%% had a mixer uniformity coefficient variation of less than 10%, 14.23 % were between 10-15%, 42.85% were between 15-20%, and 25% were greater than 20% while in Bishoftu 50 % had CVs between 10-15% and 50% were greater than 20% (Table 6). Crude fiber includes the materials that are indigestible to humans and non-ruminant animals. It is defined as the material that is insoluble in dilute acid and dilute alkali under specified conditions. Crude fiber is used as an index of an ingredient's feeding value since materials high in fiber are typically low in nutritional value.

Table 6: Descriptive statistics of crude fiber content (%) measured among similar batches of commercial layers feeds in and around Addis Ababa and Bishoftu.

Regions	Feed producers	Min	Max	Mean	Kurtosis	Skewness	SD	CV (%)
Addis Ababa	01	2.90	9.67	7.15	-1.20	-0.39	2.19	30.60
	02	4.96	9.00	7.10	0.77	-0.32	1.04	14.60
	03	4.19	7.71	5.65	-0.91	0.59	1.06	18.80
	04	3.20	7.50	5.70	-0.60	-0.50	1.38	24.20
	05	3.50	9.00	7.50	-0.80	-0.40	1.20	16.00
	06	4.10	7.60	6.00	-0.60	-0.60	1.00	16.70
	07	3.81	8.41	5.85	-0.56	-0.27	1.37	23.40
	08	3.51	7.41	5.85	-0.36	-0.17	1.16	19.80
	Mean	**3.77**	**8.29**	**6.35**	**-0.53**	**-0.26**	**1.30**	**23.45**
Bishoftu	09	2.90	9.67	7.15	-1.20	-0.39	2.19	30.66
	10	4.96	9.00	7.10	0.77	-0.32	1.04	8.56
	11	4.19	7.71	5.65	-0.91	0.59	1.06	10.33
	12	3.18	7.45	5.72	-0.59	-0.48	1.44	20.44
	Mean	**2.90**	**9.67**	**6.40**	**-0.48**	**-0.15**	**1.43**	**17.50**

4.2. 6. Sodium chloride content

The variation between similar production batches with respect to sodium chloride concentration is presented in Table 7. The result revealed that only 37.5% feed producing plants in Addis achieved coefficient of variation less than 20% the corresponding figure for feed producers in Bishoftu was 50 %. NaCl concentrations data were normally distributed with non-significant skewness, therefore, the mean is the best measure of central tendency for NaCl content across similar production batches.

Table 7: Descriptive statistics of sodium chloride content (%) measured among similar batches of commercial layers feeds in and around Addis Ababa and Bishoftu.

Regions	Feed producer	Min	Max	Mean	Kurtosis	Skewness	SD	CV
Addis Ababa	1	0.34	0.57	0.47	0.24	-0.77	0.06	13.0
	2	0.34	0.60	0.48	-0.32	-0.19	0.07	14.1
	3	0.09	2.58	0.55	2.0	0.54	0.49	89.9
	4	0.32	2.58	0.56	2.0	0.61	0.48	86.6
	5	0.34	0.57	0.48	-0.50	-0.52	0.07	13.9
	6	0.09	0.63	0.46	1.60	-0.63	0.12	26.4
	7	0.32	2.58	0.66	0.68	0.93	0.66	99.4
	8	0.30	1.59	0.55	1.51	0.79	0.35	64.7
	Mean	**0.27**	**1.46**	**0.53**	**0.91**	**0.09**	**0.29**	**50.99**
Bishoftu	9	0.34	0.57	0.47	0.84	-0.77	0.06	13.0
	10	0.34	0.60	0.48	0.62	-0.19	0.07	14.1
	11	0.09	0.63	0.42	0.87	-0.54	0.14	32.2
	12	0.32	0.69	0.46	0.66	0.14	0.09	20.1
	Mean	**0.26**	**1.09**	**0.50**	**0.72**	**-0.02**	**0.22**	**19.84**

NaCl concentrations measured among similar production batches produced in feed processing plant number 3, 4, 7 and 8 was skewed to the right and are expected to have higher frequency of outliers compared to other feed producing plants.

4.2.7. Available P content

The results elucidated that out of the total feed processing plant in Addis, only 12.5% had coefficient of variation between 15-20%, the rest 87.5 % were greater than 20% while in Bishoftu all had CVs were greater than 20% (Table 8).

Table 8: Descriptive statistics of Available P content (%) measured among similar batches of commercial layers feeds in and around Addis Ababa and Bishoftu

Regions	Feed producers	Min	Max	Mean	Kurtosis	Skewness	SD	CV (%)
Addis Ababa	01	0.09	1.00	0.52	0.20	-0.15	0.23	44.23
	02	0.18	0.71	0.45	-0.32	0.06	0.08	17.78
	03	0.39	0.93	0.61	2.05	0.55	0.14	22.95
	04	0.20	0.70	0.40	0.00	-0.70	0.10	25.00
	05	0.10	1.00	0.40	-0.50	0.20	0.10	25.00
	06	0.20	1.00	0.50	1.60	-0.50	0.10	20.00
	07	0.19	0.89	0.43	0.51	-0.09	0.13	30.23
	08	0.22	0.91	0.48	0.79	-0.11	0.11	23.04
	Mean	**0.20**	**0.89**	**0.47**	**0.54**	**-0.09**	**0.12**	**26.14**
Bishoftu	09	0.39	0.92	0.61	0.21	-0.83	0.08	12.90
	10	0.03	1.67	0.63	2.52	1.61	0.19	30.65
	11	0.03	1.67	0.63	2.52	1.61	0.19	30.65
	12	-0.05	0.89	0.39	0.17	-2.09	0.28	72.17
	Mean	**0.11**	**0.99**	**0.45**	**0.92**	**0.02**	**0.14**	**28.3**

With some exceptions the Available P content in similar production batches were normally distributed with non-significant skewness, therefore, the mean is the best measure of central tendency for Ca content. Nevertheless, production batches produced in feed processing plant number 10 and 11 which skewed to the right and plant number 12 which skewed to the lift expected to have high frequency of outliers in Available P content. According to George & Mallery (2010) kurtosis the values between -2 and +2 are considered acceptable to prove normal univariate distribution.

4.2.8. Ca content

The results analysis presented in Table 9 revealed that that out of the total feed processing plant in Addis, only 12.5% had coefficient of variation less than 20%.

Table 9: Descriptive statistics of Calcium content (%) measured among similar batches of commercial layers feeds in and around Addis Ababa and Bishoftu.

Regions	Feed producers	Min	Max	Mean	Kurtosis	Skewness	SD	CV (%)
Addis Ababa	01	0.31	1.46	0.52	0.20	-0.15	0.23	43.19
	02	0.29	0.71	0.45	-0.32	0.06	0.08	17.08
	03	0.28	0.93	0.61	2.05	0.55	0.14	23.16
	04	0.30	0.70	0.40	0.00	-0.70	0.10	27.90
	05	0.30	1.00	0.10	-0.50	0.20	0.10	23.70
	06	0.20	1.00	0.50	1.60	-0.50	0.10	20.10
	07	0.28	0.97	0.43	0.51	-0.09	0.13	25.86
	08	0.28	0.97	0.43	0.51	-0.09	0.13	25.86
	Mean	**0.34**	**0.92**	**0.54**	**2.30**	**-0.83**	**0.08**	**14.47**
Bishoftu	09	0.75	1..07	0.52	7.24	1.61	0.19	38.91
	10	0.06	1.67	0.48	7.21	1.61	0.19	39.92
	11	0.06	1.67	0.48	7.21	1.61	0.19	39.92
	12	0.06	0.89	0.47	8.94	-2.09	0.28	60.61
	Mean	**0.34**	**0.92**	**0.42**	**4.05**	**0.14**	**0.15**	**29.89**

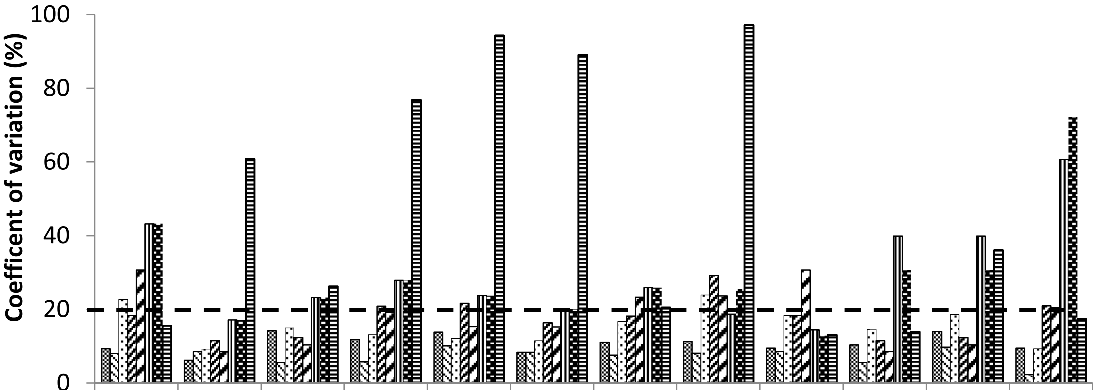
While in Bishoftu of none had CV less than 20. The data further revealed that Ca concentrations data were normally distributed with non-significant skewness, therefore, the mean is the best measure of central tendency for Ca content across similar batches.

Nevertheless, Ca content in similar production batches produced in feed processing plant number 10, 11 and 12 which was skewed to the right or to the lift in later case are expected to have high frequency of outliers in Ca content. According to George and Mallery (2010) the kurtosis values between -2 and +2 are considered acceptable to prove normal univariate distribution.

4.2.9. Mix uniformity among feed processing plants

Results presented in Figure 2 shows that the concentration of nutrients among similar batches produced in the study area vary considerably across feed processing plants for the analytes in focus. The batches produced in feed producing plant number 2 and 9 had excellent to good feed mix uniformity for all analytes in focus except for Na and CF contents respectively. While similar batches produced in feed producing plant number 11 and 12, displayed acceptable mix uniformity in six out of eight nutrients considered for testing mix uniformity. In the country, similar batches produced in feed processing plant number 1and 7 failed to produce feed with acceptable mix uniformity in 5 out of 8 nutrients.

This may suggest that difference in equipment and feed manufacturing processes probably factored in delivering similar batches having uniform and consistent feed mix uniformity. On the other hand, similar batches produced in different feed producing plants exhibited excellent mix uniformity in terms of ME, moisture content and to lesser extent in CP content. In the contrary, batches were extremely variable in terms of Na, Ca and Available P content regardless of the difference in the feed processing plants. Variations between batches in terms of CF and fat contents were somewhere between the two extremes. This may indicates, in addition to peculiarities of the feed processing plants the source material used for feed formulations may be factored into feed mix uniformity variations observed among similar production batches.



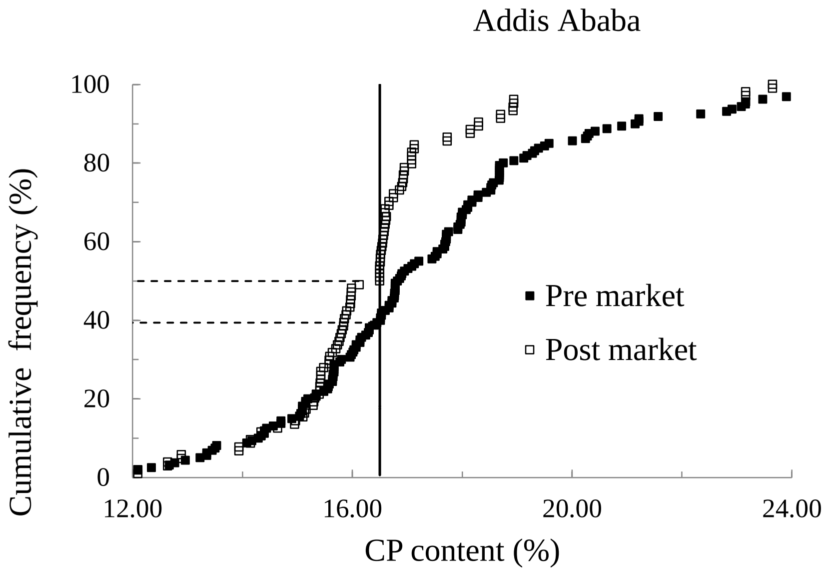
	1	2	3	4	5	6	7	8	9	10	11	12
	Addis Ababa								Bishoftu			
MC	9.32	6.2	14.2	11.84	13.84	8.33	11.08	11.33	9.44	10.37	14	9.52
ME	7.96	8.52	5.58	5.71	10.08	8.37	7.53	8.09	8.56	5.6	9.75	2.26
CP	22.66	9.18	14.92	13.13	12.11	11.49	16.65	23.92	18.36	14.56	18.58	9.3
Fat	18.34	11.5	12.34	20.9	21.6	16.3	18.13	29.19	18.34	11.5	12.31	20.94
CF	30.66	8.56	10.33	19.2	15.3	15.2	23.33	23.62	30.66	8.56	10.33	20.44
AP	43.19	17.08	23.16	27.9	23.7	20.1	25.86	18.66	14.47	39.92	39.92	60.61
Ca	43.23	17.08	23.16	27.9	23.7	20.1	25.86	25.56	12.9	30.65	30.65	72.17
Na	15.59	60.8	26.25	76.76	94.3	89.07	20.5	97.14	13	13.88	36.09	17.42

Figure 3: Nutrient concentrations variations between similar production batches produced in twelve feed processing plants. The chain line shows coefficient of variation commonly recognized by the feed industry as the cutoff point for uniform mix.

4.3. Compliance of nutrient concentration in pre and post market feeds

4.3.1. Crude protein contents

The results of proximate analysis results showed that out of the total premarket feed samples, collected in Addis and Bishoftu 39.37% and 43.75% were out of compliance with respect to CP content, the average total CP deficiency was 1.7% and 1.3%, respectively (Figure 4). In contrasts the out of compliance frequency of post market feed sample was 50%, and 57.5% respectively with average total CP deficiency of 1.2% and 0.68% in the same order as above (Figure 4).



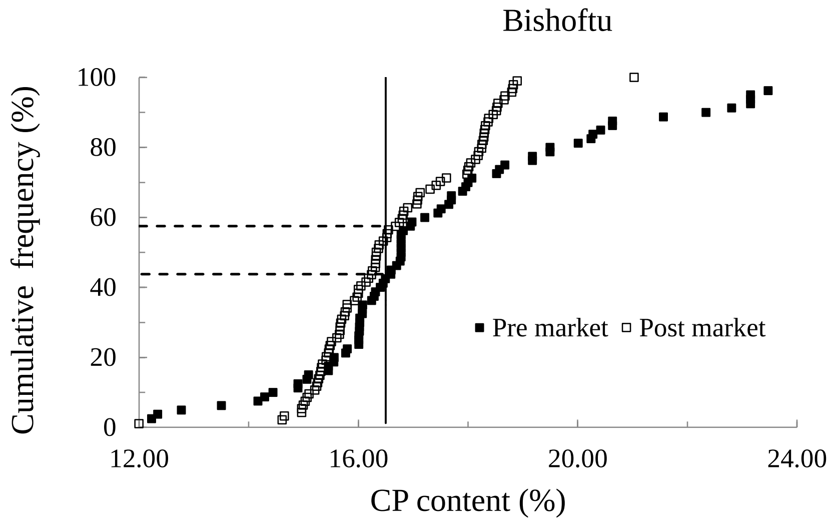


Figure 4: Cumulative Frequency Distributions of CP concentration (%) in pre and post market commercial layers feed sample. Vertical solid line represents the out-of-compliance boundary, and horizontal dotted line represents the frequency for the boundary.

The independent test further showed that the difference in out of compliance frequency between premarket and post market feed sample only at Addis Abeba were statistically significant at $P \leq 0.05$ (Tables 10).This suggests the presence of strong association between out of compliance frequency and the two feed sample categories. However, there is no statically significant association between out of compliance frequency and sampling locations (Table 10).

Table 10 : Pre and post market feed compliance frequencies with respect to crude protein content.

Location	Feed sample	Compliance frequency		Total	Test statistic	χ^2	
		out	In			<0.05	<0.01
Addis	Premarket	63	97	160	6.62		6.64
	Post market	53	51	104			
Bishoftu	Premarket	32	48	80	3.01	3.84	
	post market	50	44	94			

Thus, the numerical differences in out compliance frequencies between study locations with respect to CP content were attributed to random variations in raw materials and feed compounding process commonly occur during feed formulations.

Table 11: Compliance frequency of commercial layer feed with respect to CP content at the study locations.

Location	Compliance frequency		Total	Test statistic	(χ^2<0.05)	
	Out	In			$\leq$0.05	$\leq$0.01
Addis	116	148	264	2.92	3.84	
Bishoftu	85	89	174			

The graphical representation of a grouped frequency distribution with continuous classes of negative and positive deviation from the ESI standard is presented in Figure5 and 6.

