Chicken Feed Formulation at Farm Level in Ajmer District of Rajasthan

राजस्थान के अजमेर जिले में खेत स्तर पर कुकुट दाना निरूपण

Joseph Longo

Thesis

Doctor of Philosophy in Agri Business

2015

Institute of Agri Business Management
S.K. Rajasthan Agricultural University
Bikaner – 334 006

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Thesis

Submitted to the

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By

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Institute of Agri Business Management

S. K. Rajasthan Agricultural University, Bikaner

Date: 22-12-2015

CERTIFICATE –I

This is to certify that **Mr. Joseph Longo** had successfully completed the Preliminary Examination held on 10/03/15 as required under the regulation for the Ph. D. degree.

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CERTIFICATE –II

This is to certify that this thesis entitled **'Chicken Feed Formulation at Farm Level in Ajmer District of Rajasthan'**, submitted for the degree of **Doctor of Philosophy** in the subject of **Agri Business** embodies bonafide research work carried out by **Mr. Joseph Longo** under my guidance and supervision and that no part of this thesis has been submitted for any other degree. The assistance and help received during the course of investigation have been fully acknowledged. The draft of this thesis was also approved by the evaluation committee on 18/08/2015.

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This is to certify that **Mr. Joseph Longo** of the Institute of Agri Business Management, Bikaner has made all corrections/ modifications in the project report entitled **'Chicken Feed Formulation at Farm Level in Ajmer District of Rajasthan'**, which were suggested by the external examiner and the advisory committee in the oral examination held on 16-12-2015.... The final copies of the thesis duly bound and corrected were submitted on 22-12-2015, and forwarded herewith for approval.

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List of Acronyms

D.O.R.B	Deoiled rice bran
DOSC	Deoiled soya cake
DOMC	Deoiled mustard cake
DGNC	Deoiled groundnut cake
L.S.P.	Limestone powder
D.C.P	Dicalcium phosphate
RHS	Right hand side

1. INTRODUCTION

1.1 Background to the Study

1.1.1 The Indian meat industry

The contribution of livestock sector to the food basket in the form of milk, eggs and meat has been immense in fulfilling the animal protein requirement of ever-growing human population. The livestock sector is an important component of Indian agriculture. India has a huge livestock population and efficient utilization of these resources including production and utilization of livestock products is important to earn increased returns and sustain livestock production activities (Mane, 2012).

During the last three to four decades, India has witnessed the green, white, yellow and blue revolutions and now the time has come to realize one more revolution i.e. red/pink revolution in the form of meat production. In fact, in spite of big potential because of large livestock population, the meat industry in India has not taken its due share. There are many reasons for the slow growth rate of the Indian meat industry, including the negative attitude of public towards meat on account of misinformation campaign and socio-political considerations (*Ibid*).

1.1.2 Livestock population, meat production, slaughter rate and export

The present production of meat is estimated at 6.27 million tons in 2010 (FAO, 2012), which is 2.21% of the world's meat production. The contribution of meat from buffalo is about 23.33%, while cattle contributes about 17.34%, sheep 4.61%, goats 9.36%, pigs 5.31%, poultry 36.68% and other species 3.37%. The meat production has increased from 764,000 tones in 1970-71 to 6.27 million tons in 2010. The compounded average growth rate during the last two decades works out to be 4.5%. It is noticed that about 10.6% cattle, 10.6% buffaloes, 24.1% sheep, 58.7% goats, 95.0% pigs and 19.0% chicken are slaughtered each year. The value of meat and by-products is ₹ 79,889 crore including skin and hides, while the export value of meat and meat products work outs to be more than ₹ 6,000 crore in the year 2009-10. The contribution of buffalo meat accounts for more than 75% of total exports/foreign earnings (Mane, 2012).

While FAO (2012) estimated an annual rate of 6.27 million tones of meat production in India, GOI (2014), estimated the annual rate of meat production in the country to be standing at 6.35 million tons in the year 2013 – 2014. This indicates that the industry is constantly growing. Table 1 summarizes the meat production in the year 2013 – 2014.

Table 1: Meat production in India 2013 - 2014

Animal species	Meat production in ('000 Tones)	Estimate of slaughtered animals in ('000)
Poultry	1916.60	88137.10
Buffalos	1164.32	32324.30
Goats	970.42	12071.10
Pigs	486.03	1266844.00
Sheep	431.87	3195.86
Cattle	333.23	9735.85
Others	0.69	187.80

Source: Ministry of Agriculture, Govt. of India

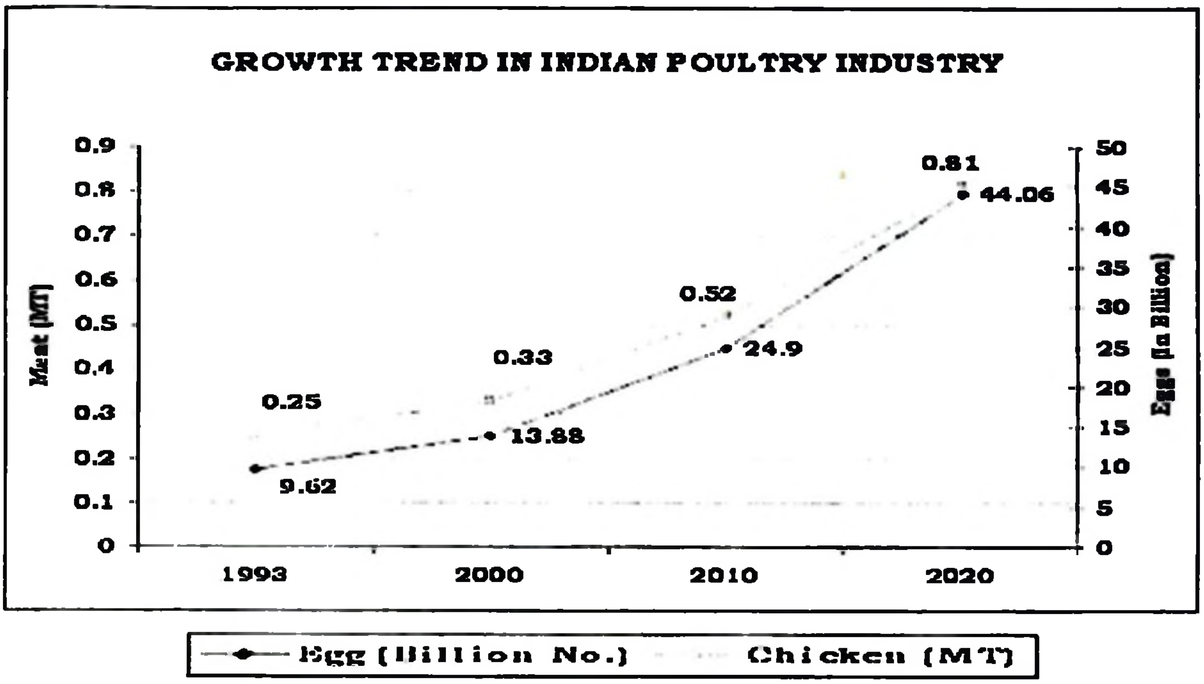
1.1.3 Contribution of poultry in the Indian meat industry

According to Mane (2012), poultry meat has gained wide acceptance among consumers and the sector is growing at a rate of 10-15% annually. The chicken meat contributes about 37% to total meat production and more growth is expected in the near future. This state of affairs might be due to popularity of poultry meat, affordability in terms of price, easy availability and less prevalence of religious taboos that surround poultry meat consumption.