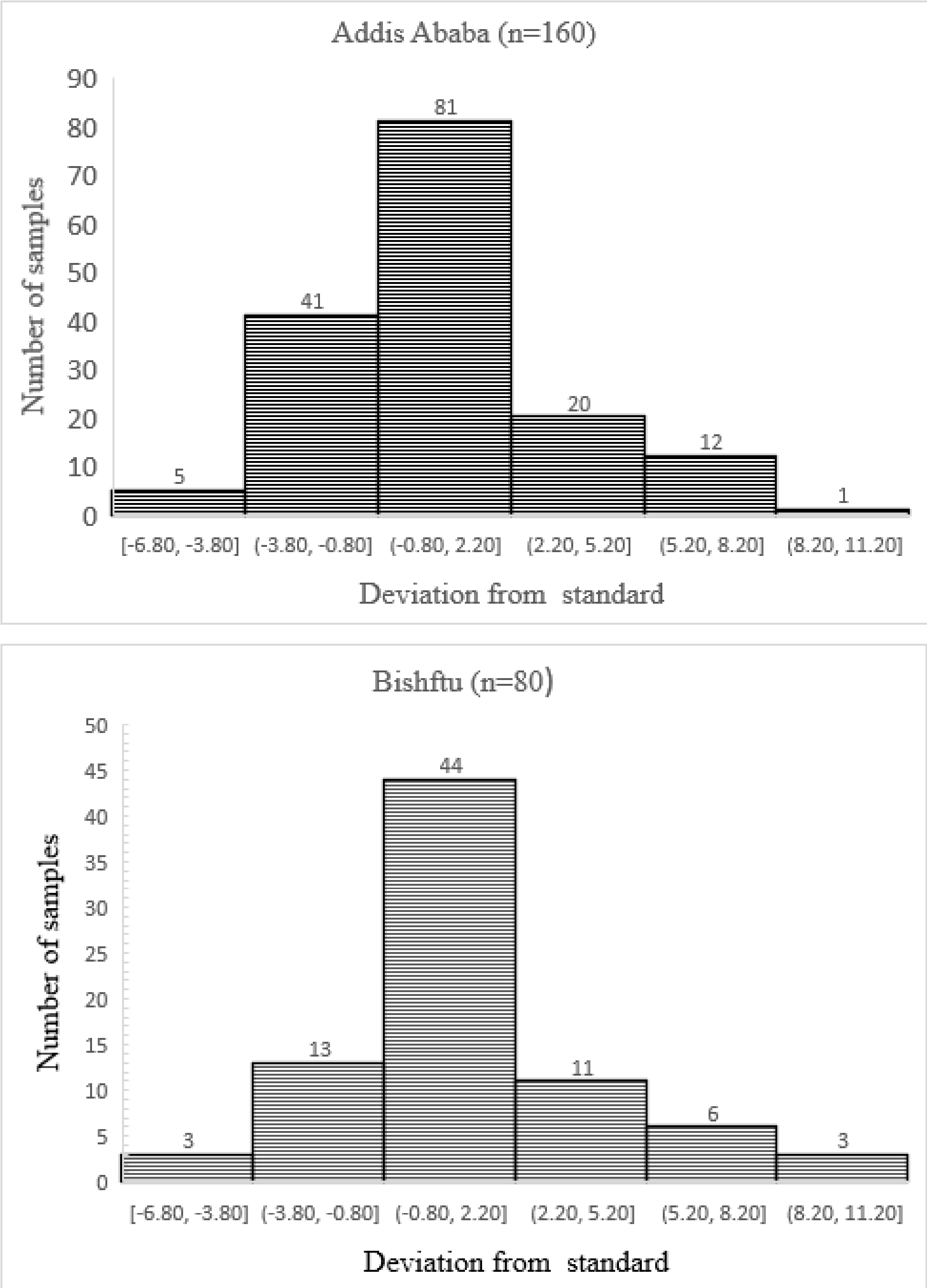


Figure 5: Frequency distribution of negative and postive deveations of CP concentration (%)in premarket feed sample from ESI standard

The largest negative deviation grouped frequency of premarket samples from Addis occurs within a range of -80 to < -2.20 while the second largest group scan between -3.80 to < - 0.80 and the two together represent 88.75% of the total study sample population the third largest group scan between -6.80 to < -3.80 which represent 7.5% of the total study population. (Figure 5).The positive deviation groups representing 12.5, 7.5 and 0.62 % of the total premarket sample population and fluctuate between >2.20 – 5.20 and 5.20, > 8.20 and 8.20 > 11.20 respectively. The negative and positive deviation groups of premarket samples from Bishoftu followed similar distribution pattern as premarket samples from Addis Ababa. The largest negative and positive deviation groups which accounted about 55 % and 13.75 % of the total sample population varies between – 0.80 and < -2.20 and ≥ 2.20 and 5.20 respectively.

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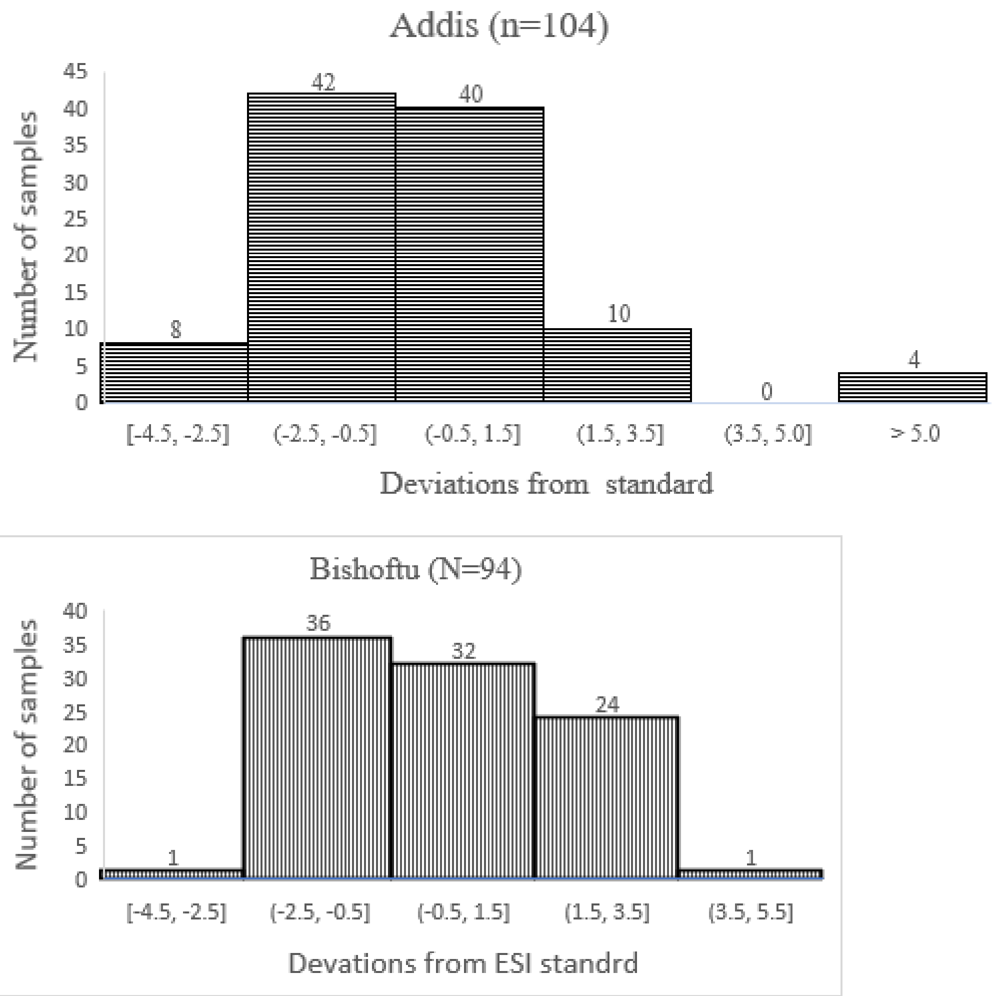


Figure 5: Frequency distribution of negative and positive deviations of CP concentration (%) in post market sample from ESI standard

4.3.2. Metabolizable energy content

Proximate analysis results of metabolizable energy contents of the feed samples from the two study locations are depicted in Figure 6. The result revealed that the premarket feed samples exhibited out of compliance frequencies of 33.8% and 36.6 % at Addis and Bishoftu the average total ME deficiency of -104.1 and -62.5 kcal/kg respectively. While the corresponding figure for the post market feed samples in the same order as above was 48.33%, and 43.61% with average total ME deficiency of -112.4 and -65.5 kcal/kg respectively (Figure 6). Post market feed samples exhibited higher out of compliance frequency than premarket feed samples at only in Addis Abeba. However, the association between out of compliance frequency and pre and post market feed samples was significant only at Addis Ababa (Tables 12).

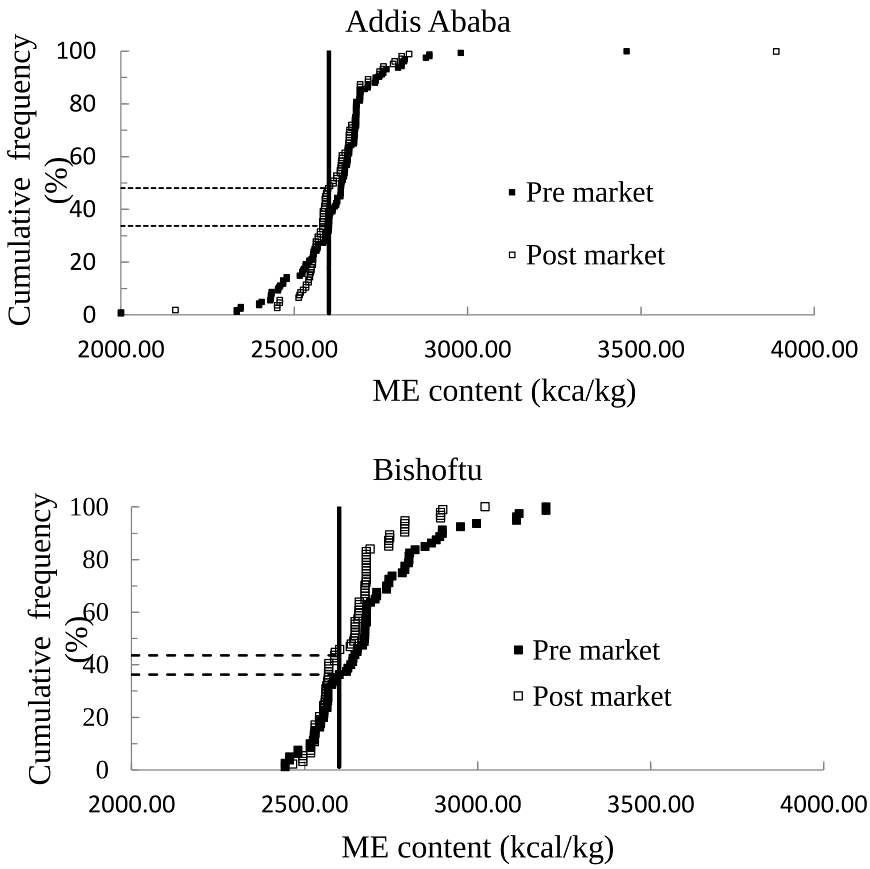


Figure 6: Cumulative Frequency Distributions of ME (kcal/kg) content in pre and post market commercial layer feed. Vertical solid line represents the out-of-

compliance boundary, and horizontal dotted line represents the frequency for the boundary.

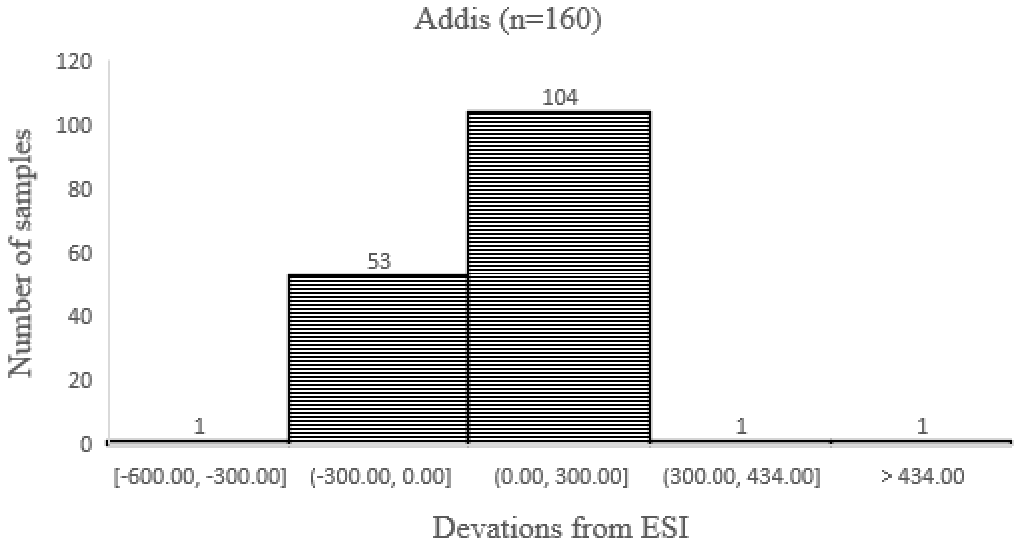
Thus the difference in ME between the pre and post market feed sample at Bishoftu is merely attributed to random variations. In addition to random variations, the difference between the two sample categories in Addis may be attributed to the variations induced due to segregation at loading, unloading and transport the feed from point of production to point of use. The graphical representation of a grouped frequency distribution with continuous classes of negative and positive deviation of ME content of premarket samples, from the ESI standard is presented in Figures7 and 8. This variation may be due to inadequate mixing of the feed since the ME value was obtained from a factor of the fat, protein and carbohydrate content in the feed. The implication is that birds fed with ration containing less fat, protein and carbohydrate will not have much energy for growth and this feed sample may contribute to stunted growth and low production in birds (NRC, 1994).

Table 12: Metabolizable energy content compliance frequency differences among pre and post market feed samples at the study locations.

Location	Feed sample	Compliance frequency		Total	Test statistic	χ^2	
		out	In			≤ 0.05	≤ 0.01
Addis	Premarket	63	97	160	7.49	3.84	6.64
	post market	51	53	104			
Bishoftu	Premarket	32	51	80	2.39	3.84	6.64
	post market	45	49	94			

The negative deviation grouped frequency varies between -300.00 - 0.00 kca/ kg and – 600.00 kca/ kg to -300.00 kcal/kg representing 33.12 % and 0.625 % of the total premarket samples collected from Addis. The positive scan between, 0 - 300.00 kcal/kg and 300.00 – 434.00 kcal/kg deviation groups representing 65 % and 0.625 % of the total premarket sample population in Addis respectively.

In contrast, the grouped frequency distribution of ME content of premarket samples skewed to the right at Bishoftu suggesting that large proportion of premarket samples have ME content exceeding the minimum value of ME required by ESI (2019) for commercial layer feed.



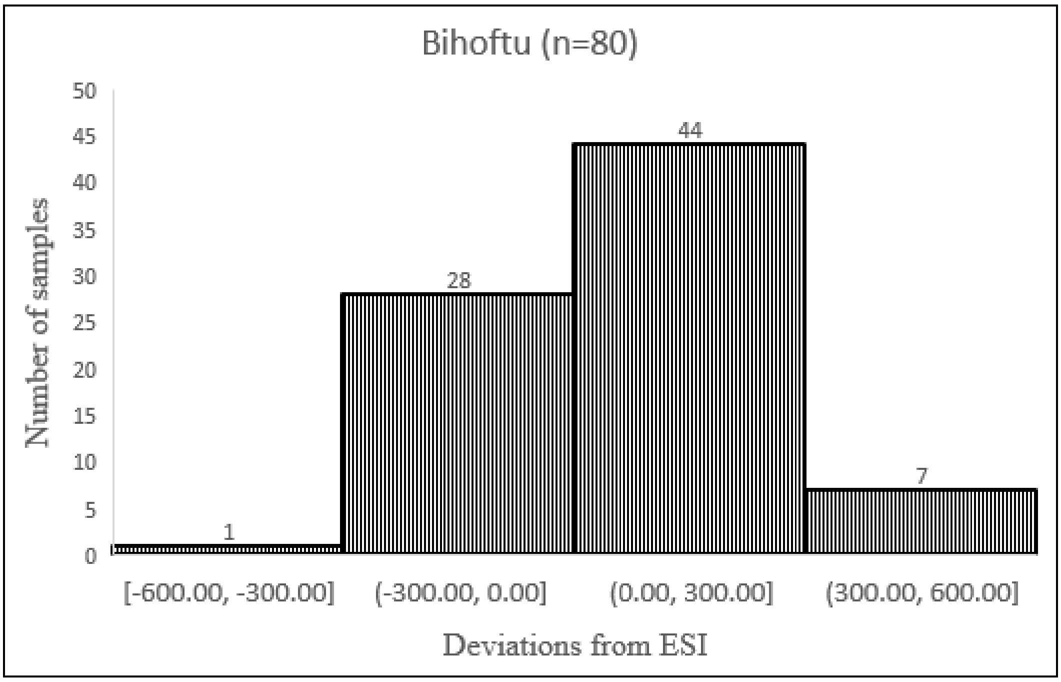


Figure 7: Frequency distribution of negative and positive deviations of ME (kcal/kg) content in premarket feed sample from ESI standard.

Table 13: Metabolizable energy content compliance frequency of commercial feed samples at the study locations.

Location	Compliance frequency		Total	Test	χ^2	
	out	in		statistic	≤0.05	≤0.01
Addis	108	156	264	0.02	3.84	6.64
Bishoftu	74	100	174			

As a result the negative deviation groups occur only in two classes that scan between -300.00 and 0.00 and – 600.00 – 300.00 representing 3.5 % and 1.25 % respectively. Of the total population. While the positive deviation groups occur in two separate sub classes which represent 55 and 8.8 % of the total pre market sample population at Bishoftu that fluctuate between >0.0 and 300.00 and > 300.00 – 600.00 and 313 and > 313 respectively .