In the same way, Karthikeyan and Nedunchezhian (2013) highlighted that poultry occupies a crucial place in India as the eggs and chicken meat are important and rich sources of protein, vitamins and minerals. Moreover, Chicken is the most widely accepted meat in India. The less constraints due to being a religious taboo unlike beef or pork are also helping factors in popularity of poultry industry. The prices of chicken meat are much lower when compared with that of mutton or goat meat. Many Indian families in urban areas have begun to accept eggs as a regular supplementary part of their vegetarian diet. The forecast surveys also indicate a great opportunity for this sector with the prediction that as the present younger generation goes to the adulthood, the acceptability and demand for eggs and chicken meat in next decades is likely to increase many-folds very rapidly

(Karthikeyan and Nedunchezhian, 2013). Figure 1 shows the growth trend in Indian poultry industry.

Figure 1: The growth trend in Indian poultry industry



Source: http://www.indiastat.com

1.1.4 Poultry farming

Poultry can be defined as domestic fowls, including chickens, ducks, geese, emu, turkeys, quail and pigeon, raised for the production of meat or eggs and the word is also used for the flesh of these birds used as food (The American Heritage: Dictionary of the English Language. 4th edition. Houghton Mifflin Company. 2009).

Poultry farming means raising various types of domestic birds for the purpose of meat, eggs, and feather production (Encyclopedia Britannica Inc. June 6, 2013). The most common and widely raised poultry birds are chicken. About 50 billion chickens are being raised every year as a source of food in terms of meat and eggs. Chickens which are raised for eggs are called layers and chickens which are raised for meat production are called broilers (http://en.wikipedia.org/wiki/poultry_farming).

Poultry farming is an important business both from nutritional and commercial points of view. Nutritionally poultry farming supplies animal protein which is highly needed in human nutrition. From a commercial perspective, poultry farming is a lucrative business.

1.1.5 Status of poultry farming in India

Poultry farming is a significant sector in Indian agriculture. The Indian poultry industry has been on the continuous growth trajectory in the recent past. This has been aided by different factors including national developmental regulations, emerging organized retail industry, export opportunities, availability of funds for new projects, and financing policy for prospective poultry farmers (Mohanraj and Manivannan, 2012). The poultry Industry in India has emerged as the most dynamic and rapidly expanding segment in livestock economy as evident from the production level touching about 47 billion eggs and 850 million tons broilers with a compounded annual growth rate of 13% and 15%, respectively. Currently, India is the 3rd largest egg producer and 4th in broiler production in the world. The poultry industry is one of the fastest growing sectors in the country (ibid).
Further, Rajesh and Nambiar (n.d.), in their study titled 'The poultry industry in India', pinpoint India's poultry industry as a sector representing a significant success story. It is further highlighted that agricultural production has been rising at the rate around 2 percent per annum over the past two to three decades, while in the same time frame poultry industry has been rising at the rate of around 8 percent per annum, with an annual turnover of US$ 7 500 million (*ibid*).There has been a rapid rise in India's egg and poultry meat production. Poultry meat has outpaced its two major competitors – beef and veal, and buffalo meat (*ibid*).

Not only is the growth of the poultry industry limited in urban areas, but also in rural areas. In an attempt to estimate the demand for egg and poultry meat for India in 2020, using National Sample Survey (NSS) data, the results revealed a relatively strong growth for egg and poultry meat both in the urban and rural areas in the next two decades. Egg consumption was found to grow at a much faster pace than poultry meat with the rise in income and nearly triples by 2020 (Samarendu and Rajendran, 2003). Similarly, average per capita poultry meat consumption was found to increase from 0.69 to 1.28 kilograms during the same period. Projections from the study indicated that the total egg consumption will increase from 34 billion in 2000 to 106 billion in 2020 and total poultry meat consumption will increase from 687 million kilograms to 1,674 million kilograms during the same time period (*ibid*). Generally, the Indian poultry industry is currently in a very rapid growth rate.

1.1.6 Status of poultry farming in Ajmer district

In Ajmer district, being among drier parts of the country where both rain and irrigation water are scarce, poultry farming is an important occupation (Jat and Yadav, 2012).

Dadheech and Vyas (2012) highlighted that Ajmer is the most popular district in Rajasthan state, as far as poultry farming is concerned. The authors further pointed out that the district had a total number of 250 poultry farms, with 2,500,000 birds including 1,200,000 layers which produce about 700,000 eggs daily. While Dadheech and Vyas (2012) reported about Ajmer district having a total of 250 poultry farms, State Poultry Training Institute (2015) reported that the total number of poultry farms in Ajmer district sums to 619. This is a tremendous increase in the number of farms; an increase of about 147.6 percent in a span of three years. This shows how significant and vibrant the poultry sector is in the district.

According to the State Poultry Training Institute (SPTI), two broiler breeds are commonly reared in Ajmer. These breeds are Cobb and Ross. Of the two breeds, Cobb400 is the most predominant. On the part of layer breeds, BV300, Bovans and Hyline are commonly reared in the district. Of the three breeds, BV300 is the most predominant breed.

Focusing poultry sector in terms of layer and broiler production, SPTI (2015) reports that of the 619 poultry farms found in the district about 75 per cent are dealing with egg production, while about 25 percent are dealing with broiler production. This indicates that egg production is by far more predominant than chicken meat production. Due to bio security reasons mixing of layer and broiler farming in the same farm is technically not advisable (SPTI, 2015)

For chicken farming business to be both successful and sustainable, parent stocks and feed mills are a prerequisite. Ajmer district has four parent stock farms specializing only in chicks production. These four farms supply chicks demanded by all chicken framers in the district. Additionally, the district has a total of 6 feed mills supplying feeds, an important input in chicken production (SPTI, 2015). According to SPTI, the district has an abundant supply of raw materials that are needed by feed processing firms. The locally available and commonly used ingredients are yellow maize, deoiled soya cake, deoiled groundnut cake, deoiled rice bran, marble grits, mineral mixture and common salt.