4.3.3. Crude Fiber Content

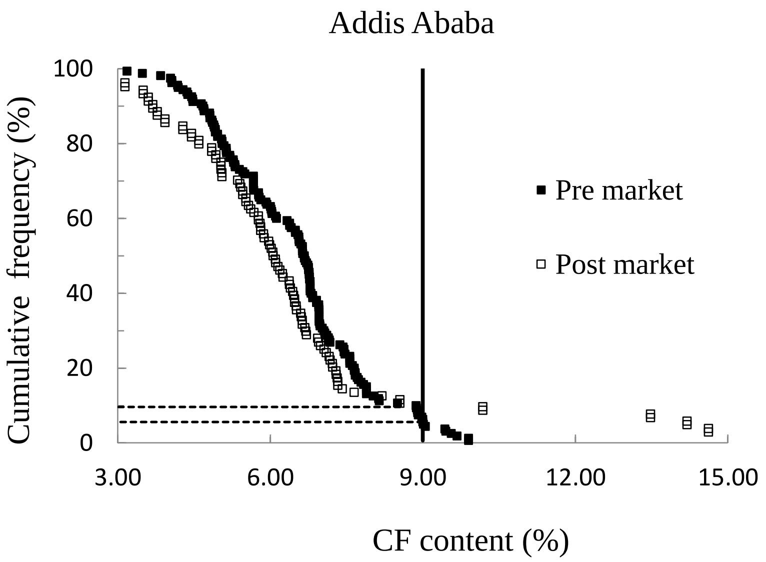
Unlike CP and ME content, the noncompliance frequencies of crude protein content in commercial layers feed sample was modest regardless of the study variables (Figure 9).In

Addis about 5.6 of premarket sample and 9.6% post markets ample exceeded the minimum value of CF content sited by ESI (2019) standard for commercial layers feed. The corresponding figures for Bishoftu in the same order as above were 6.5% and 10%.

Table 14: Compliance frequency of crude fibber content in pre and post market feed sample in the study locations.

Location	Feed sample	Compliance frequency		Total	Test	χ^2	
		out	In		statistic	≤0.05	≤0.01
Addis	Premarket	8	152	160	4.84	3.84	6.64
	post market	13	91	104			
Bishoftu	Premarket	10	70	80	3.97	3.84	6.64
	post market	4	90	94			

The CF is used to define a variety of indigestible polysaccharides including cellulose, hemicelluloses, pectin's, oligosaccharides, gums and various lignified compounds. With little gradation, the fiber fraction of poultry diets was long considered of diluting or even anti-nutritive nature, as reviewed by Mateo*s et al.*, (2012).



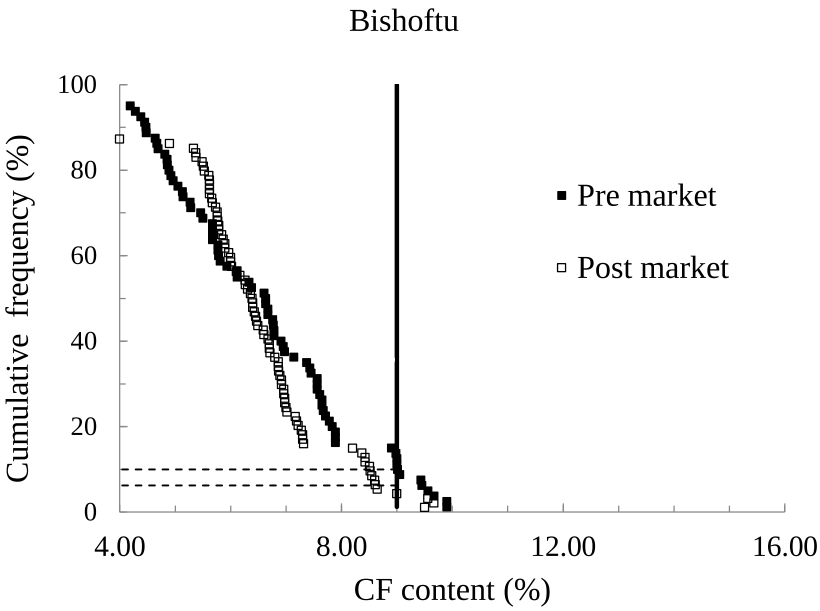


Figure 8: Cumulative Frequency Distributions of CF content in pre and post market commercial layer feed sample. Vertical solid line represents the out-of-compliance boundary, and horizontal dotted line represents the frequency for the boundary.

Thus, it has commonly been used as a negative coefficient in prediction equations of the nutritive value of feeds (Lunn and Buttriss, 2007). The result of independent test suggests that post market feed samples exhibited higher out of compliance frequency than premarket feed samples at only in Addis Abeba both. (Table 13). Moreover, the associations between out of compliance frequency of CF content and feed sample categories in one hand and CF content and sampling locations on the other hand were statically significant at ($P \leq 0.05$) (Table 15).

Table 15: Compliance frequency of crude fibber content in pre-market feed samples across the study locations.

Location	In and out compliance frequency		Total	Test statistic	χ^2	
	out	In			$\leq$0.05	$\leq$0.01
Addis	8	152	160	4.32	3.84	6.64
Bishoftu	10	70	80			

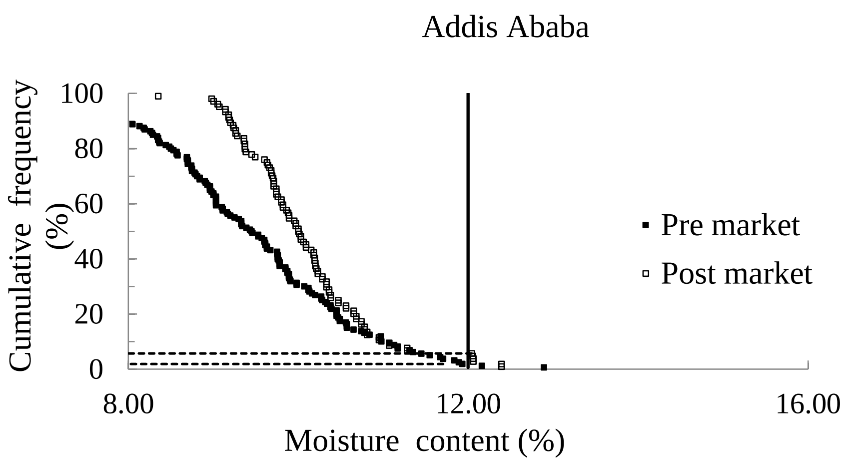
This suggests that higher out of compliance frequency in CF content was expected in post market feed samples compared to premarket feed samples. The results of independent test further revealed that higher out compliance frequencies in CF was expected in feed samples from Bishoftu compared to feed samples collected from Addis Ababa (Tables 15).

Table 16: Out of compliance frequency of crude fiber content of commercial layer feeds across the study locations.

Location	Compliance frequency		Total	Test	χ^2	
	out	In		statistic	≤0.05	≤0.01
Addis	13	91	104	4.27	3.84	6.64
Bishoftu	4	90	80			

4.3.4. Moisture content

The proximate moisture content analysis results presented in Figure 10 revealed that all most all feed sample comply with ESI (2019) commercial layers feed standard. From the 240 premarket feed sample analyzed 236 (98%) comply with the standard. Similarly outof 198 post market feed sample analyzed only 7 samples (about 4 %) exceeds the in-compliance limit (Table 17).



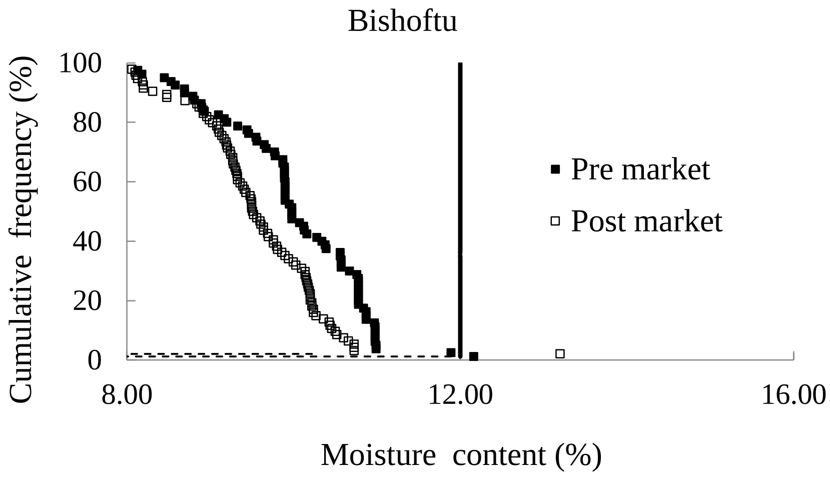


Figure 9: Cumulative Frequency Distributions of moisturecontent in pre and post market commercial layer feed sample. Vertical solid line represents the out-of-compliance boundary, and horizontal dotted line represents the frequency for the boundary.

Moreover, the variations in moisture content observed across the study variables has no statistically detectable pattern suggesting that variations are attributed to random variations (Table 17).

It is necessary to know the moisture content of raw materials and compound feeds as a check on their feeding requirements, for use in calculating analytical data on a dry matter basis and also because moisture has an important function in determining the form of the diet. It also has an effect on its stability and its shelf life. Controlling the moisture content of any feed is very important, because of it is the mainly cause for afflation. Moreover, high DM contents control the growth of mold in feeds, thereby reducing deterioration which is particularly important in tropical countries. As stated by Islam *et al.*, (2015), with some exceptions our result suggests that commercial layer feed sample analyzed are appropriate for use and storage.

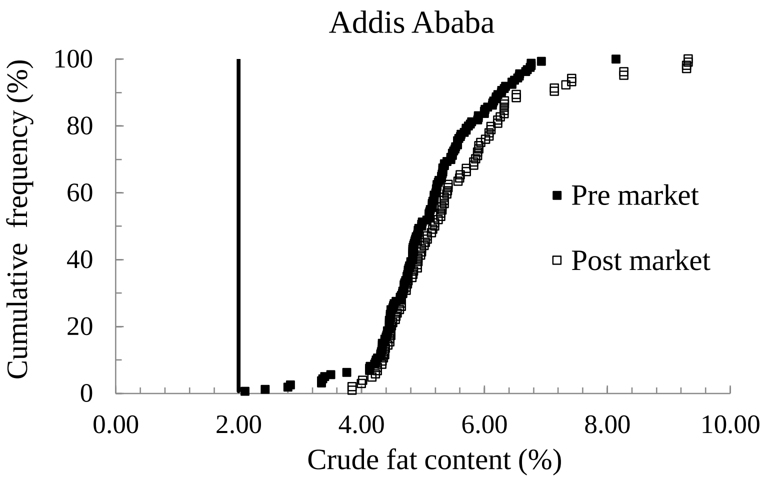
Table 17: Compliance frequency of moisture content in pre and post market feed sample in the study locations.

Location	Feed sample	Compliance frequency		Total	Test statistic	χ^2	
		out	In			≤0.05	≤0.01
Addis	Premarket	2	158	160	3.09	3.84	
	post market	5	99	104			
Bishoftu	Premarket	1	79	80	0.52	3.84	
	post market	2	92	94			

4.3.5. Crude fat content

The proximate analysis results are presented in Figure 11 showed that regardless of the study variables the crude fat content of commercial feed sample comply with ESI (2019).

The crude fat content of the feed samples ranges from 2.1 to 8.6% while ESI (2019) recommends a minimum of 2 % crude fats inclusion rate in commercial layers feed formulation. The maximum amount is defined more by technical reasons than by nutritional ones, as diets of up to 7.5% of crude fat are excellent for layers (Pérez-Bonilla et al., 2011).



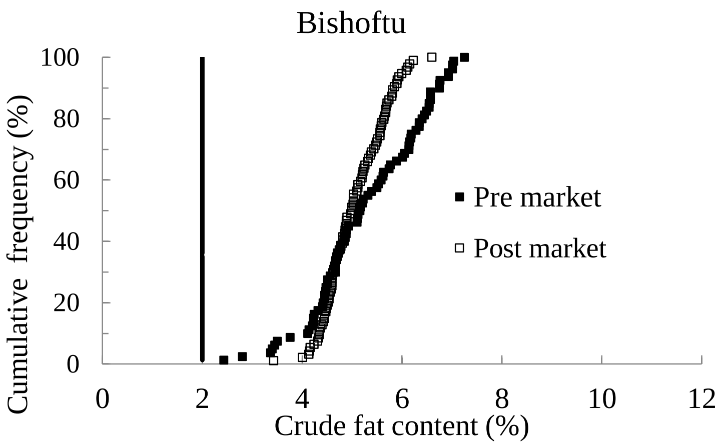


Figure 10: Cumulative Frequency Distributions of crude fat content in pre and post market commercial layer feed sample. Vertical solid line represents the out-of-compliance boundary.

4.3.6. Available P content

The proximate analysis of Available P content in pre and post market sample are depicted in Figure 12. The results showed that the deference between pre past market commercial feed sample in out of compliance frequency with respect to Av. P content was modest (6.3 vs. 7.6%) at Bishoftu and 11.3 % vs. 7.7% (Figure 12). The independent test further attested that no association between out of compliance frequency and feed sampling category or sample locations (Table 17).

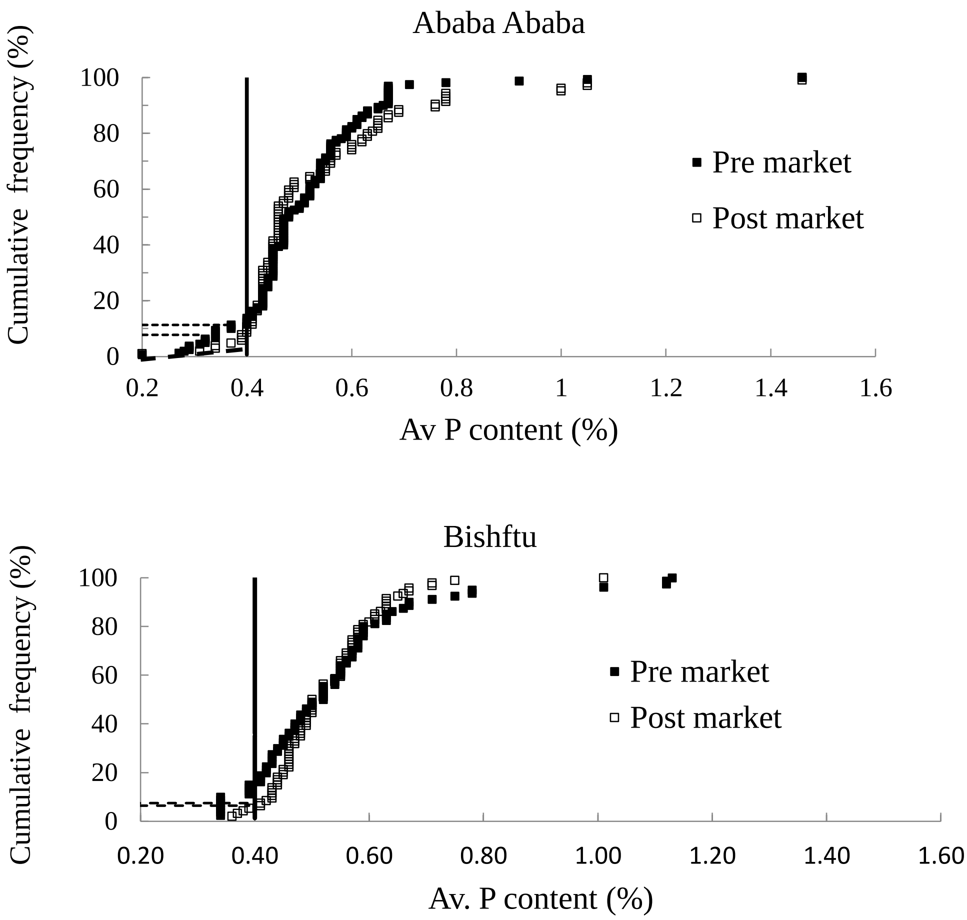


Figure 11: Cumulative Frequency Distributions of available phosphorus content in pre and post market commercial layer feed sample. Vertical solid line represents the out-of-compliance boundary, and horizontal dotted line represents the frequency for the

boundary.

This may indicate the difference between pre and past market feed sample in out of compliance frequency with respect to available P content is attributed to random variations in feed ingredient and or differences in feed compounding practices.

Ethiopian standard Institute (2019) recommended dietary phosphorus level for laying hens at 0.4 % available phosphorus per kilogram of diet. Low dietary phosphorus during the laying period can lead to increased incidence of cage layer fatigue, reduced bone ash, increased severity of osteoporosis and diminished bone strength. Phosphorus plays key role in carbohydrate metabolism, fat metabolism and the regulation of acid-base balance in body.

4.3.7. Calcium content

Out of the total premarket feed samples analyzed 18.1% and 25.1% were out of compliance with respect to calcium content at Addis and Bishoftu, the average total calcium deficiency of -1.4% and -1.15%, respectively (Figure 13).

Table 18: Compliance frequency of available phosphorus content in pre and post market feed samples within the study location.