1.1.7 Significance of poultry farming in Ajmer district

Ajmer is semi – tropical area surrounded by mountains, a geographical feature which makes it suitable for both agriculture and livestock production, particularly chicken (SPTI, 2015). According to SPTI, the weight attributed to crop production and that attributed to chicken production is 50% - 50%. This means chicken farming is as important as crop production. In fact, the two projects are complementary in nature, in the sense that farm crops benefit from chicken farming in terms of manure and chicken farming benefit from farm enterprise in terms of feeds. This implies that chicken farmers are a market for crop farmers while crop farmers are a market for poultry manure. Considering the income of the district at large, the contribution of the poultry sector to the overall income is about 20% (SPTI, 2015). This is a very significant contribution.

1.1.8 Market outlets for poultry products in Ajmer

There is a huge market for Ajmer's poultry products ranging from within Rajasthan state, India at large and abroad. All districts within Rajasthan are supplied with poultry products from Ajmer. Within India, popular markets for Ajmer poultry products are Delhi, Agra, Varanasi and Indore in Madhya Pradesh state. Export markets include; United Arab Emirates (UAE), Iran, Iraq and Malaysia (SPTI, 2015).

1.1.9 Major challenges of poultry sector in Ajmer district

Several challenges affect the poultry sector in the district. According to Dadheech and Vyas (2012) and SPTI (2015), major challenges affecting the sector are sporadic viral infections, fluctuating ingredient costs and nonexistence of farmers' owned marketing organization. Due to absence of farmers' organization, farmers are forced to rely on middlemen for selling their product. Being such a significant industry national wide and in the district in particular, poultry farming commands a special attention in terms of management practices including housing, lighting, feeding and watering, as well as disease prevention and treatment, so as to maximize profit from poultry farming.

1.2 Problem statement

The profitability of poultry business lies on strict observance of sound poultry management practices. Management aspects such as housing and feeding and treatment require a special attention. Poultry farmers need to possess proper knowledge level regarding recommended poultry farming practices (Jat and Yadav, 2012).

Poultry feeding is the most critical element in poultry production, in terms of health of the birds and cost of production. Feed quality will affect feed consumption, hence health. No one feed ingredient contains all the nutrients required for a complete diet. When mixed together, ingredients complement each other to form a complete feed. Each feedstuff has a place in a balanced poultry diet (Frame, 2008). It follows therefore, that feed of proper quality and quantity is necessary for health and productivity of birds.

In terms of cost, poultry feeding is a major item of cost in poultry production. Feed cost accounts for over 70% of the total cost of eggs and broiler production (Mathew and Moji, 2008). In order to maintain a reasonable margin of profit despite the rising cost of commercial feeds, there must be a design to reduce the cost of production and still maintain high level of performance in the birds (*Ibid*). Farmers who formulate their own feeds at home reduce a substantial amount of costs and stand a better position to make good returns in the poultry business.

On the bases of the aforementioned facts, this research aimed at addressing the aspect of poultry feed formulation at farm level in Ajmer district. Additionally, the research addressed aspects related to general poultry management practices, including housing, lighting, feeding and watering, with a particular emphasis on feeding management.

1.3 Problem justification.

Poultry farming is a significant sector in Indian agriculture (Jat and Yadov, 2012; (Mohanraj and Manivannan, 2012; Rajesh and Nambiar, n.d.). The poultry

Industry in India is the most dynamic and rapidly expanding segment in livestock economy. India is among the top poultry products producers, being the 3rd largest egg producer and 4th in broiler production in the world (Samarendu and Rajendran, 2003). Ajmer is highly potential area for poultry production in Rajasthan state with about 250 farms (Dadheech and Vyas, 2012).Feeding costs are the most significant costs in poultry production (Mathew and Moja, 2008). In areas where ingredients are locally available and at a reasonable price, poultry feed formulation at farm level is worth adopting.

Results of the study will be beneficial to farmers, policy makers, academicians and other actors in the poultry value chain.

1.4 Objectives of the study

As pointed earlier, poultry farming is an extensive industry comprising of various types of domesticated birds. These various poultry species have different characteristics and somewhat different management systems. Given the financial constraints and limited time span that was available, the study limited itself to chicken farming.

The objectives of the research were;

i. To study the chicken management practices.
ii. To study the feeding management practices.
iii. To formulate Balanced Least Cost chicken feeds from locally available ingredients for different chicken classes.

2. LITERATURE REVIEW

2.1 Overview

This section reviews related literature on poultry farming. The review broadly covers chicken management practices, feeding management practices and feed formulation.

2.2 Chicken management practices

2.2.1 Forms of chicken farming

Basically, there are three forms of chicken farming: extensive farming, semi-intensive farming and intensive farming (Maas, 2006)*)*. Extensive farming is a system where by chickens are free to roam and scavenge. This system is also called free-range system. In this system the level of capital and labor investment is low. Housing is only needed during the night for security purposes (*ibid*). The free-range system is mainly practiced by small-scale chicken farmers.

The semi-intensive production system, also known as backyard production, is more advanced as compared to the free range system. A lot of techniques and expertise developed in intensive systems can be applied in semi-intensive poultry raising systems (Maas, 2006)). Stressing on the housing, Maas (2006) expressed that housing options under semi intensive systems include; housing with a run, housing with litter but without a run and housing with slatted flooring.

Intensive systems are mainly used in production of specialized commercial breeds (Ovwigho *et al.*, 2009). These are mainly found in and around urban areas with good markets for eggs and chicken meat. Intensive chicken farms require more investment of both capital and labor. Ovwigho *et al.*, (2009) pointed out that the deep litter and battery cage systems are the most predominant housing systems in intensive poultry farming. Flock sizes in intensive production are normally in the thousands and application of modern scientific practices such as artificial incubation, standard nutrition and disease control, are significantly followed (*ibid*). In both the semi-intensive and intensive production systems, housing is very important for optimal production levels.

2.2.2 Chicken housing

Fanatico (2007), stressed that poultry housing systems should focus on providing an environment that satisfies the birds' thermal requirements. Special attention should be given to newly hatched birds as they have a poor ability to control body temperature, and require some form of supplementary heating, particularly in the first few days after hatching (*ibid*).

In the issue of poultry housing, Fanatico (2007) had the following comments: "While access to the outdoors is an important feature of many alternative or free-range production systems, the indoor environment and management are also crucial. Poultry need access to an appropriate indoor environment for good production and welfare. Ideally, poultry farmers should choose an environment; whether to be indoors or outdoors. Attention to ventilation, temperature, lighting, and litter conditions is needed". Fanatico (2007) further added that, good management practices like rodent control should be done with a minimum of toxic materials. The author further added that poultry production can alternatively be done on a small scale, with portable houses.

Chicken housing affects productivity. Gerzilov (2012), conducted an industrial experiment with *ISA-Brown* commercial layers during the laying period (from 18 to 76 weeks of age). The layers were reared under three poultry management systems: in conventional cages type *BKN-3* – 66,300 layers distributed equally in five poultry houses; in enriched cages type *Eurovent 1500-EU-60* – 123, 430 layers distributed equally in two poultry houses; and in barn with slat flooring with manure pit and deep litter – 30, 000 layers distributed equally in four poultry houses.