Location	Feed sample	In and out compliance frequency		Total	Test statistic	χ^2	
		out	In			$\leq$0.05	$\leq$0.01
Addis	Premarket	18	142	160	0.89	3.84	
	post market	8	96	104			
Bishoftu	Premarket	10	70	80	2.82	3.84	
	post market	5	90	94			

In the same order as above the corresponding values for post market samples were 43.62% and 28.8% with average total calcium deficiency of -1.59% and -2.09% (Figure 13). Test of independent revealed that the association between out of compliance frequency and premarket and post market feeds at both locations were statistically significant at P ≤0.01 and P ≤0.05 respectively, indicating the presence of strong association between out of compliance frequency and the two feed sample categories (Tables 19)

Table 19: Pre and post market feed compliance frequencies with respect to calcium content.

Location	Feed sample	Compliance frequency		Total	Test statistic	χ^2	
		out	In			≤0.05	≤0.01
Addis	Premarket	20	140	160	25.7	3.84	6.64
	post market	41	63	104			
Bishoftu	Premarket	20	60	80	6.57	3.84	6.64
	post market	41	53	94			

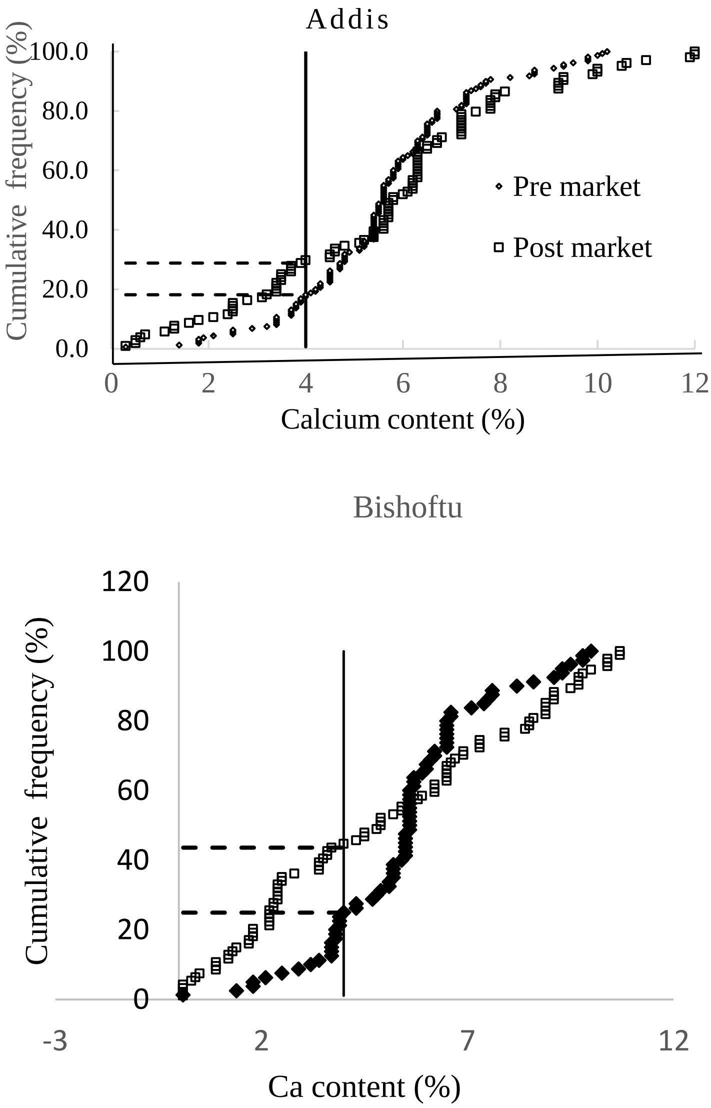


Figure 12: Cumulative Frequency Distributions of calcium content in pre and post market commercial layer feed sample. Vertical solid line represents the out-of-compliance boundary, and horizontal dotted line represents the frequency for the boundary.

The graphical representations of a grouped frequency distribution of Ca in premarket samples with continuous classes of negative and positive deviations are presented in Figures14 and 15. The largest negative deviation grouped frequency of premarket samples from Addis occurs within a range of -0.3 to < -1.7 while the second largest group scan between – 3.7 to – 1.7 and the two together represent 21.87 % of the total study sample population (Figure 13).

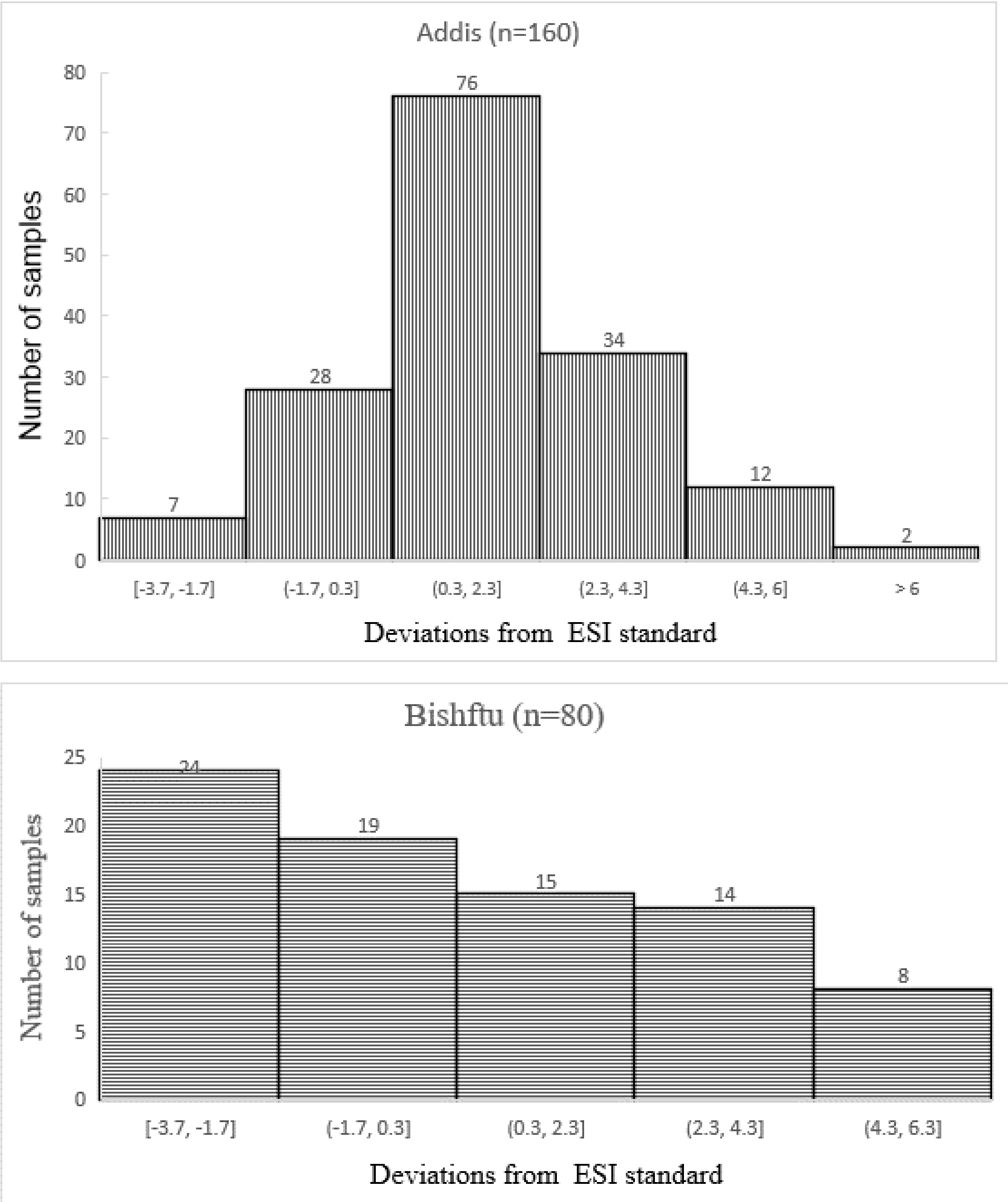


Figure 13: Frequency distribution of negative and positive deviations of calcium content (%) of premarket feed sample from ESI standard

The graphical representation of a grouped frequency distribution of Ca in pre and post market samples with continuous classes of negative and positive deviation are presented in Figures14 and 15.

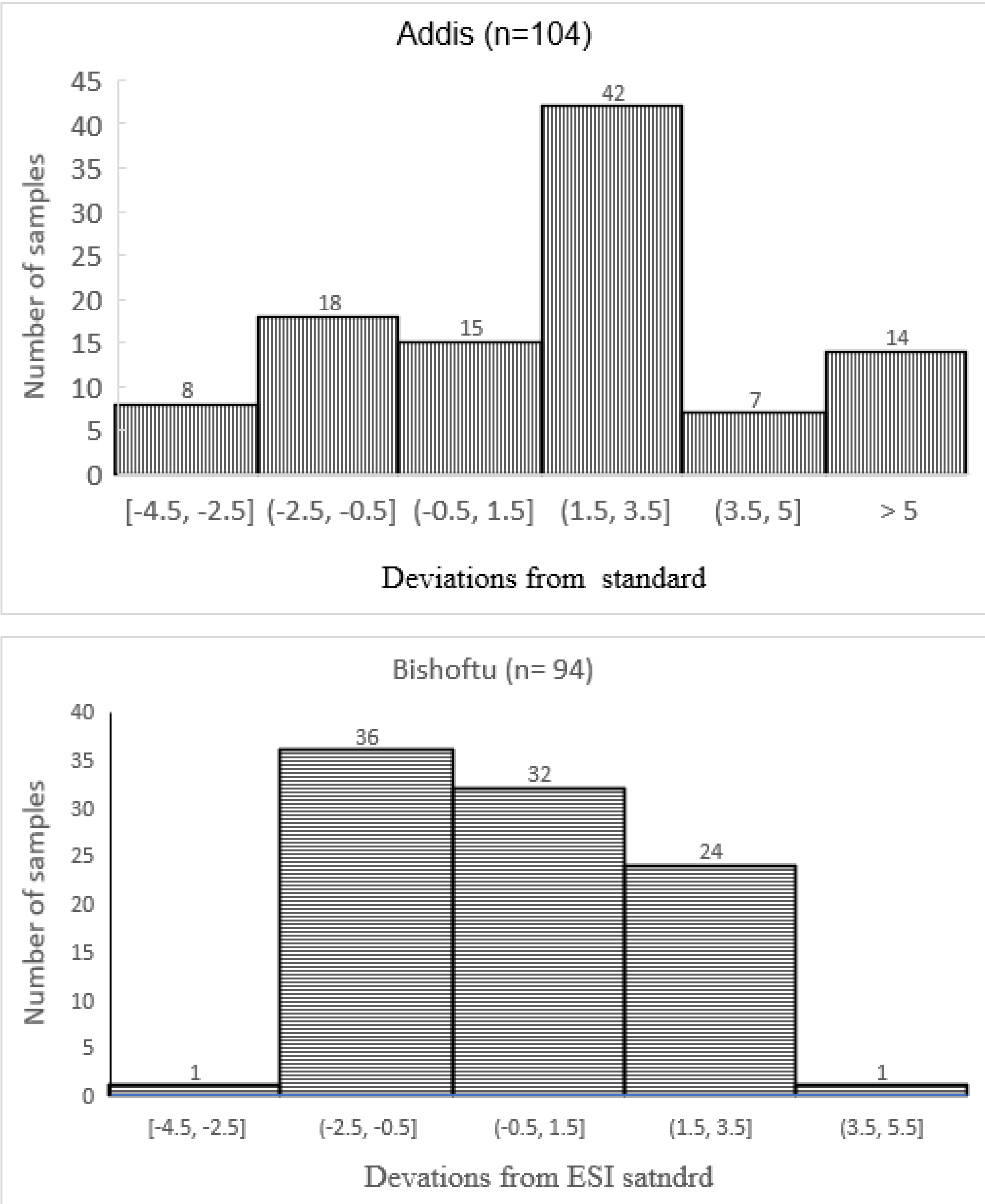


Figure 14: Frequency distribution of negative and positive deviations of calcium content (%) of Postmarket feed sample from ESI standard

The largest negative deviation grouped frequency of premarket samples from Addis occurs within a range of -1.7 to < -0.3 while the second largest group scan between -3.7 to<-1.7. And the two together represent 21.75% of the total study sample population (Figure 5).

The positive deviation groups representing 47.5, 21.25, 7.5 and 1.25 % of the total premarket sample population which fluctuate between 0.3 - 2.3, > 2.3 - 4.3, > 4.3 - 6, and > 6. The negative and positive deviation groups of premarket samples from Bishoftu followed similar distribution pattern as premarket samples from Addis Ababa. The largest negative and positive deviation groups which accounted about 18.75 % and 30 % of the total sample population varies between -3.7 to – 1.7 and 0.3 and ≥ 2.3 and the positive deviation groups representing 18.75 ,17.5 and 10 % of the total premarket sample population which fluctuate between 0.3 -2.3 , > 2.3 – 4.3 and > 4.3 – 6.3 respectively .

4.3.8. Sodium chloride content

Out of the total premarket feed samples analyzed 11.2% and 33.75% were out of compliance with respect to sodium Chloride content at Addis and Bishoftu, with the average total positive deviations of +0.54% and +0.05%, respectively (Figure 16). The corresponding values for postmarket samples were 8.0% and 19.14% with average total positive deviations of 0.02 and 0.07% (Figure 16) ESI recommend dietary NaCl requirements for layers are 0.5 % which primarily based on growth performance study literature elsewhere.

Table 20: Pre and post market feed compliance frequencies with respect to sodium chloride content.

	Feed sample	Compliance frequency		Total	Test statistic	χ^2	
		out	In			<0.05	<0.01
Addis	Premarket	18	142	160	9.37		6.64
	post market	9	94	104			
Bishoftu	Premarket	27	53	80	4.81	3.84	6.64
	post market	18	76	94			

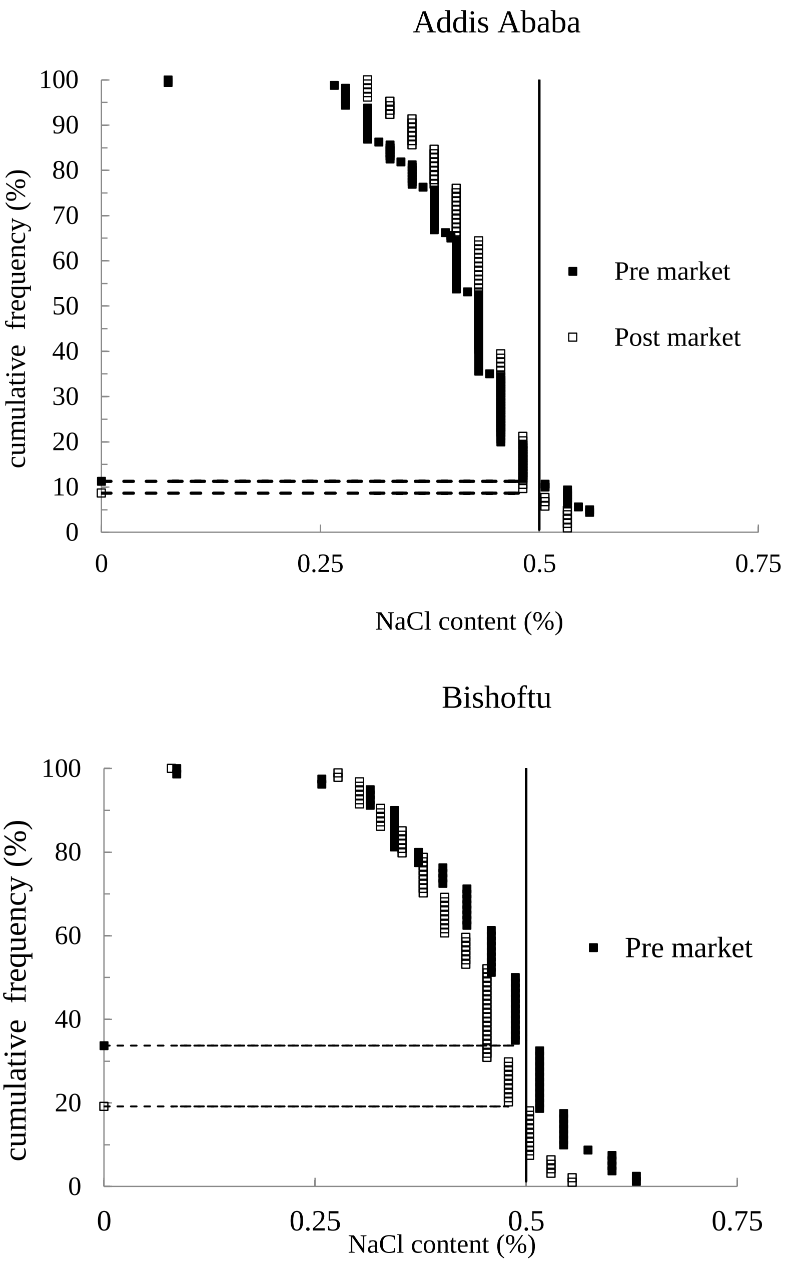


Figure 15: Cumulative Frequency Distributions of sodium chloride content in pre and post market commercial layer feed sample. Vertical solid line represents the out-of-compliance upper boundary, and horizontal dotted line represents the frequency for the boundary.

The independent test revealed that the association between out of compliance frequency and feed sample categories at both locations were statistically significant at P <u><</u>0.05. This may suggest that the observed difference in compliance frequency between pre and post market with respect to sodium chloride concentrations were attributed not only to random variations but variations in feed formulation processes, transport and storage (Table 20).