The results showed that for the whole laying period the layers kept in conventional cages exhibited an average egg laying capacity of 336.1 eggs per hen, the egg laying capacity was over 90 % from 25 to 50 weeks of age, the mortality was the lowest - 5.35% and feed conversion ratio per egg was the highest - 155.9 g.

The layers kept in enriched cages gave the highest yield of eggs from a hen - 339.2, the egg laying capacity was over 90 % from 26 to 59 weeks of age, and the mortality was 7.96% and feed conversion ratio per egg was the lowest - 150.1g. The layers reared in the floor/litter system were characterized with the lowest yield of eggs per hen - 330.5 eggs, the egg laying capacity was over 90 % from 26 to 61 weeks of age, the mortality was the highest - 9.43 % and feed conversion ratio per egg was 151g (Gerzilov, 2012). From this study we can obviously see that housing system affects health of the birds, mortality and productivity.

Several aspects have to be considered when planning for a chicken house. Maas (2006) provide guidelines to be followed when designing the poultry house as follows: "Build the house in an east-west direction, so the chickens are less exposed to direct sunlight. Place the house where there is grass, herbs or other vegetation. Plant trees around it to keep its roof shaded. Make sure that the roof has a large overhang of 90 cm or more to limit direct sunlight and keep out the rain. Build the roof as high as possible above the floor. The chicken house will then be cooler and better ventilated. Keep the bottom 50 cm of the side walls closed and the rest open to allow enough fresh air into the house. Close the top part of the sidewalls with chicken wire or some other suitable material. A chicken house can have a corrugated metal roof, but in a sunny place, this will certainly overheat the house. In this case cover the roof with leaves or some other material. A disadvantage of this is that rodents like rats and mice can nestle in the covering. Do not keep too many chickens in the chicken house. Doing so can make the house too warm and help to spread parasitic infections. In hard-floor housing, there should be no more than 3 chickens per square meter. In houses with wire netting or slatted floors, a higher chicken density is possible. Finally, to stimulate feeding in cooler weather, turn on light in the house before sunrise and after sunset. This also helps to keep a steady level of egg production"

In addition to climate, other factors worthy prior consideration are; easiness of cleaning and disinfection of the house, hence a concrete floor is important. Provision and distribution of feeders, drinkers, perches, laying nests and light sources have to be thoroughly thought of (Venkateswara Hatcheries (VH), 2010). After housing a special attention on daily bases has to be placed on proper functioning of drinkers, feeders, lighting installations and laying nests. The authors further insisted that house climate should be checked and the condition of the flock and the hens' behavior has to be assessed. The mentioned equipments are important for carrying different management practices in the chicken house which are important for health and performance of chicken McPhee (2002). The next sections reviewed important equipments in the chicken house.

2.2.2.1. Chicken feeders

Feeders are important for preventing food wastage. A lot of feed is wasted if is scattered on the ground or floor. If there are only few chickens, hand-filled feeders are the best, otherwise automatic feeders will be best for large flocks of chicken (Maas et al., 2006). Feeders can either be rectangular or round shaped. It is important to ensure that there are enough feeders. With rectangular dishes or long feeders, each layer needs at least 12 cm of space along one side of a dish (*ibid*).

Table 2: Space at the feeder required per bird and per feeder type

Feeder type	Chicken Category		
	Broiler	**Layer growers**	**Layers**
Rectangular feeder	5 cm	9 cm	12cm
Round feeder	2 cm	4cm	5cm

Source: Maas, (2006).

To avoid feed wastage, a feed trough should never be more than 1/3 full. Lips should be built around the edges of the feeders to catch spilt feed. To reduce the amount of feed wasted, only a small amount of feed should be placed at a time in each feeder, and feeding should be done several times a day. This can also increase feed intake by the chicken. A metal feeder with tray of 40 cm in diameter is sufficient for 10 mature layers (Maas, 2006).

According to McPhee (2002) each laying bird should be given a space of 8 cm at the feeding trough. To prevent feed being wasted, the lip of feeder should be level with the height of the bird's back and the trough should be kept less than half full.

According to Venkateswara Hatcheries (VH) (2010), the height of the feed inside the feeder, should never be more than one-third full and should be level with the back of the birds, to prevent them from scratching contaminated litter into the feeders and to limit feed wastage. This is achieved by adjusting the height of the feeder itself. To reduce spoilage and mould problems, feed should be supplied at sunrise and at about 14.00 hours (or more frequently if the birds empty the feeder), with all feed finished by sundown. Feeders can be made of wood, sheet metal or bamboo, and are best suspended from the roof to keep rats out. The height of the feeder should be adjustable. Supplementary vegetable matter should be fed at beak level, either hanging from the ceiling wrapped in a string or placed in a net or placed in a floor-standing hopper with wire or slatted sides. It should not be thrown on the floor.

Feeder space is measured as the linear distance of lip available to the birds. This is either the circumference of a round tube-feeder tray or twice the length of a trough if the birds feed from both sides. If troughs are used, at least 10 cm of feeding space should be accessible to each bird. When circular feeders are used, there should be at least 4 cm feeding space per bird (VH, 2010 and McPhee, 2002).

2.2.2.2. Drinkers

Both quality and quantity of water are important for chicken health. Water should be regularly tested and treated to control disease germs such as *Colibacillosis, Coccidiosis* and *Necrotic Enteritis*, that are dangerous to chicken health (Dadheech and Vyas, 2012). Maas, (2006) explained that it important to supply chickens with enough water that is cool, clean and fresh, especially during warm weather. Maas, (2006) further elaborated that provision of water can be done using upside-down bottles which are fixed on the wall. Another possibility is to buy simple round metal or plastic bowls. The advantages of a drinker with a reservoir are that water is available for longer periods and is less likely to get dirty. Cleanliness of the drinkers should be done daily to avoid contamination (Maas, (2006). VH (2010) specifies the quality of water as per table 3.

Table 3: Drinking water standards for chicken

Parameters	Units	Maximum Permissible Limit
Total Dissolved Solids	Mg/ltr	1000 - 2000
pH	Mg/ltr	6.5 – 8.0
Hardness	Mg/ltr	600
Calcium	Mg/ltr	75
Magnesium	Mg/ltr	50
Iron	Mg/ltr	0.3
Manganese	Mg/ltr	0.1
Copper	Mg/ltr	1
Zinc	Mg/ltr	5
Ammonia	Mg/ltr	0
Nitrates	Mg/ltr	0 - 15
Sulphates	Mg/ltr	200
Chlorides	Mg/ltr	200
Fluoride	Mg/ltr	4
Arsenic	Mg/ltr	0.05
Cloudiness/Turbidity	U	5
Bacteria/ml	Nos.	10 - 50
Coliforms/ml	Nos.	0
Hydrometric level	degree	30
Organic substances	Mg/ltr	1
Sodium	Mg/ltr	50 - 250
Salinity	ppm	Less than 1000

Source:Venkateswara Hatcheries (VH) PVT LTD (2010)

Drinking space is an important aspect to consider when fixing drinkers in the chicken house. There should be enough drinking space available for each bird. Maas,(2006) recommends the drinking space as per drinker type and chicken category as shown in table 4.