In general, the out of compliance frequencies of commercial layer feeds with respect to sodium chloride concentration was higher at Bishoftu compared to that of Addis Ababa. The independent test further showed that these differences were statistically significant at P $\leq$0.05 (Table 20).

Table 21; Out of compliance frequency of commercial layer feeds with respect to sodium chloride content in the study area.

Location	Compliance frequency		Total	Test	χ^2	
	out	In		statistic	<0.05	<0.01
Addis	27	237	264	10.45		6.64
Bishoftu	45	129	174			

The graphical representation of a grouped frequency distribution of Na Cl in pre and postmarket samples with continuous classes of negative and positive deviation are presented in Figures17 and 18. The largest negative deviation grouped frequency of premarket samples accounted 87.5 % of the total feed sample population and scans between -0.3 and <0.0. While the largest positive deviation group which represents 6.8% of the total sample raining from > 0.00 to 0.3 (Figure 17) The largest negative and positive deviation groups of premarket feed sample from Bishoftu ranges from –0.12 to <0.00 and >0.0 to 0.12 representing 32.5% and 42.5 % of the total sample population respectively.

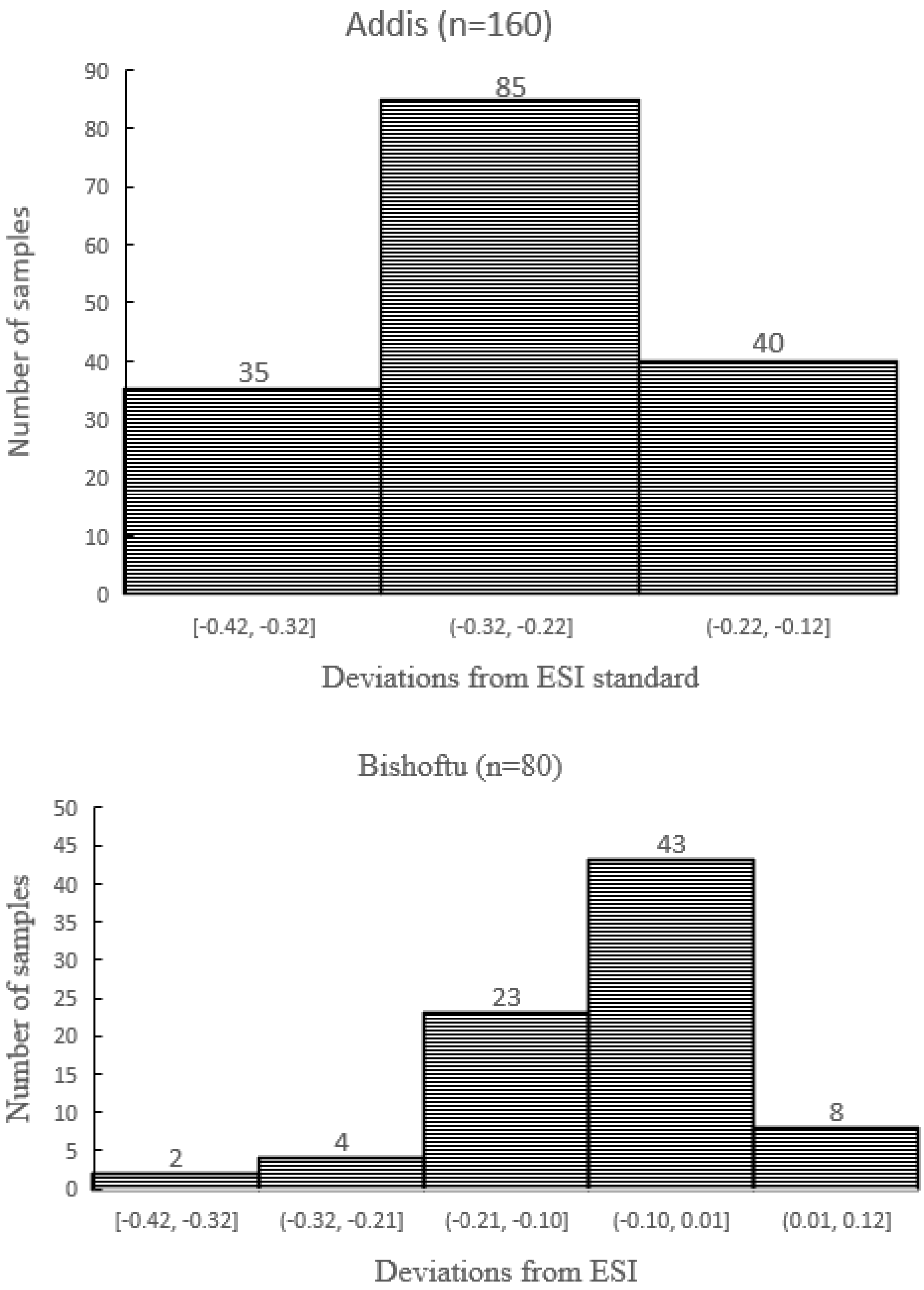
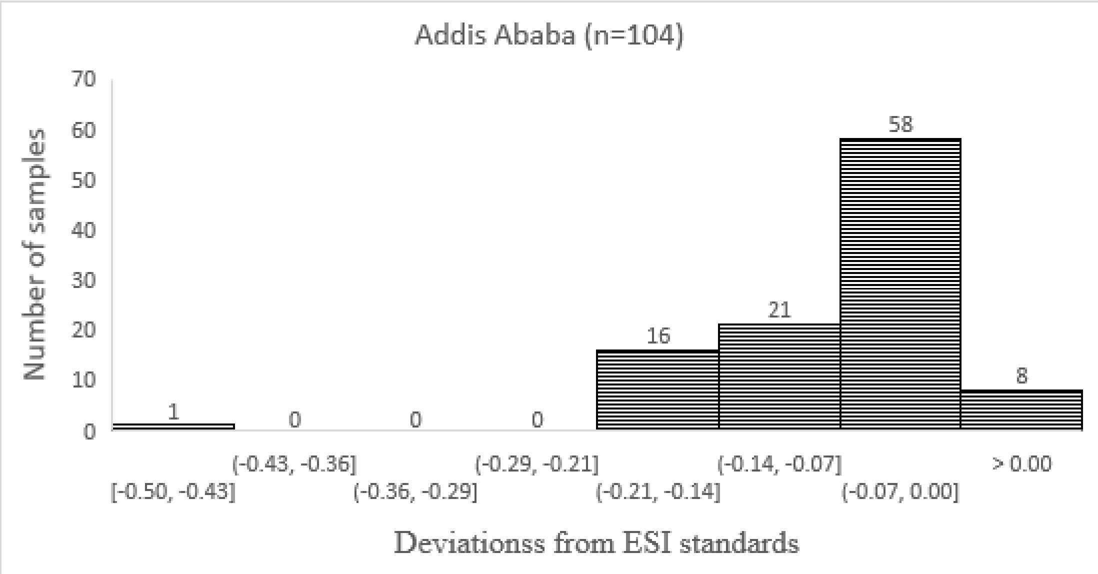


Figure 17: Frequency distribution of negative and positive deviations of sodium chloride contents (%) of premarket feed sample from ESI standard

Distribution of negative and positive deviation group of the post market feed samplepopulation at Bishoftu and Addis skewed to the left where largest negative deviation grouped frequencyhaving value greater than zero, comprises only 28.72 and 7.7

% of the total population respectively. While the negative deviationgroup at Addis represents 92.3% of these 55.8, 21.0 and 16% have values that scan between -0.07 and <0.0, >-0.07 and -0.14, and -0.14 and -0.21 respectively (Figure 18).



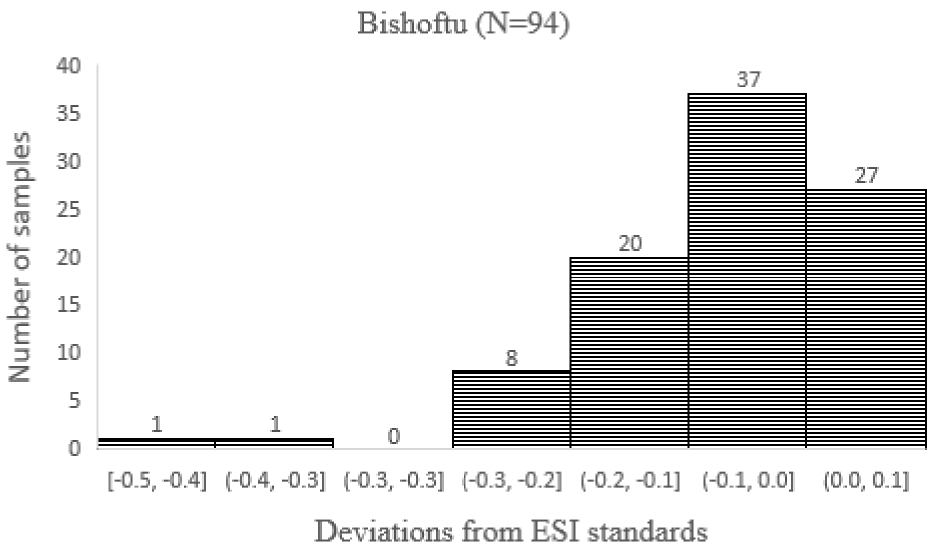


Figure 18: Frequency distribution of negative and positivedeviations of sodium Chloride content (%) of postmarket feed sample from ESI standard

The corresponding figure for samples from Bishoftu was 72 92.3% of these a group that account 40%, 21.0 and 8% scan between -0.1 and <0.0, <-0.02 and <-0.10, and -0.14 and -0.21 respectively (Figure 18).

5. DISCUSSIONS

The nutritional requirements of the poultry animals are essential for good performance, and the poultry industry relies on the supply of commercially available ready-to-use feed. There are many commercial producers of poultry feed in Ethiopia and raw materials to produce this feed are of different origins and quality, as well as final products. Also, the regulations in Ethiopia provide the ranges of required quantities of poultry feed, which are very wide, but generally in line with recommendations given by poultry hybrid breeder companies. All this in practice implies that different feed producers in Ethiopia may have different concentrations in the same poultry feed category.

Therefore, the present study aimed to investigate the concentrations of nutrients in commercial layers feed available on market differentiated into two distinct categories in and around Addis Ababa and Bishoftu town. The first category, named as post market feed sample, represent commercially manufactured feeds that has passed through the marketing channels and reached commercial layers farm. The second category qualified as premarket feed sample and represent feed quality at point of production. The established nutrient levels (Crude protein, metabolizable energy, crude fat, crude fiber, moisture content, calcium and phosphorus levels in analyzed poultry feeds were, then, also compared to Ethiopian commercial layers feed standard requirements. In addition, compound feed mix uniformity and associations between out of compliance frequency and study variables were examined.

5.1. General features of the study population

Small, medium and large-scale commercial layers farms accounted 70.02 %, 19.19 % and 12.12 % of the total post market feed sample used in this study. Large commercial farm owners are engaged poultry production while their primary business is feed production, therefore use their own feed in their farm. In the contrary, the small and medium commercial farms obtain their feed commercial feed compounders as described by Nzietchueng, (2008). Premarket feed sample were collected at point production from legally registered and licensed feed producers in the study locations.

The feed producer's mainly engaged in production of combined poultry feed products that account about 66 % of the total feed output annually. In comparison with feed production experiences elsewhere in the world share of poultry feed production is quite high in our study. These findings are comparable to the Seyoum *et al.,* (2018) who have noted the dominance of poultry feed production in 32 feed processing plants surveyed in 2016. In separates study (Negash 2020) also arrived at comparable figures in study made using 44 feed processing plants distributed four regions.

These findings further confirm the trend which characterizes East Africa, as the low usage rates of dairy feed production and utilization technologies in neighboring Kenya, Uganda and Rwanda were of 33 %, 4% and 12% (Lukuyu *et al.,* 2009). For instance, in England, cattle and calf feed products make up 39.8 % of the total production followed by poultry, pig and sheep feed at 31.3, 16.4 and 6.8 % respectively (DEFRA, 2014), whilst in 2022, poultry, pig cattle and calf represented 41, 25.11, 20 % of global feed production (Shahabandeh, 2022).

For instance, Egbunike and Ikpi (1988) found that feed mills in Nigeria were operating at 36.52% of the installed capacity, whilst a more recent study of the feed milling industry in neighboring Kenya found that feed mills operate at 44.8% of the installed capacity (Githinji *et al.,* 2009). Although this is a cause for concern as it implies production inefficiencies, it also offers an opportunity for growth in the use of animal feeds, as feed millers would be able to absorb extra demand.

This research revealed that the industry lacks statutory regulation and monitoring whilst none of the producers label the nutrient contents of their feeds. Manufacturers seem to have no legal obligation to monitor the quality of their feeds either, an issue which is brought about by the lack of enforcement of regulations. As in many African countries it was often stressed that farmer feedback is the most important form of quality control and hence feed manufactures as a result feed producers seldom analyze their compound feeds or raw materials. Within industry, chemical analyses of feed ingredient samples are impractical owing to the cost and time involved (Negash, 2020).

5.1.2 Feed formulation and marketing

Feed accounts for more than 65% of live production costs of poultry production (Wilkinson, 2018); thus, accurate feed formulation is vital to ensure poultry are receiving an optimal diet and nutrients are not in undersupply or oversupply. This research revealed that most common formulation method used, the linear programming at least-cost, does not consider the variability of ingredients. However, this is difficult when the nutrient specifications of feed ingredients are highly variable and not considered (Moss *et al.,* 2020). To compensate for any discrepancies between the book values and true nutrient values of the feed, safety margins are applied to formulations in hope that the minimum nutrient requirements of poultry are being met.

Considering the fact that that feed can constitute up to 80% of total costs, it becomes clear that L-C (lest cost) formulation can provide manufacturers with an opportunity to minimize the cost of inputs used, whilst farmers can be guaranteed efficient feed at a minimum diet cost (Pesti and Miller, 1993 : Kellems and Church, 2010).

This is important for commercial feed companies; if nutrients fall below the minimum nutrient contents reported, it may render them legally liable, and in a fully integrated system, bird performance may suffer, causing substantial economic losses to the business (Peña *et al.,* 2017). Safety margins decided by nutritionists are further complicated by the difference between analyses of samples and the actual nutrient content of those ingredients in the feed being manufactured at a given time as multiple batches of a feed ingredient may be delivered to the mill and stored within one silo.

However, increasing safety margins raises diet cost, and the size of the safety margin required to avoid nutrient levels falling below the intended level is ambiguous. Therefore, improving the certainty of the specifications used for dietary ingredients and increasing awareness of the variability that may be expected would allow the choice of appropriate safety margins. Improving the estimation of safety margins should also improve the balance of reduced feed costs and economical meat and egg production.

5.2. Feed mix uniformity

Mixing is one of the most critical processes in feed manufacturing. The principal objective in feed mixing operation is to produce rations in which nutrients and medication are evenly distributed (Herrman and Behnke, 1994). Mixing efficiency, another term for feed homogeneity, determines how thoroughly a batch of feed is mixed (Goodband, 1990). Conversely, the concept of feed homogeneity is significant that if feed ingredients, particularly low-inclusion ingredients are not properly incorporated, animal performance is affected negatively (Medallaine *et al.,* 2018). The ultimate goal of feed uniformity analysis is to obtain an analytical value from a sample that reflects the actual value of a 'population'.

Fan *et al*. (1970) critically reviewed several uniformity measures for reporting experimental results and mixing theory. The ASABE standard regarding solids mixing (S303.4; ASABE Standards, 2011a) calls for at least 10 samples taken and uses CV as the primary uniformity measure. ASABE standard S380 (ASABE Standards, 2011b), related to portable farm batch mixers, calls for 15 equally spaced samples with either a salt (at 0.5%) or whole kernel corn (at 5.0%) tracer; CV is also used as the uniformity measure. Rippel *et al*. (1998), used 10 and 5 samples per batch for analysis.

Uniform mixing is essential to produce products for animal feed in order to achieve technical parameters in accordance with established marketing standards (nutritional levels, stability, and safety of its constituents included in the recommended proportion and shelf life). Due to the increased use of low inclusion ingredients, efficiency in the mixing process becomes even more important. The inclusion of enzymes in very low concentration, such as phytase, the need for greater uniformity in the mixture of diets and concentrates increases, in order to obtain an adequate nutritional balance for calcium and phosphorus in animal metabolism (Johnston and Southern, 2000). Piglets in the nursery phase showed worse performance only when they received rations with CV in the mixture above 28.4% (Traylor *et al.,* 1994).

According to Rocha *et al.* (2015) as Mn, Cu, Zn and Cl are intrinsic in the feed ingredients, so the use of Manganese Sulphate ($MnSO_4$), Copper Chloride ($CuCl_2$), Zinc Sulphate ($ZnSO_4$), and Sodium Chloride (NaCl) may cause errors in the results interpretation, and some of these errors may be caused by the granulometry of the indicator used (Wilcox and Unruh, 1986). A check of the particle size distribution within the mix can also be a tool in evaluating mix uniformity (Rippel *et al.,* 1998; Jordan, 2001; Vegricht *et al.,* 2007; Bierman, 2008; Dahlke and Strobehn, 2009).

The different mixers used in the present study indicate that there is potentially an effect on the quality of the mixture, as observed with the results of the analysis of the minerals. Each kind of mixer has a different ideal mixing time. For example, horizontal mixers generally tend to have a shorter ideal mixing time than vertical mixers. With the wear and tear of the mixer tapes and drills, mixing times need to be increased to meet proper mixing standards. Diets containing low-density ingredients may also require extra time to achieve the desired mixing uniformity (McCoy, 1994).

Mixing uniformity, as estimated by coefficient of variation (CV) of a specific nutrient or ingredient (usually chlorine from salt), is used to measure degree of dispersion of ingredients throughout a batch of feed. Herrman (1994) expressed the results of mixing tests in four categories: excellent, good, reasonable, and poor according to the obtained CVs. Mixtures with a CV lesser than 10% were classified as excellent, mixtures with a CV of 10 to 15% were considered good, CV of 15 to 20% was considered reasonable, and mixtures with a CV greater than 20% were classified as poor. With this in mind mixing uniformity as estimated by CV a specific nutrients in similar batches produced by twelve feed producers in the study locations are discussed below.

5.2. 1. Moisture content

Mixing uniformity, as estimated by coefficient of variation (CV) of a specific nutrient or ingredient or marker (usually chlorine from salt), is used to measure degree of dispersion of ingredients throughout a similar batch of feed (Herrman and Behnke, 1994).In this study, mixing uniformity estimated by coefficient of variation (CV) in moisture content between similar production batches scans between 8.1 to 14.1% at Addis and 9.4 to 23% Bishoftu, with a mean of 11% and 14.3% respectively. It is often recommended that a coefficient of variation less than 10 percent indicates appropriate mixing, but recent data suggest that up to 20 percent CV may be adequate for most practical diets. In this context, with exception of feed producer No. 10 all feed processors have had archived excellent to a good mix uniformity which attributed to uniform moisture content of the raw materials used to formulate the feeds.

Corn and soybean meal (SBM) which a have an average moisture content of 10 to 12% the most used feed ingredients in feed industry in the study locations. However, the process of grinding and mixing results in moisture losses between 0.5 and 1.5 % in the final feed compared the initial moisture contents of the feed ingredients (Moritz *et al.,* 2002). Furthermore, typical variation of laboratory results, compared to the actual moisture content of the feed, is roughly 1.5 percentage points either way (NRI, 1995), moisture ranges fall well within safe storage boundaries of finished product (Saiful, *et al.,* 2015).

Moisture variability directly impacts production cost and feed quality and is dependent on ingredient type, source, age and handling. The moisture contents among similar batches mixed in Addis Ababa and Bishoftu ranges between 7.9 and 11.1 and 8.1 and 14.4 and with a mean for 8.66% and 7.95% respectively. Our results in agreement with previous studies who reported moisture content variation of 8.58 to 12.16% among 17 commercial layer feed samples collected from Ethiopia (Nagesh, 2020). High moisture content of feed with high temperatures and poor aeration during storage predisposes feeds to mycotoxins and spoilage (Saiful, *et al.,* 2015), which can pose health problems to birds when fed. Though none of sampled feed processing plants produce pelletized feed, too little moisture in feed has a negative impact on pellet durability, increasing the level of fines, process loss, and energy consumption while decreasing press yield (Moritz *et al.,* 2002).

5.2.2. Metabolizable energy content

Our research indicates metabolizable energy contents in similar batches produced in Addis Ababa and Bishoftu ranges between 2322 and 3459 and 2443.45 and 3197 and with a mean of 2638 and 2691 respectively (Table 3). In previous studies (Nagesh, 2020) reported wider variation in ME content (1092-2890 kcal/kg) for feed sample collected across the country. The deviation from our results was expected as his observation includes isolated feed producers located in remote areas where quality could be compromised as there is no freedom of choice for farmers to select suppliers based on feed quality merits.

Low coefficient of variation (CV) in metabolizable energy content between similar production batches suggest that feed processing plants at both locations displayed excellent feed mixing efficiencies and hence the source ME constituents homogeneously dispersed throughout mixed feed.ME serves as an accurate indicator of feed quality, can be reliably used for feed quality control and is crucial for diet formulation (Li *et al.,* 2014 and Zhang *et al.,* 2016). Simply because, ME is directly proportional to digestibility of nutrients and hence directly affects their availability and absorption (Li *et al.*, 2014 and Zhang *et al.*, 2016).

Energy is not a nutrient, but a property of energy-yielding nutrients such as carbohydrates, lipids, and protein. Thus the variations in ME content encounter among similar batches in this study was in part can be attributed to variation the raw materials used in feed formulation. For example, the energy content in barley and wheat, the feed ingredients commonly used in poultry feed, can vary by 15–18% (Ofori *et al*., 2019), with similar results for wheat (Regmi *et al.*, 2008), soybeans (Baker and Stein 2009 and Li *et al.,* 2014) Energy is recognized as the most expensive component of poultry diets and corn is the main source of dietary energy in many production systems in the world. Metabolizable energy is widely used as the energy currency to formulate poultry diets and the use of accurate metabolizable energy values of corn, as well as other feed ingredients, is crucial for economic feed formulation and results of chicken production (Li *et al.,* 2014 and Zhang *et al.,* 2016).

Our finding suggest that post market feed samples had higher out of compliance frequency than premarket feed samples at both locations. However, the association between out of compliance frequency and pre and post market feed samples was significant only at Addis Ababa (Tables 12). Thus the difference in ME between the pre and post market feed sample at Bishoftu is merely attributed to random variations. In addition to random variations, the difference between two samples in Addis may be attributed to the variations induced due to segregation at loading, unloading and transport the feed from point production to point of use.

5.2.3. Fat content

Crude fat (CF) content in commercial feed oscillates between 0.07% - 9.67% and 2.8% - 16%. With a mean of 4.75% and 7.07% at Addis Ababa and Bishoftu respectively. Our finding was in in agreement with previous research conducted by Negash, (2020) who came across similar magnitude in fat content variations among 17 commercial layers feed examined. Our finding showed that mix uniformity, as estimated by coefficient of variation (CV) in fat content, suggest that 25% to 50 % of feed producers had CV's between poor mix uniformity primarily because rations are not generally formulated for crude fat. Fat content is a function of oilseed and bypass fat content, therefore, variability in fat content may represent variability in premix nutrient content or degree of mixing.

5.2.4. Crude fiber

Like moisture content values, crude fiber values were normally distributed with non-significant skewness. This indicates that crude fiber values among similar batches have low frequency of outliers of which in turn indicates the existence of comparable degree dispersion of ingredients throughout similar batches. Crude fiber is used as an index of an ingredient's feeding value since materials high in fiber are typically low in nutritional value.

In present study crude fiber values of similar batches produced in Addis Ababa and Bishoftu ranges between 2.4 and 9.67 and 2.8 and 9.67 with a mean of 5.85% and 6.40% respectively. The crude fiber content values reported in this study were comparable with Martin (2005), who reported crude fiber content 2.5 % in maize – soya-based mixture to 6.0 -7.0 % in mixture based on barely, sunflower extract meal and cereal by product such as bran in poultry feed. Nagesh (2020) encountered a wider crude fiber content variations that range from 1.76-23.51% in his layer feed quality assessment study.

Variations in CF across feed categories and the study locations were attributed to the fact that poultry diets are composed of a wide range of plant-based products and grains (cereal), implying significant levels of the cell wall or cellulose content. Thus, chickens need to be able to contend with diets with varied levels of CF. The fiber sources are also by-products oil crops, and their variability, oscillate between 2.63- 9.68, 19.65 34.25, 9.35-15.27 and 6.07- 27.74%, with a mean value of 6.66%, 27.56%, 10.99% and 13.58% in soybean, sunflower seed, and rapeseed, respectively, is therefore can influence the analyzed content of CF in the final feed unless considered at time of feed formulation. Because of this variation and lack of a timely nutrient analysis of ingredients, formulating rations to meet the layers' maintenance and production dietary needs becomes a challenge.

5.2.5. Crude protein content

The result shows that the crude protein values of similar batches mixed in Addis Ababa and Bishoftu ranges between 9.7 and 24.11 and 11.39 and 26.50 and with a mean of 16.70 % and 17.46% respectively (Table 5). The values of CP found in our research was comparable with findings of (Negash, 2020). Our research found out except, plant No 1, at Addis, all feed producers produced feed mixture having reasonably adequate mix uniformity when estimated from CVs of PC content between similar production batches. Variability in crude protein concentration of total mixed rations delivered was reported by James and Cox (2008). With means near 17.2%, the standard deviations were 1.4% to 2.1% and the maximum to minimum range was as high as 12%. They noted significant differences between feed producers in loading accuracy, reflective of operator ability and diligence, and equipment differences.

The variation observed in CP content among similar production batches in our study in part can be attributed to variations in raw materials used in the formulation. Chitra, (2021) reported variability in crude protein concentration of soybean meal, sunflower oil cake, rapeseed oil cake and groundnut cake as high as 33.07- 52.14%, 22.14 -34.90%, 30.08-38.64%, 30.15 47.05% and with a mean value of 45.18%, 26.77%, 36.40 %, 40.81 respectively. In fact, it is also known that soil nitrogen, genetic potential and harvesting conditions can affect the protein content of soybeans, sunflower seeds and rapeseed (Fontaine *et al.*, 2001; Chander *et al*., 2008; Salvagiotti *et al.*, 2008).

In surveyed feed processing plants feeds are formulated by linear programing software based on the expected energy means of ingredients (corn and SBM), which can be obtained from ingredient composition tables (Negash, 2020). Formulating such feeds based on the expected mean values, but not the actual means, might reduce the performance of the birds, as the chance of achieving the specific limit in the feed is 50% (half of the samples will be below average). It has been reported that an appropriate method of predicting ingredient composition and nutritional value before use compared to the reference (using mean values from published tables) can increase the accuracy of diet formulation by 2% to 10% (Fab, 2018).

5.2. 6. Sodium chloride content

Sodium (Na) and chlorine (Cl) are essential minerals for poultry and play a critical role in regulating water-electrolyte metabolism, acid-base balance and maintaining osmotic pressure (OSM) (Bohn *et al.,* 2017). Sodium and Cl are low-cost nutrients with great influence on feed conversion ratio (FCR), eggshell quality, and excreta moisture (Murakami *et al.,* 2003). To provide the requirements of these minerals in poultry diets, NaCl is commonly used, which contains approximately 40% Na and 60% Cl. In most of the laying hen requirement tables, only Na is listed. Levels of NaCl used in commercial diets for laying hens vary from 0.15 to 0.50% (Bohn *et al.,* 2017). Variations are associated with feedstuffs used but must provide the requirements of 0.15% of Na and 0.13% of Cl that have been recommended for laying hens (Murakam *et al.,* 2003). However, recently a new requirement of 0.225% Na and 0.20% Cl for Leghorn layers has been proposed (Murakam *et al.,* 2003).

The variations in sodium chloride concentration among similar vary considerably among feed producers and study locations. High dietary intakes of Na or K will cause large osmotic changes within the intestinal lumen of birds, increasing the water content of the excreta. High-moisture excreta provide more favourable environment for fly larvae development. The proportion of Na and Cl, together with are important to maintain acid-base balance. The equilibrium among these elements is necessary to obtain good growth, adequate bone development, good eggshell quality, and better use of amino acids (Bohn *et al.,* 2017). Nevertheless, literature have not recorded that feeds that are high in ash-content are beneficial to poultry birds that are being raised for meat and egg (Man *et al.,* 2021).

5.2.7. Calcium content

Next to AP, Ca exhibited highest variability in similar batches produced in the study area. It has been reported that limestone in feed can contribute more than 50% of total dietary Ca consumed by broilers (Kim *et al.,* 2019). For all-vegetable based broiler diets containing no meat or bone meal, this may increase to 70%. In the case of layers, limestone can contribute more than 95% of Ca intake per hen per day. The remaining Ca comes from cereals, legumes and their by-products, bone meal, inorganic phosphates, mono-calcium phosphate or di-calcium phosphate, premixes and feed additives.

Interestingly, the maximum Ca content in pure $CaCO_3$ is 40.04%, based on chemical composition and molecular weight of Ca, C and O, Walk (2016) analyzed Ca content in finished feed were, on average, 22% higher than the calculated content, and that calculated dietary Ca content could vary considerably, depending on the reference (table value) used for ingredient Ca concentration. This implied that relying on calculated values only may fail to provide an accurate estimate of dietary Ca content or its ratio to P.

Limestone variability can influence the analyzed content of Ca in the final feed, although these factors are generally not considered in feed composition tables. For example, the Dutch feed tables specify that the total Ca content of limestone is 38%, whereas in a survey of 192 fine limestone samples, Plumsted *et al.,* (2020) reported that the analyzed Ca content ranged from 30.4 to 40.0%. More recent literature has indicated that the Ca content of limestone can be as high as 42% (Anwar *et al.,* 2016; David *et al.,* 2019; 2020).

It has been reported that limestone in feed can contribute more than 50% of total dietary Ca consumed by broilers (Kim *et al.,* 2019). For all-vegetable based broiler diets containing no meat or bone meal, this may increase to 70%. In the case of layers, limestone can contribute more than 95% of Ca intake per hen per day. The remaining Ca comes from cereals, legumes and their by-products, bone meal, inorganic phosphates, mono-calcium phosphate or di-calcium phosphate, premixes and feed additives.

Most of the setbacks in feed mixing are due to variations among feed ingredients in particle shape, size and density. Feed ingredients with uniform densities and sizes tend to mix quickly and simply (e.g. cracked or ground grains have densities the same as that of the seed meals) (Trill *et al.,* 2017). Hence, there's sometimes little or no issue in getting a uniform mix of those feed ingredients. Densities of minerals on the other hand are greater than that of oilseed meals and grains. Variation in physical form and density of individual feed ingredients makes the preparation of uniform feed mixtures tough (Trill *et al.,* 2017). This in part explains the high variability among batches in ash, Ca and AP content in our study.

Finally, the physical properties of raw materials such as particle size, density and hygroscopicity can also influence the mixing efficiency (Herrman and Behnke, 1994). The more uniform the particle sizes between the ingredients, the shorter the mixing time and the lower the CV. Even after mixing, the batch is more resistant to segregation (Herrman and Behnke 1994). And poultry feed consists of ingredients of different particle sizes, as they prefer coarsely ground grains for a more developed gizzard (Amerah *et al.,* 2007).

Evenly mixed feed batches are affected by feeds with different bulk densities and this could explain why they had the lowest percentage of good mixing efficiency in our study, even though the laying hen feed had a limestone inclusion level of 4.5%. In addition, a hygroscopic material such as salt and choline chloride can absorb moisture, causing clumping of the mixed feed, resulting in poor mixing efficiency (Behnke, 2006). Recognizing these factors and regularly checking the quality of the mix can help maintain the acceptable mix CV to provide nutritionally consistent laying hen feed.

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5.2.8. Available phosphorous

Negash (2020) mentioned variability of quality of feeds between batches of production due to uneven supply of quality raw material from the primary producers as the major problem of commercially manufactured feeds. In Ethiopia. While applying an uncertainty analysis to mixed livestock rations, Buckmaster and Muller (1994) concluded that forage nutrient concentrations are likely to contribute most to the inter-batch variation in TMR nutrient concentrations.Total phosphorus content oscillates between 0.22% - 0.63% and in corn and 0.36%–0.84%, with soybeans (Batal *et al.*,2010). These may in part explain the high CV in Available P concentrations observed in similar production batches in the study area. Because of this variation and lack of a timely nutrient analysis of ingredients, formulating rations to meet the layers' maintenance and production dietary needs becomes a challenge.

Mixing ingredients is an essential process in feed manufacturing, as these ingredients must be combined effectively to be supplied as a complete feed to animals (McCoy, Behnke, Hancock and Mcellhiney, 1994). The mixing process should create a random distribution of ingredients in all mass portions to provide the animals with an adequate daily nutrient intake (Çiftci and Ercan, 2003). With the increased use of low-inclusion ingredients, such as industrial amino acids and other additives, efficient blending has become even more critical for an adequate nutrient supply (Groesbeck *et al.*, 2007)

5.2.9. Mix uniformity among feed processing plants

Each feed producers is unique due to the formulation of the diet, the particle size of the raw ingredients, wear and tear on the mixer parts, mixer cleanliness, individual sampling, mixing time, and the marker chosen for mixer uniformity (Clark *et al.*, 2007).The selection of ingredients with similar particle sizes should improve the efficiency and result of mixing and a more uniform mixture of the final product (Clark *et al.*, 2007; Groesbeck *et al.*, 2007). Thus, minimizing particle sizes is not only important for optimizing growth performance of pigs but also for enhancing feed manufacturing processes (Amornthewaphat *et al.*, 1998).

Research elsewhere has shown that the total nutritional variability of a finished feed can be explained in three ways: by the nutritional composition of the ingredients (Fairbairn *et al*. 1999), by the formulation characteristics, and by the feed manufacturing process (Groesbeck *et al.*, 2007; Bunzel, 2008). The feed manufacturing process consists of several operations including storage and selection of raw materials, weighing of raw materials, grinding of raw materials and mixing of dry ingredients, filling of feeds, storage and shipping.

In our study, there is convincing evidence to assume significant differences among the feed processing plants in loading accuracy, reflective of operator ability and diligence and equipment differences that are factored in controlling variations among similar batches (Buckmaster, 2009). From short conversation made during sample collection, loading accuracy and mixing equipment in the feed manufacturing section is seldom calibrated regularly inmost feed compounders but the effect somehow was high in older units such as feed processing plant 1and 7 which has failed to produce feed with acceptable mix uniformity in 5 out of 8 proximate compositions.