Table 4: Drinking space

Drinker type	Chicken Category		
	Broiler	**Layer growers**	**Layers**
Rectangular drinker	2 cm	2 cm	2 cm
Round drinker	1 cm	1 cm	1 cm

Source: Maas, (2006).

Regarding quantity of drinking water, McPhee (2002) recommends that at least 0.5 liter of drinking water should be provided to each laying bird. This amount is equivalent to 2.5 liters for 5 birds. McPhee (2002) further explained that drinkers should always be filled with clean drinking water.

2.2.2.3. Perches

Chickens enjoy spending the night on high perches. Nervous birds can also quickly find shelter there during the day. A space is needed under the perches to catch the bird droppings. This helps to keep the litter dry and facilitates the collection of manure. Perches are small slats 5 cm wide and 35 cm long, usually made of wood. It is best to place them about 5-7 cm apart. Each chicken needs at least 15 cm of sitting space, depending on its size. Although perches are indispensable in all kinds of chicken houses, they can vary in kind and in location (Maas, 2006).

In houses with litter, it is important to place a wooden board under the perch to catch most of the droppings. The dropping board must be cleaned daily, and the manure removed regularly, preferably once a week. This board should be installed about 75 to 80 cm above the ground, with the perches placed 1m above the ground. To prevent the chickens from coming into contact with their droppings, the gap between the board and the perch should be closed at the front (*Ibid*).

Stressing on the issue of perches, McPhee (2002) explained that chicken like to sit on perches at night and that they do not like to be too close to each other when they are asleep. That being the case, McPhee (2002) provided specifications of a standard perch as follows: It has to be about 5 cm square with corners rounded to give the bird a comfortable grip. Perches should be about 30 cm apart and 30 to 60 cm above ground level. Between 1 and 2 meters of perch space would be adequate for 5 to 6 birds. Other than perches, there should be no other areas where the birds could sit such as window sills and nest box tops (*ibid*).

2.2.2.4. Laying nests

Hens usually prefer to lay eggs in protected nests, rather than simply on the floor of the house. The laying nests can either be individual or communal. In all poultry houses except battery cages, eggs are collected by hand. It is best to install a sloping cover over the nest box to prevent chickens from sitting on the nests and making them dirty. Laying nests are usually placed above the ground at 0.6 to 1 m height. A jumping perch should be placed in front of the nests. To keep the litter in the nest, make a small retaining board of 10-15 cm height at the front of the nests. During the night the nests should be closed with boards to prevent chicken from sleeping in (Maas, 2006).

Highlighting on the importance of laying nests, McPhee (2002) pointed out that chickens like to lay eggs in a clean and comfortable nest away from other birds. Therefore, one or two nests should be provided for every 5 to six birds. McPhee (2002) further pinpointed that nests should be 20 to 30 cm high, deep and wide and be 30 t0 60 cm above the floor. Dry, clean nesting materials such as wood shavings and rice husks will keep the eggs clean. To facilitate the birds climbing into the nest, a perch should be built close to the nest at the front.

2.2.2.5. Light sources

Light is a very crucial aspect in egg production. Improper light management may seriously hamper the laying potential of chicken (VH, 2010). There are two ways to try to raise the production of chickens by using artificial lighting. If the house is lit in the cooler hours before sunrise or after sunset, the chickens are able to eat more. If the day length is increased by using artificial lighting, laying hens are encouraged to lay more eggs. Day length must not be increased until just before young chicks start laying. Otherwise, it can lead to premature laying. It is best to start raising the chicks when the days are getting shorter. If you need to start the growing period when the days are getting longer, try to artificially ensure a constant day length. Just before the laying period starts, lengthen the days by one hour a week until you have 14 hours of light per day. After production rates have reached a maximum, lengthen the amount of light per day by one hour a week until there are 16 hours of light. Once day length has been increased from 12 to 14 hours, you will need to provide artificial light after sunset to maintain the extra day length. If you do not do so, egg production will decrease. If you are raising laying hens when the days are getting longer, you do not have to provide extra light to stimulate egg production. However, the hens will probably eat more if the house is lit during the cooler periods of the day. Whichever kind of light you install; it must be strong enough. If you use oil lamps, there must be enough of them, and they should be located in the centre of the chicken house, and should be screened off with thin slats or wire gauze, even if they are hung up. If you have electricity, a chicken house can be lit with ordinary light bulbs. 40 Watt bulbs should be placed 3 m apart and 60 Watt bulbs about 5 m apart (VH, 2010; Maas, 2006 and McPhee, 2002)

2.3 Chicken feeding practices

Stressing on the issue of poultry rearing systems, Jason (2009), explained that rearing poultry on pasture instead of in a barn or other permanent structure is an increasingly popular enterprise for hobby and small farmers across the world. Jason (2009) further pointed out that, two general systems are used by producers; the Salatin system consisting of an open-floor enclosed pen or other structure that is moved once or twice a day around the pasture. The birds are kept in the pen 24 hours a day but are provided with fresh pasture by moving the pen. The Day-Range system consists of a mobile pen that is kept inside a fenced area. The birds are free to roam within the fenced-area during the day and are put in the mobile pen at night if predators are a problem. The mobile pen is moved daily to prevent accumulation of manure and the fence is moved as necessary to provide access to fresh pasture. One of the many benefits of both systems is that the birds are eating plants, bugs, and anything else they can forage in the pasture. Although studies indicate the forage doesn't contribute much to the protein or carbohydrate needs of the birds, the foraging does improve some characteristics of the meat and is appealing to customers that feel such foraging is a more humane way to raise poultry compared to conventional confinement operations. As such, consumers are willing to pay more for the poultry (*ibid*).

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Addressing the nutritional requirements of birds, Poole (2007), pointed that fowls have a simple digestive tract like humans, and therefore eat similar food, such as cereals and meat. Their food is composed of a number of nutrients that are essential to their health, maintenance and egg and feather production. The six main nutrients are protein, carbohydrates, fats, vitamins, minerals and water. This entails that poultry feed formulation should be carefully done to ensure that all nutrients needed by the birds are available in the feed. Feeds deficient in some nutrients or imbalanced feeds will affect health of birds hence productivity. Poole (2007) further insisted that feed should be made available to poultry at all times, in the form of a mash or pellets. Feeds can be sourced from commercial poultry feed dealers or formulated at farm level.