Likewise, with a few exceptions technical staffs in the feed manufacturing factories do not get regular practical training that help them up-grade their knowledge and skill and their performance is not satisfactory in producing quality feeds. Some feed manufacturers do not properly label their products and the buyer cannot get product information for making quality-based buying decisions. The quality status of feed they bought cannot be known until they feed their animals and see animal production responses in the form of egg and milk productions. All these factors may accounted for fluctuations in concentration of analytes in focus between similar batches observed in this study.

On the other hand, regardless of the peculiarities feed producing plants, similar production batches in the study area exhibited excellent mix uniformity in terms of ME and moisture content, followed by the second set of nutrients such as CP, CF and fat content. In the contrary, all batches produced in the study area were extremely variable in terms of Ca, Available P, and sodium content. Most of the setbacks in feed mixing are due to variations among feed ingredients in particle shape, size and density. Feed ingredients with uniform densities and sizes tend to mix quickly and simply (e.g. cracked or ground grains have densities the same as that of the seed meals) (Trill *et al.,* 2017).

The feed manufacturing process are made up of several unit operations including raw material storage and selection, raw material weighing, raw material grinding and mixing of dry ingredients, feed bagging, storage and dispatch. In our study, there is convincing evidence to assume significant differences between feed processing plants in loading accuracy, reflective of operator ability and diligence and equipment differences that are factored in controlling variations among similar batches (Buckmaster, 2009).

Focusing on some feed ingredients commonly used in poultry nutrition, the energy content in barley and wheat can vary by 15% to 18% (Ofori *et al.,* 2019), with similar results for wheat (Regmi *et al.,* 2008) and soybeans (Baker and Stein). 2009) and corn (Li *et al.,* 2014) Energy is not a nutrient, but a property of energy-yielding nutrients such as carbohydrates, lipids, and protein. Total phosphorus content oscillates 0.22% - 0.63% and in corn and 0.36%–0.84%, with soybeans (Batal *et al.,* 2010). Focusing on some feed ingredients commonly used in poultry nutrition, the energy content in barley and wheat can vary by 15% to 18% (Ofori *et al.,* 2019), with similar results for wheat (Regmi *et al.,* 2008) and soybeans (Baker and Stein). 2009) and corn (Li *et al.,* 2014)

Variability in crude protein concentration of soybean meal, sunflower oil cake, rapeseed oil cake and groundnut cake fluctuate between 33.07- 52.14%, 22.14 -34.90%, 30.08-38.64%, 30.15 47.05% and with a mean value of 45.18%, 26.77%, 36.40 %, 40.81 respectively (Chitra, 2021). The fiber sources are also by-products oil crops, and their variability, oscillate between 2.63- 9.68, 19.65 34.25, 9.35-15.27 and 6.07- 27.74%, with a mean value of 6.66%, 27.56%, 10.99% and 13.58% in the same order as above, respectively, is therefore can influence the analyzed content of CF in the final feed unless considered at time of feed formulation.

Because of this variation and lack of a timely nutrient analysis of ingredients, formulating rations to meet the layers' maintenance and production dietary needs becomes a challenge. Moreover, in our study fat and fiber had higher coefficients of variation (10–30%) next to Na, Available P and Ca probably because rations are not generally formulated for CF. Fat content is a function of oilseed and bypass fat content, therefore, variability in fat content may represent variability in premix nutrient content or degree of mixing.

In addition, variation in physical form and density of individual feed ingredients makes the preparation of uniform feed mixtures tough (Trill *et al.,* 2017). This in part explains the high variations among batches in Ca and AP content in countered in our study. It has been reported that limestone in feed can contribute more than 50% of total dietary Ca consumed by broilers (Kim *et al.,* 2019). For all-vegetable based broiler diets containing no meat or bone meal, this may increase to 70%. In the case of layers, limestone can contribute more than 95% of Ca intake per hen per day. The remaining Ca comes from cereals, legumes and their by-products, bone meal, inorganic phosphates, mono-calcium phosphate or di-calcium phosphate, premixes and feed additives.

Interestingly, the maximum Ca content in pure $CaCO_3$ is 40.04%, based on chemical composition and molecular weight of Calcium, carbon and oxygen. Walk (2016) analyzed Ca content in finished feed were, on average, 22% higher than the calculated content, and that calculated dietary Ca content could vary considerably, depending on the reference (table value) used for ingredient Ca concentration. This implied that relying on calculated values only may fail to provide an accurate estimate of dietary Ca content or its ratio to P.

Limestone variability can influence the analyzed content of Ca in the final feed, although these factors are generally not considered in feed composition tables. For example, the Dutch feed tables specify that the total Ca content of limestone is 38%, whereas in a survey of 192 fine limestone samples, Plumstead *et al.* (2020) reported that the analyzed Ca content ranged from 30.4 to 40.0%. More recent literature has indicated that the Ca content of limestone can be as high as 42% (Anwar *et al.,* 2016; David *et al.,* 2019; 2020).

In studied feed processing plants, feeds are formulated by linear programming software based on the expected energy values of the ingredients (corn and SBM), which can be retrieved from ingredient composition tables (Negash, 2020). Formulating such feeds based on the expected mean values but not the actual mean values could affect the performance of the birds as there is a 50% chance of reaching the specific limit in the feed (half of the samples are below the average) . It has been reported that an appropriate method of predicting ingredient composition and nutritional value before use compared to the reference (using mean values from published tables) can increase the accuracy of the diet formulation between 2% and 10% (Fab , 2018).

Similarly, Negash (2020) mentioned variability of quality of feeds between batches of production due to uneven supply of quality raw material from the primary producers as the major problem of commercially manufactured feeds. Buckmaster and Muller (1994) applied an uncertainty analysis to mixed livestock rations and concluded that forage nutrient concentrations are likely to contribute most to the inter-batch variation in TMR nutrient concentrations. Most of the setbacks in feed mixing are due to variations among feed ingredients in particle shape, size and density.

Feed ingredients with uniform densities and sizes tend to mix quickly and simply (e.g. cracked or ground grains have densities the same as that of the seed meals) (Trill *et al.,* 2017) Hence, there's sometimes little or no issue in getting a uniform mix of those feed ingredients. Densities of minerals on the other hand are greater than that of oilseed meals and grains. Variation in physical form and density of individual feed ingredients makes the preparation of uniform feed mixtures tough (Trill *et al.,* 2017). This in part explains the high variability among batches in ash, Ca and AP content in our study.

Finally, the physical properties of raw materials such as particle size, density and hygroscopicity can also influence the mixing efficiency (Herrman and Behnke, 1994). If particle sizes are more consistent between ingredients, the shorter the mixing time and (doi.org) the lower the CV; Even after mixing, the batch is more resistant to segregation (Herrman and Behnke 1994). And poultry feed consists of ingredients of different particle sizes, as they prefer coarsely ground grains for a more developed gizzard (Amerah *et al.,* 2007).

In addition, a hygroscopic material such as salt and choline chloride can absorb moisture, causing clumping of the compound feed and poor mixing.This may in part explain the high variability Na content encountered between similar production batches in our study, though the actual values seldom exceeds the upper limit set by ESI for laying hens. Recognition of these factors and regularly checking the quality of mix can help maintain the acceptable mix CV to deliver nutritionally uniform layers' feed.

5.3. Compliance of nutrient concentration in commercial layers feed

The quality of feed can strongly influence the production time and the quantity of eggs produced. A longer production time means more costs for housing and labour for the farmer. The quality of feed also has a strong impact on the feed conversion ratio (FCR). Feed with a high FCR means that the farmer needs more feed to produce 1 kg of meat or eggs than feed with a lower FCR. The Ethiopian Standard Council approved new standards for poultry feeds in 2019. The renewed standards pay more attention to nutrient balances in the feed, quality assurance, the right methods of testing and ingredient selection. In Ethiopia, feed quality is regulated / monitored by Veterinary Drug and Animal Feed Administration and Control Authority. The new standards include a list of which testing methods should be used. All these methods in accordance with the international Organisation for Standardisation guidelines. Further guidelines for nutrient requirements for both layers and broilers are given in different life stages. These guidelines can help feed manufacturers produce better quality feeds with better digestibility. These feeds can increase yield while lowering production costs.

5.3.1. Crude protein contents

CP in the feed provides essential amino acids. Increased crude protein in the diet of birds leads to improvement in egg size and weight (Kuashalendra; 2016). The results of proximate analysis showed that out of the total premarket feed samples, collected in Addis and Bishoftu 39.37% and 43.75% were out of compliance with respect to CP content, the average total CP deficiency was 1.7% and 1.3%, respectively (Figure 3). In contrasts the out of compliance frequency of post market feed sample was 50%, and 57.5% respectively with average total CP deficiency of 1.2% and 0.68% in the same order as above (Figure 3). The minimum requirement of ESI, (2019) for layer was cited as 16.5%.

Several researchers have reported on crude protein in poultry feeds Bukar and Saeed (2014), Okafor and Ezebuo (2014) and Vakili *et al,.(*2015) Dewa and Tikau (2019), Hasan *et al.* (2022), Ofori *et al*. (2019), and Ojabo and Wunduga (2020), observed in their studies comparable crude proteins as this study in the range of 16.44 ± 1.29 - 24.26 ± 04.16 %, ; 16.15 - 20.97 %, 10.66 ± 0.76 - 20.16 ± 1.75 g/100g, 13.89 ± 0.46 - 14.04 ± 0.03 %, 16.15 - 20.97 %,19.46 - 24.31 %, 20 - 22 %, and 19.46 - 24.31 %, 20 - 22 % respectively. While Ogbebor *et al.,* (2021) recorded higher crude protein of 36.50 ± 0.92% - 70.92 ± 0.51 %

Negash (2018) reported out of complain frequency of 29 % in CP content in 17 premarket commercial layer feed samples collected across four regions in Ethiopia. However, the same author in same study has reported none compliance frequencies as high as 50 % for compound of feeds other livestock species. The high out of compliance frequencies reported in this study compared to the previous studies in part attributed to differences in sample size and sampling methodology and possibly random variability associated with feed analysis.

In this study the main sources of variability associated with the CP content may be attributed to feed formulation process and the random variability associated with proximate analysis in the laboratories. In this study, the feed samples were analyzed using NIRS, the random variability connected to the analysis in the labs is known to be near negligible. The near-infrared spectrophotometry (NIRS) analysis is used world-wide as a rapid tool, providing stable and repeatable predictions (Fontaine *et al.*,2002). In practice, the NIRS appears as a quick and efficient tool to help the reformulating process at a feed mill level (Fernández-Ahumada *et al.,* 2008). However, feeds formulated based on the expected nutrient averages, ignoring the inherent nutrient variability in feedstuffs may only meet the nutrient requirements of the birds 50 per cent of the time, with high variation in meeting the minimum requirements.

CP is the main ingredient and cost component of the feed (Kuashalendra *et al.,* 2016; Elmasoeur and Russ, 2013). Elmasoeur and Russ (2013) reported that due to the high cost of protein materials for formulating feeds, some feed manufacturers resort to cheaper protein materials for formulation, which may be due to the low protein content of some feeds. However, the most likely explanation for the nutrient shortages in our study is feed formulation techniques which overlooked the inherent nutrient variability of feed ingredients. Inadequate feed analytical services as well as lack of statutory control over feed quality have further provoked the situation.

On the other hand, in this study about 60 % commercial feeds produced or distributed to the end users had higher CP concentrations than CP requirement of laying hens declared by ESI. Theoretically a small or moderate CP over estimation would increase the production cost without necessarily affecting the performance, in the contrary underestimate CP will also reduce performance (NRC, 2012). Because protein is not stored in the body to any significant extent, any protein consumed in excess of the bird's requirements will be oxidized for energy. However, since protein sources are expensive and uneconomical for providing energy, protein levels are usually specified accurately and closer to minimum requirements than other nutrients.

5.3.2. Metabolizable Energy Content

The results revealed that the premarket feed samples exhibited out of compliance frequencies of 33.8% and 36.6 % at Addis and Bishoftu with the average total ME deficiency of 104.1 and 62.5 kcal/kg respectively. While the corresponding figure for the post market feed samples in the same order as above was 48.33%, and 43.61% with average total ME deficiency of -112.4 and -65.5 kcal/kg respectively (Figure 7). This variation more likely comes from the variations ingredients since the ME value was obtained from a factor of the fat, protein and carbohydrate content in the feed. The implication is that birds fed with ration containing less fat, protein and carbohydrate will not have much energy for growth and this feed sample may contribute to stunted growth and low production in birds (NRC, 1994).

Out of compliance frequency reported in this study is still high but compared to previous studies conducted in Ethiopia by Nagesh (2018) for other livestock species including commercial layers seems low. Nagesh (2018) analyzed 64 compound feed samples for metabolizable energy content of which 52 samples (81%) were failed to meet ESI (2018) standards while 12 of them are over the standard. His values ranged between 1364-2746 Kcal/kg, 1092-2890 kcal/kg and 1703-2880 kcal/kg while the standard is 2500, 2650 and 2600 kcal/kg for layer, beef and lactating dairy cow, respectively.

This study result corresponds to about 1984.40 - 3339.60 Kcal/kg and 2801.14 - 3026.9 Kcal/kg of metabolizable energy values published in Dewa and Tikau (2019) and Ojabo and Wunduga (2020), respectively. In contrast, Bukar and Saeed (2015) observed a slightly higher metabolizable energy value of 1737.30 - 4622.70 kcal/kg.

The difference in out of compliance frequencies reported in this study compared to the above study is in part are attributed to differences in sample size, sampling methodology and possibly feed ingredients quality variations associated within a season. Nevertheless, both studies show that a great attention is needed to fulfill the energy requirement of the animal because most of the feed manufacturing industries do not meet the energy content of commercial layer feed demanded by Ethiopian standard authorities.

Post market feed samples exhibited higher out of compliance frequency than premarket feed samples at only in Addis Abeba. However, the association between out of compliance frequency and pre and post market feed samples was significant only at Addis Ababa (Tables 12). Thus the difference in ME between the pre and post market feed sample at Bishoftu is merely attributed to random variations. In addition to random variations, the difference between two samples in Addis abeba may be attributed to the variations induced due to segregation at loading, unloading and transport the feed from point production to point of use.

5.3.3. Crude Fiber Content

Unlike CP and ME content, the noncompliance frequencies of crude fiber content in commercial layers feed sample was modest regardless of the study variables (Figure 9). In Addis about 5.6 of premarket sample and 9.6% post market sample exceeded the minimum value of CF content sited by ESI (2018) standard for commercial layers feed. The corresponding figures for Bishoftu in the same order as above was 6.5% and 10%.

The CF content in present study agrees with Crude fiber contents published in Okafor and Ezebuo (2014) and Vakili *et al.,* (2015), Ojabo and Wunduga (2020), Ogbebor *et al.,* (2021) 4.3 - 9.0 % and 2.89 - 6.60 % and 3.53 ± 0.04 - 8.45 ± 0.16 %, 5.27 - 10.39 %, while 3.41 ± 0.17 - 15.90 ± 6.46 % and 1.70 - 38.75 % observed in Bukar and Saeed (2014) and Bukar and Saeed (2015) respectively were lower crude fiber contents.
Dietary CF provides substrates for the gut micro biota to maintain gastrointestinal tract function and health (Mateos *et al.,* 2012). However, The CF is used to define a variety of indigestible polysaccharides including cellulose, hemicelluloses, pectin's, oligosaccharides, gums and various lignified compounds. With little gradation, the fiber

fraction of poultry diets was long considered of diluting or even anti-nutritive nature, as reviewed by Mateos *et al.*, (2012). Thus, it has commonly been used as a negative coefficient in prediction equations of the nutritive value of feeds (Lunn and Buttriss, 2007).

5.3.4. Moisture content

Controlling the moisture content of any feed is very important, because it is the mainly cause for aflatoxin. Moreover, high DM contents control the growth of mold in feeds, thereby reducing deterioration which is particularly important in tropical countries. As stated by Islam *et al.* (2015), with some exceptions our result suggests that commercial layer feed sample analyzed are appropriate for use and storage. The moisture content in this study agrees with 8.52 - 10.44 % obtained in Vakili *et al.*, (2015) and Nagesh (2020) who reported moisture content variations of 8.58 to 12.16% among 17commercial layer feed samples collected from Ethiopia.

In Bukar and Saeed (2014), Bukar and Saeed (2015), Dewa and Tikau (2019), Ofori *et al*. (2019) Hasan *et al.* (2022) published studies, higher moisture levels were observed in poultry feed in the range of 4.98 higher moisture contents were observed in the poultry feeds in the ranges of 4.98 ± 01.58 - 11.33 ± 4.48 %, 3.81 - 15.97 %,%, 0.17 ± 0.13 - 36.31 ± 0.38%, 7.84 - 11.8 % and 6.13 ± 0.28 - 11.02 ± 1.52 % respectively, whereas Ogbebor *et al.* (2021) and Okafor and Ezebuo (2014) reported lower moisture content in poultry feeds.

5.3. 5. Crude fat content

The crude fat content of the feed samples ranges from 2.1 to 8.6% while ESI (2019) recommends a minimum of 2 % crude fats inclusion rate in commercial layers feed formulation. The maximum amount is defined more by technical reasons than by nutritional ones, as diets of up to 7.5% of crude fat are excellent for layers (Pérez-Bonilla et al., 2011).