Stressing on farmers who opt to formulate their own feeds, Poole (2007), guided that in the mixing procedure; the cereals should be weighed out first, and should be coarsely ground, the protein supplements, such as meat meal and *luceme* meal, should then be mixed in, followed by the vitamin and mineral premix. Mixing can be done in special mixing machines or concrete mixers, or by turning the ingredients over a few times with a shovel on the floor (*ibid*).

Discussing the issue of poultry feed formulation; the Alabama Cooperative Extension System (n.d.) made a point that, the primary concern when formulating a diet is to meet the bird's nutrient requirements. The authors further pointed that, a bird will eat to satisfy its energy or calorie needs. And that all other dietary nutrients must be provided based on the amount of energy that the chicken will consume and should have the proper balance of energy to other nutrients. Authors as well pointed out that feed consumption differs with seasons of the year and breed of the chicken. During summer, feed consumption tends to decrease as environmental temperature increases, so protein, energy, vitamins, and minerals must be increased in the diet. In the winter, the opposite is true and birds eat more to maintain their body heat. Growing birds require more protein than mature chickens do. In addition, heavy meat-type chickens require more protein than lighter egg-laying strains do. Nutrients that include protein, energy, vitamins, and minerals comprise the most important part of a feed. Different combinations of feed ingredients can be selected to formulate a diet with the

same nutrient composition, while the ingredients used may be subject to change due to availability and cost (*ibid*).
Addressing the issue of feed quality, Frame (2008), pointed that feed quality will affect feed consumption. He also insisted that the feed provided to birds should not be stale, rancid, or moldy. Frame (2008), further added that feeds should be stored away from heat, moisture, and direct sunlight. On the case of purchased feeds, here are his instructions, "purchase feed as fresh as possible. Vitamins will start to degrade if finished feed is stored for prolonged periods. Plan your schedule so that new feed is purchased at least every two months and check for a recent manufacturing date on the bag before buying".

Frame (2008), also addressed the issue of incompleteness of individual feed ingredients. No one feed ingredient contains all the nutrients required for a complete diet. When mixed together, ingredients complement each other to form a complete feed. Each feedstuff has a place in a balanced diet. The author pointed out various ingredients and the nutrients they supply as; corn, sorghum, wheat and other grains – these are sources of carbohydrates which supply energy to the birds. On the other side soybean meal, meat products, canola meal and fish meal are sources of protein which supply amino acids. Fats (supply energy). Vegetable oil, tallow, blended fat products are the sources of fats. Mineral Salts include limestone, calcium carbonate, calcium phosphate, oyster shell and commercial trace mineral mix. Further, commercial vitamins should be added to feeds to make it balanced. These ingredients have to be mixed in different proportions and sold in the form of a mash, pellet, or crumble. Mash feed consists of all ingredients ground into particles and mixed loosely together (*ibid*).

Stressing on the issue of home mixed rations, Fanatico (1998) pointed out that some poultry producers decide to mix their own rations in order to be assured that only 'natural' ingredients are used. According to her, there is safety in mixing poultry rations at own farm level because the farmer is assured of the nature of ingredients. The author further commented that, poultry feed ingredients include energy concentrates such as corn, oats, wheat, barley, sorghum, and milling by-products. Protein concentrates include soybean meal and other oilseed meals (peanut, sesame, safflower, sunflower, etc.), cottonseed meal, animal protein sources (meat and bone meal, dried whey, fish meal, etc.), grain legumes such as dry beans and field peas, and alfalfa. Grains are usually ground to improve digestibility. Soybeans need to be heated-usually by extruding or roasting-before feeding in order to deactivate a protein inhibitor. Soybeans are usually fed in the form of soybean meal, not in "full-fat" form, because the valuable oil is extracted first. Whole, roasted soybeans are high in fat which provides energy to the birds (*ibid*).

2.4 Chicken feed formulation

This section broadly covers a number of aspects including; meaning of feed formulation, rationale of formulating feeds at farm level, important considerations when formulating feeds at farm level, methods of poultry feed formulation, meaning of linear programming, assumptions of linear programming and necessary information for applying linear programming technique in feed formulation, as well as the linear programming model.

2.4.1 Meaning of feed formulation

Different scientists have defined feed formulation in different ways. However, all of them target to the same central concept. Al – Deseit (2009) defined feed formulation as the process of quantifying the amounts of feed ingredients that need to be put together, to form a single uniform mixture that supplies all nutrients that are required by a particular type or class of animals. The aim of feed formulation is maximization of the returns through minimization of costs. However, cost minimization should not be at the expense of quality which could mean adverse effects to animal health (Eshun, 2008).

In addition to defining feed formulation, Olatunde and Moji (2008) defined a ration. A ration is the total amount of feed given to the animals on daily basis. While ration formulation means the process by which different feed ingredients are combined in a proportion necessary to provide the animal with proper amount of nutrients needed at a particular stage of production.

Moreover, Pasha (n.d.), highlighted that feed formulation is a process by which different feed ingredients are combined in a proportion necessary to provide the bird with proper amount of nutrients needed at a particular age/stage of production. It requires the knowledge about nutrients, feedstuffs and nutritional requirement of the birds in the development of nutritionally adequate rations that will be eaten in sufficient amounts to provide the level of production at a reasonable cost. The ration should be palatable and will not cause any serious digestive disturbance or toxic effects to the birds.

There are basically two types of feed formulations that can be used in poultry farms. These are commercially formulated and self-formulated feeds. Commercial feeds are industrially made by feed manufacturers and are in the form of mashes, crumbles or pellets. On the other hand, there are two options of preparing self-formulated feeds; the first option involves using commercial protein supplements which are in form of concentrates to mix feed on the farm, while the second option involves self-formulating or self-compounding of feed using individual feed ingredients or feedstuffs locally available in a certain locality (Eshun, 2008).

Smith (2001) defined commercial feeds as being composed of several ingredients, mixed in various proportions to form a nutritionally complete diet. Thus instead of being farm-mixed, commercial feeds are mixed by commercial feed manufacturers into primary and secondary forms. According to Ensminger (1992), primary feeds are complete diets, mixed from individual ingredients, sometimes adding a premix at a rate of less than 45 kg per 1000 kg of feed prepared as mash, pellets or crumbles. Secondary feeds are those mixed from one or more ingredients and a concentrate, normally used at the rate of 136 kg per 1000kg (i.e. 30% concentrate) of feed. Numerous types of commercial feedstuffs, ranging from additives to complete rations exist on the market, designed for different species of livestock (Ensminger, 1992).

2.4.2 Rationale of formulating feeds at farm level

According to Olatunde and Moji (2008) poultry feeding is a major item of cost in poultry production industry. The authors highlighted that feed cost accounts for over 70% of the total cost of producing eggs and broiler (*ibid*). That being the case, poultry feeds definitely have a significant impact on profitability and expansion of poultry business. Several commercial farms have collapsed while others have witnessed a slow growth rate due to ever increasing poultry feed costs (Ogundipe, 2002). Moreover, Fetuga (1989) reported that feed costs represent between 70-80% of the total cost of producing various livestock products. This indicates that feed costs are a decisive element in poultry farming profitability. In the same way, Talat (2004) noted that feeds account to over 80 % in poultry production, and that if a farmer is able to bring this cost to about 50 to 60% he stands a better position to make good returns in the poultry business. The fact that various feed ingredients are locally available in different geographical locations where poultry farming is done and that the prime objective of poultry farming is profit maximization, balanced least cost feed formulations have to be made through application of the available techniques as a means towards profit maximization(*Ibid*).

2.4.3 Important considerations when formulating feeds at farm level

Talat (2004) pointed out important considerations that have to be made when formulating feeds at farm level as; acceptability of the feed to the birds, digestibility, cost and presence of anti-nutritional factors. In the aspect of acceptability, the ration being formulated has to be palatable enough to stimulate intake by the birds. Any feed refused by the bird is worthless, since the feed has to be consumed by birds to serve its purpose.

Concerning digestibility, the nutrients in the feed have to be digested and released into the gastrointestinal tract to be utilized by the animals. About cost, it is important to note that the requirement of the birds can be met through several combinations of feed ingredients. However, when the costs of these ingredients are considered, there can only be one least-cost formulation. The least cost ration should ensure that the requirements of the animal are met and the desired objectives are achieved.

Another crucial point according to Talat (2004) is the presence of anti-nutritional factors and toxins in some feed ingredients. This affects the digestion of some nutrients by making them unavailable to the birds. An example is the presence of anti -trypsin factor in soybean meal. Some feed ingredients may also contain toxic substances which may be detrimental to the animal when given in excessive amounts. The inclusion of these ingredients should be limited or eliminated from the formulation (*ibid*).

Moreover, Pasha (n.d.) insisted that certain important considerations have to be taken into account during fee formulation. The author underscored that ration formulation does not merely involve mathematical calculations to meet the requirement of the birds, since the result of the calculation may turn out to be impractical and not ideal for feeding of poultry. Therefore, an experienced animal nutritionist needs to evaluate the feed formulation before it can be given to the birds (*ibid*).

Pasha (n.d,) further explained that several factors have to be considered in making good feed formulations. Such factors include; acceptability of the feed to the birds, digestibility, cost and presence of anti-nutritional factors and toxins. Other factors that should be considered in feed formulation are texture, moisture and the processing that the feed has to undergo (*ibid*).

Addressing the nutritional requirements of birds, Poole (2007), pointed that fowls have a simple digestive tract like humans, and therefore eat similar food, such as cereals and meat. Their food is composed of a number of nutrients that are essential to their health, maintenance and egg and feather production. The six main nutrients are protein, carbohydrates, fats, vitamins, minerals and water. This entails that poultry feed formulation should be carefully done to ensure that all nutrients needed by the birds are available in the feed. Feeds deficient in some nutrients or imbalanced feeds will affect health of birds hence productivity. Stressing on farmers who opt to formulate their own feeds, Poole (2007), guided that in the mixing procedure; the cereals should be weighed out first, and should be coarsely ground, the protein supplements, such as meat meal and *lucerne* meal, should then be mixed in, followed by the vitamin and mineral premix. Mixing can be done in special mixing machines or concrete mixers, or by turning the ingredients over a few times with a shovel on the floor (*ibid*).

Frame (2008) addressed the issue of incompleteness of individual feed ingredients. No one feed ingredient contains all the nutrients required for a complete diet. When mixed together, ingredients complement each other to form a complete feed. Each feedstuff has a place in a balanced diet. The author pointed out various ingredients and the nutrients they supply as; corn, sorghum, wheat and other grains – these are sources of carbohydrates which supply energy to the birds. On the other side soybean meal, meat products, canola meal and fish meal are sources of protein which supply amino acids. Fats (supply energy). Vegetable oil, tallow, blended fat products are the sources of fats. Mineral Salts include limestone, calcium carbonate, calcium phosphate; oyster shell and commercial trace mineral mix. Further, commercial vitamins should be added to feeds to make it balanced. These ingredients have to be mixed in different proportions and sold in the form of a mash, pellet, or crumble. Mash feed consists of all ingredients ground into particles and mixed loosely together (*ibid*).

2.4.4 Some methods of poultry feed formulation that are used at farm level

2.4.4.1 Trial-and-error Method: As the name suggests, the formulation is manipulated until the nutrient requirements of the birds is arrived at. This is the most popular method of formulating rations applied by most poultry farmers (Oladukun and Johnson, 2012). Trial-and error method can be done manually on paper or with the aid of a computer using programme like spreadsheet for example Excel, Lotus123, and Quattro pro. This method makes possible the formulation of a ration that meets all the nutrient requirements of the birds (Jeny, 2004). However, this method is laborious and takes time before one can arrive at a satisfactory result.

2.4.4.2 Two-By-two Matrix Method: This method solves two nutrient requirements using two different feed ingredients. A 2 x 2 matrix is set and a series of equations are done to come up with the solution to the problem (Jeny, 2004).

2.4.4.3 The Person Square Method: Is a simple, well established and popular method of determining the correct proportions of two feed ingredients necessary to obtain a desired level of a particular nutrient. The method is most often used for protein balancing in a particular formulation. The method permits substitution of feed ingredients without disturbing the desired protein content of the diet. It is also used for some other nutrients (Oladukun and Johnson, 2012). Person Square Method relies on the Digestible Crude Protein (DCP) as the basic nutritional requirement for feed. The most common ingredients used are whole maize, maize germ, soya beans, sunflower or fishmeal.

http://www.theorganicfarmer.org Vtag/layers-mash/, illustrates the application of Pearson Square method basing on layers, broiler and local chicken feed formulation: "Assuming that the farmer wants to make feed for their chickens using the Pearson Square method, they have to know the crude protein content of each of the ingredients used in feed making. The farmer may use whole maize (8.23 % DCP), Soya (45 % DCP), Fishmeal (55 % DCP), maize bran (7 % DCP) and Sunflower (35 % DCP). To make a 70 kg bag of feed for layers, a farmer would require the following ingredients: 34 kg of whole maize, 12 kg of Soya, 8 kg of fishmeal, 10 kg of maize bran and 6 kg of Lime (as a calcium source). Each category of chickens has its own requirements in terms of nutrition. For example, feed for layers should have at least 18 per cent crude protein. If one were to formulate feed for layers, then they would have to calculate the percentage of digestible crude protein in each of the ingredients to ensure that the total crude protein content is at least 18 per cent to meet this nutritional requirement.