Our results were in agreement with previous research conducted by Negash, (2020) who came across similar magnitude in fat content variations among 17 commercial layers feed examined and also agree with Saeed (2014), Bukar and Saeed (2015), Dewa and Tikau (2019), Ofori *et al.*, (2019), Ogbebor *et al.*, (2021), Hasan *et al*., (2022),.where as in their various studies, Wunduga (2020) and Okafor and Ezebuo (2014) reported lower levels of crude lipids in poultry feed than in the present study

Supplemental fat affects the productivity and egg size of layers (Prez-Bonilla *et al.,* 2011), but the effects depend on the amount and type of fat used and the linoleic acid (LIN) content of the diet (Grobas). *et al.,* 1999). In addition, additional fat may improve digestibility of other dietary components (Mateos and Sell, 1980) as well as egg mass production and feed efficiency (Prez-Bonilla *et al.,* 2011).

5.3. 6. Sodium chloride content

Sodium (Na) and chlorine (Cl) are essential minerals for poultry and play a critical role in regulating water-electrolyte metabolism, acid-base balance and maintaining osmotic pressure (OSM) (Bohn *et al.*, 2017). Sodium and Cl are low-cost nutrients with great influence on feed conversion ratio (FCR), egg shell quality, and excreta moisture (Murakami et al., 2003).To provide the requirements of these minerals in poultry diets, NaCl is commonly used, which contains approximately 40% Na and 60% Cl. In most of the laying hen requirement tables, only Na is listed. Levels of NaCl used in commercial diets for laying hens vary from 0.15 to 0.50% (Bohn et al., 2017). ESI recommends 0.50% dietary NaCl for laying hens (ESI, 2019).

Nutrients or additives supplied in excess of requirements will be wasted, add unnecessary cost to the diet, and, in extreme cases, can even be toxic to the animal. it was apparent in our study that, at least in a significant portion of feed produced, nutrient uniformity criteria with respect to NaCl concentration is not being met.It is often recommended that a coefficient of variation less than 10 percent indicates appropriate mixing, but recent data suggest that up to 20 percent CV may be adequate for most practical diets.Subsequently about 44% of premarket and 27% post feed samples contain excess amount of NaCl than that allowed by ESI for laying hens. This may lead to the negative consequences of an increased dietary intake of sodium chloride including but limited to, higher water consumption levels (Mushtaq, 2007) which in turn increases the risk of many diseases (including foot pad dermatitis -FPD) and other health problems encountered in poultry production (Juskiewicz, 2009).

5.3.7. Available P content

The magnitudes CV encountered among similar production baches with respect to available phosphorus content in this study are within the range of reported by different scholars (Herrman and McClure,I995 and Wicker and Poole, I99l). For instance, Wicker and Poole, I99l investigated samples collected from 100 commercial and integrated feed manufacturers, nearly 50% had a CV above l0% and 1 in 5 had CVs in excess of 20%. These plants, of course, are manufacturing grain-soy based feeds where the physical properties of ingredients are well controlled and more sophisticated mixing equipment is the norm. In a smaller study of on farm swine feed manufacturers, Herrman and McClure (I995) found a mixing CV average of 13% with a range of 4 to 34%. Our results attested that no association between out of compliance frequency and feed sampling category or sample locations. Hence the variation Available P is attributed to random variations in feed ingredient and or differences in feed compounding practices.

Nevertheless, our results showed that the deference between pre and post market commercial feed sample in out of compliance frequency with respect to Av. P content was modest (6.3 vs. 7.6%) at Bishoftu and 11.3 % vs. 7.7% (Figure 12). Ethiopian standard Institute (2019) recommended dietary phosphorus level for laying hens at 0.4 % available phosphorus per kilogram of diet. Low dietary phosphorus levels during lay can result in increased fatigue of the cage layer, decreased bone ash, increased severity of osteoporosis, and decreased bone strength. Phosphorus plays a key role in carbohydrate metabolism, fat metabolism and the regulation of acid-base balance in the body.

5.3.8. Calcium content

This study revealed that on the average the out-compliance frequency of commercial feed with respect to Ca content was as high as 27 %. Ca is an essential nutrient for poultry that is generally provided to laying hens at approximately 4.6% of the total feed volume. It is important for bone development command mineralization, eggshell formation, muscle and neural functions (Klasing, 1998). Diets containing calcium below the nutritional requirements of layers impair performance and egg quality (Keshavarz, 1986). However, calcium metabolism is related to and influenced by the availability of phosphorus (P) and vitamin D (Proszkowiec-Weglarz and Angel, 2013) so that any inadequacy or excess of one may significantly affect the metabolism of the other.

Calcium is one of the essential minerals in poultry nutrition. In addition to its vital functions as the main component of bone structure and participation in acid-base balance and enzymatic system, calcium is the also the main component of the eggshell. Calcium supplementation is required in animal feeds, as most consist of grains and its byproducts, which have very low calcium (Peixoto and Rutz, 1988). On the other hand, out of the total feed sample examined in this study nearly 73% had higher concentration of Ca compared to ESI requirements.

Excessive dietary calcium can reduce feed intake, cause soft feces, and increase chalky deposits in the eggshell (Keshavarz and Nakajima, 1993; Bedford *et al.*, 2017), lead to a reduction in body weight gain (BWG) and feed consumption in broilers (Han *et al.*, 2022). Research by (Luki *et al.*, 2009) has shown that the use of feeds with 2.5 to 3.0% calcium in the diet of young laying hens, regardless of the form of calcium present in the feed, not only has negative effects on the productivity of the shifts can have, but also the quality of the eggshell, which means that defective eggs are more common. In addition, high dietary calcium concentrations are known to decrease the energy value of food through chelation of lipids (Li *et al.*, 2016) and impair the bioavailability of other minerals such as phosphorus, magnesium, manganese and zinc (Selle. *et al.*, 2009)

6. CONCLUSTION AND RECOMMONDATIONS

6.1. Conclusion

The experiments reported herein investigated commercial layers feed mix uniformity and degree of compliance of pre and post market commercial layer feed to Ethiopian feed standard requirements. Our research indicates that, the composition of analytes in focus in poultry feed is highly variable among similar production batches and manufacturers, though most feed manufactures produce feed mixture having acceptable mix uniformity with respect to most the analyte in focus including ME and CP. ME ad CP are the two major nutritional parameters considered for evaluating feed nutrition quality since value about 95% feed cost is used to meet protein and energy requirements. However, to determine exactly what amount of mix uniformity is necessary for optimal growth performance in Ethiopian conditions needs further investigation.

Variations in nutrient content violate the primary goal of feed production and cost in terms of performance. This is especially true for small and medium-sized commercial layer farms that are unable to produce their own feed and are completely dependent on expensive commercial feed available on the market. Feed manufacturers do not analyze ingredients prior to use, although understanding and specifically defining ingredient quality is a top priority for producing quality feeds with good mix uniformity. Research elsewhere has linked ingredients to 40-70% of the variation in nutrient content of finished feeds (Jones, 1989).).

Feed manufacturers do not properly label their products and hence making quality-based buying decisions was not applicable. The quality status of feed cannot be known until farmers feed their birds and see bird's production responses in the form of egg and meat productions. This makes access to quality feed is very important to enhance the productivity and profitability of small and medium scale commercial layer farms.

The variance was evident even between batches from the same manufacturers and therefore it may be advisable to conduct more frequent external analysis of poultry feed samples for the composition of the nutrients studied as well as the components present in these mixes during production. Poultry producers could also be recommended quality control of commercial feed to ensure that the feed actually conforms to the parameters stated in the manufacturer's declaration

The study findings show that the out of compliance frequencies of both premarket and post market commercial feed samples with respect to crude protein, metabolizable energy and minerals was high and calls the attention of the feed regulatory authority. The reason might be due to poor formulating practices and mixing operations of feed ingredients or poor quality the raw materials used in feed formulation. It was also observed that the staffs assigned as quality and production experts in the feed manufacturing industries are not aware of the Ethiopian feed standards and not commonly used as a reference during formulating of feeds. Provision of feedback of inspection findings and making follow-up and taking necessary legal measures on those who refuse to obey feed inspection regulation would help for the improvement of quality and safety of feeds.

6.2. Recommendations

- There were significant variations among the various means of the feed samples. Some of the feed samples deviates from mean recommended values by the ESI, 2019. This situation has serious implications on small scale poultry farmers, who have little capacity to produce their own feeds but rely on relatively expensive commercial feeds, may be incurring higher feed costs than necessary.

- For successful poultry farming, the quality of the feed is a determinant factor for growth and production (meat and egg) and every attempt must be put in place to ensure that feed prepared and sold by commercial feed manufacturers contain all the essential nutrients at the right amount for the sustenance of the poultry industry.

- The selection of feed ingredients for formulation of poultry feed should not be compromised; the development of birds largely depends on the nutritive value obtained in the feed ingredients used. To ensure quality and standardization of feeds, frequent monitoring and enforcement of standards in the preparation of feed is cardinal, this will ensure that nutritional feeds are formulated to meet production needs of poultry birds.

- Encouraging the feed manufacturing industries to give regular training for their technical staffs on some important feed quality production and handling techniques such as proper feed formulation, feed quality testing and Ethiopian feed standard and their application in feed manufacturing. Training will motivate technical feed staffs and make them effective in their work which in turn contributes to an increase of safety and quality of commercially produced feeds.

- Designing and implementing customer complaint handling mechanisms by feed producers will help them respond to consumer complaints and be accountable for animal productivity loss occurred as the result of poor quality feed.

- Linear programming is the most common method of feed formulation. However, the dependability and precision of the results it yields depends on the accuracy and completeness of the input data used. Unfortunately, very little research has been done in understanding the differences in the availability of a given nutrient in different feedstuffs in time and space and determination of nutrient requirements for poultry compounds under Ethiopian conditions. There is an urgent need for more work in this field in Ethiopia.

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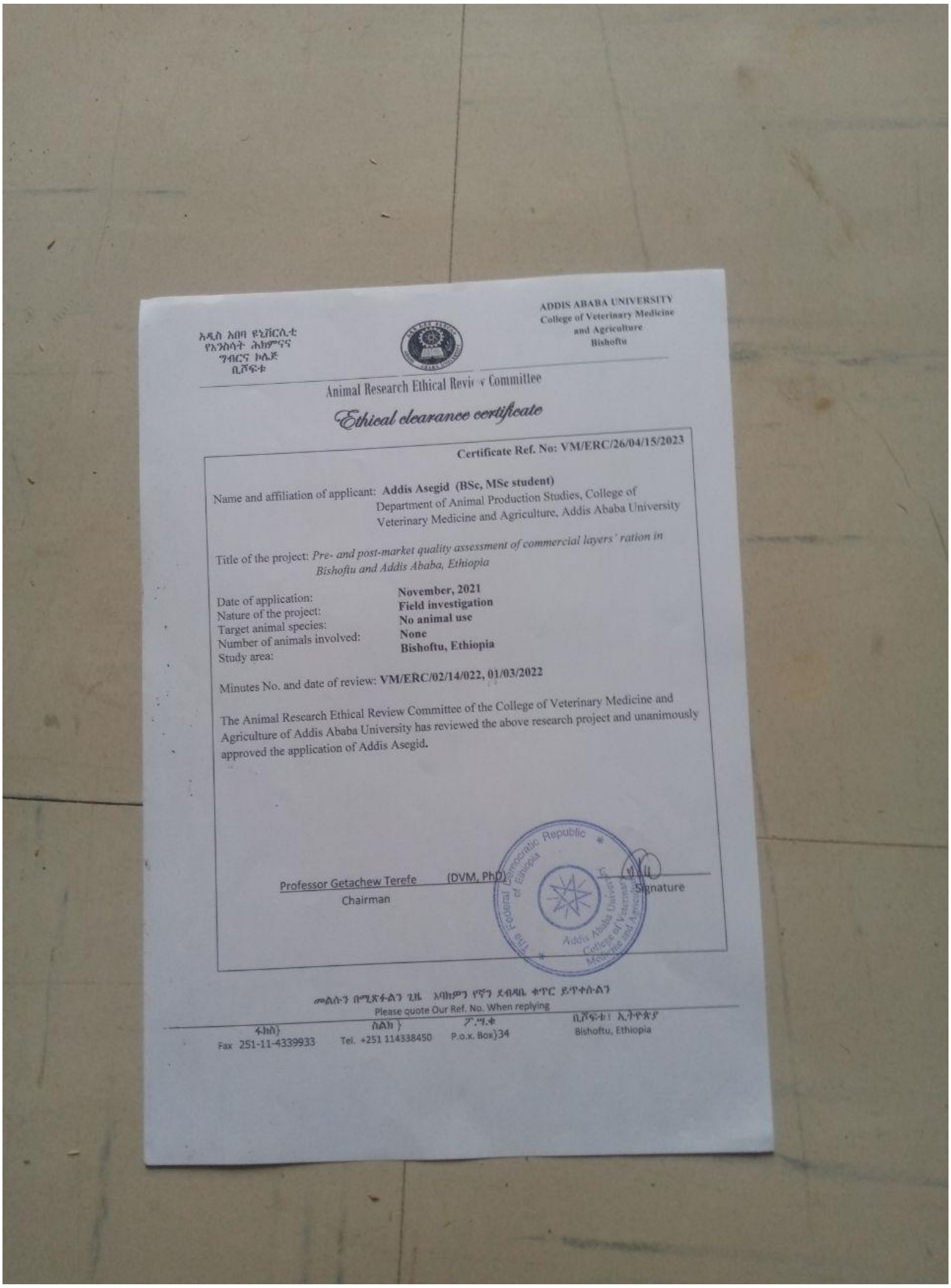
APPENDIXS

Table 1. Ethiopian Commercial layer feed standard (ESI, 2019)

No.	Constituents*	Starter	grower	Layer	Testmethod
1	Moisture,percentby mass,max	12	12	12	ES1032-1
2	Crudeprotein,% bymass,min.	19	15	16.5	
3	Crudefat,% bymass,min.	2	2	2	
4	Crudefiber, percentbymass, max.	7	9	9	
5	Metabolisableenergy(kcal/kg),min.	2600	2500	2600	
6	Salt (asNaCl), %bymass, and max.	0.5	0.5	0.5	ES1032-2
7	Calcium(asca,) %bymass	1-1.4	1-1.4	3-4**	
8	Totalphosphorus,%bymass, min.	0.7	0.65	0.65	
9	Availablephosphorus,%bymass,min.	0.4	0.4	0.4	
10	Iodine, mg/kg.min.	0.35	0.35	0.35	
11	Selenium, mg/kg	0.01-0.05	0.01-0.05	0.01-0.05	
12	Lysine,percentbymass,min.	1.0	0.7	0.6	ESISO5510
13	Manganese, mg/kg,min	60	30	30	ESISO6869
14	Iron, mg/kg,min	80	60	60	
15	Zinc, mg/kg,min	40	35	35	
16	Copper, mg/kg,min	5	4	4	
17	Magnesium, mg/kg,min.	600	500	400	
18	Potassium, mg/kg,min.	2400	2000	2000	
19	VitaminA,IU/kg.min.	9000	8000	8000	ESISO14565
20	VitaminD_3, lU/kg, min.	200	200	200	ES1032-4
21	VitaminB_1,mg/kg,min	2.00	1.5	1.00	
22	VitaminB_2(Riboflavin),mg/kg,min	3.6	1.8	1.8	
23	Pantothenicacid,mg/kg,min	6.5	6.0	5.0	
24	Niacin(nicotinic acid),mg/kg,min	27.0	11.0	11.0	

25	Methionine,percentbymass, min.	0.35	0.27	0.30	
26	Methionine+Cystine,%bymass,min.	0.6	0.5	0.55	
27	VitaminB6(Pyridoxine),mg/kg,min	4.5	4	4	ES3369
28	VitaminB12,mg/kg,min	0.012	0.008	0.008	ES3370
29	Biotin,mg/kg,min	0.2	0.15	0.15	ES3371
30	Folicacid,mg/kg,min	0.9	0.7	0.6	ES3372
31	Linoleicacid,percentbymass,min	1	1	1	ESISO17764
32	Choline, mg/kg,min	1400	1100	1100	xxxx
33	VitaminE,mg/kg,min	15	10	12	ESISO6867
34	VitaminK,mg/kgmin	1.5	2	2	xxxx



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ADDIS ABABA UNIVERSITY
College of Veterinary Medicine
and Agriculture
Bishoftu

Animal Research Ethical Revi v Committee

Ethical clearance certificate

Certificate Ref. No: VM/ERC/26/04/15/2023

Name and affiliation of applicant: **Addis Asegid (BSc, MSc student)**
Department of Animal Production Studies, College of Veterinary Medicine and Agriculture, Addis Ababa University

Title of the project: *Pre- and post-market quality assessment of commercial layers' ration in Bishoftu and Addis Ababa, Ethiopia*

Date of application:	**November, 2021**
Nature of the project:	**Field investigation**
Target animal species:	**No animal use**
Number of animals involved:	**None**
Study area:	**Bishoftu, Ethiopia**

Minutes No. and date of review: **VM/ERC/02/14/022, 01/03/2022**

The Animal Research Ethical Review Committee of the College of Veterinary Medicine and Agriculture of Addis Ababa University has reviewed the above research project and unanimously approved the application of Addis Asegid.

Professor Getachew Terefe (DVM, PhD)
Chairman

Signature

The Federal Democratic Republic of Ethiopia
Addis Ababa University College of Veterinary Medicine and Agriculture

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Broiler Finisher
Broiler Layer Breeder
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Butter unsalted
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Calf Starter
Cat Food (dry)
Cat Food (wet)
Cattle Fattening Feed
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