To find out if the feed meets this standard, a farmer can do a simple calculation as follows:
Whole maize = 34 kg x 8.23 ÷100 = 2.80 kg
Soya bean = 12 kg x 45 ÷ 100 = 5.40 kg
Fishmeal = 8 kg x 55 ÷ 100 = 4.40 kg
Maize bran = 10 kg x 7 ÷ 100 = 0.70 kg
Lime = 6 kg x 0 ÷ 100 = 0.00 kg
(Total crude protein 13.30 kg)

To get the total crude protein content of all these ingredients in a 70 kg bag, you take the total crude protein content of the combined ingredients, divide by 70 and multiply by 100 thus, (13.30÷70) x 100 = 19.0 %. This shows that the crude protein percentage in the above feed formulation is 19.0 % which is suitable for layers. Before mixing the feed, whole maize including the other ingredients has to be broken into the right sizes through crushing or milling to make it palatable for the chickens. Add 250 g of table salt on every 70 kg bag of feed".

The broiler feed formulation is as illustrated in the next section below: "Chickens meant for meat production require feed with a higher content of DCP. From the first to the fourth week, the chicks require feed with a DCP content of energy to the birds. On the other side soybean meal, meat products, canola meal and fish meal are sources of protein which supply amino acids. Fats (supply energy). Vegetable oil, tallow, blended fat products are the sources of fats. Mineral Salts include limestone, calcium carbonate, calcium phosphate; oyster shell and commercial trace mineral mix. Further, commercial vitamins should be added to feeds to make it balanced. These ingredients have to be mixed in different proportions and sold in the form of a mash, pellet, or crumble. Mash feed consists of all ingredients ground into particles and mixed loosely together (*ibid*).

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To find out if the feed meets this standard, a farmer can do a simple calculation as follows:

Whole maize = 34 kg x 8.23 ÷100 = 2.80 kg

Soya bean = 12 kg x 45 ÷ 100 = 5.40 kg

Fishmeal = 8 kg x 55 ÷ 100 = 4.40 kg

Maize bran = 10 kg x 7 ÷ 100 = 0.70 kg

Lime = 6 kg x 0 ÷ 100 = 0.00 kg

(Total crude protein 13.30 kg)

To get the total crude protein content of all these ingredients in a 70 kg bag, you take the total crude protein content of the combined ingredients, divide by 70 and multiply by 100 thus, (13.30÷70) x 100 = 19.0 %. This shows that the crude protein percentage in the above feed formulation is 19.0 % which is suitable for layers. Before mixing the feed, whole maize including the other ingredients has to be broken into the right sizes through crushing or milling to make it palatable for the chickens. Add 250 g of table salt on every 70 kg bag of feed".

The broiler feed formulation is as illustrated in the next section below: "Chickens meant for meat production require feed with a higher content of DCP. From the first to the fourth week, the chicks require feed with a DCP content of between 22 to 24 percent. From the fourth to the eighth week, the chicks require feed with a protein content of 21 to 22 per cent crude protein. To attain this requirement, farmers can formulate feed using the same method given above. To make a 70 kg bags of feed, they will need to have all the right ingredients in the proportions given below:

Whole maize = 40 kg x 8.23 ÷ 100 = 3.20 kg
Omena = 12 kg x 55 ÷ 100 = 6.60 kg
Soya beans = 14 kg x 45 ÷ 100 = 6.30
kg Lime = 4 kg x 0 ÷ 100 = 0.00 kg (Total crude protein 16.10 kg)

To determine if a 70 kg bag of feed has adequate crude protein content for birds meant for meat production, the same methods is used: (16. 10 ÷ 70) x 100 = 23 %. The feed given in this example has a total crude protein content of 23 % which is adequate to feed chicken in this category. In every 70 kg bag of feed, add 250 g of table salt."

Lastly Pearson Square method is illustrated in the formulation of feed for local chickens. Indigenous chickens are less productive in terms of egg and meat increase. They may not require intensive feeding and management. For this category of chickens, farmers can constitute feeds with a DCP of between 15 – 16 %. They can use the following formulation to make feeds for the indigenous chickens:

Whole maize = 33 kg x 8.23 ÷100 = 2.70 kg
Maize or wheat bran = 14 kg x 7 ÷ 100 = 0.98 kg
Fishmeal = 7 kg x 55 ÷ 100 = 3.85 kg
Soya = 7 kg x 45 ÷ 100 = 3.15 kg
Lime = 5 kg x 0 ÷ 100 = 0.00 kg
(Total crude protein 10.68 kg)
Percentage of total crude Protein in the ingredients = (10.68 ÷70) x 100 = 15.25 %)

For farmers rearing hybrid layers and broilers, it is advisable to buy already constituted feeds from reputable companies that sell quality feed. The main reason is that it is very difficult for farmers to constitute micronutrients such as amino-acids, trace minerals, fat and water soluble vitamins that these breeds of chicken require for proper growth. The limitation of the Pearson Square method is that it can handle only two nutrients at a time (Oladokun and Johnson, 2012).

2.4.4.4 Linear programming: Linear programming is the common method of Least Cost Feed Formulation which compares the nutrients required by the animal to the nutrients supplied by the available feed ingredients, and combines them to obtain a balanced diet at the least possible cost (*ibid*). The following section gives a detailed description of linear programming.

2.4. 5 Linear programming

2.4.5.1 Meaning of linear programming

Various scientists have defined linear programming in different ways, however all of them point to the same central concepts – profit maximization or cost minimization. Gale (2007) explained that, the subject of linear programming can be concisely defined. Gale pointed that linear programming is concerned with the problem of maximizing or minimizing a linear function whose variables are required to satisfy a system of linear constraints, a constraint being a linear equation or inequality.

Schulze (1998) offers the following description: "Linear programming is the name of a branch of applied mathematics that deals with solving optimization problems of a particular form. Linear programming problems consist of a linear cost function (consisting of a certain number of variables) which is to be minimized or maximized subject to a certain number of constraints. The constraints are linear inequalities of the variables used in the cost function. The cost function is also sometimes called the objective function. Linear programming is closely related to linear algebra; the most noticeable difference is that linear programming often uses inequalities in the problem statement rather than equalities".

Linear programming was first put into significant use during World War II when it was used to determine the most effective way of deploying troops, ammunitions, machineries which were all scarce resources (Chvatal, 1983). Patrick and

Schaible (1980) stated that linear programming is technically a mathematical procedure for obtaining a value-weighting solution to a set of simultaneous equations. There are hundreds of applications of linear programming in agriculture (Taha, 1987). Olorunfemi et al. (2001) reviewed extensively the use of linear programming in least cost ration formulation for aquaculture. Olorunfemi *et al.*, (2006) applied linear programming into duckweed utilization in least-cost feed formulation for broiler starter. Kuester and Mize (1973) reported that Linear Programming (LP) is a technique for optimization of a linear objective function, subject to linear equality and linear inequality constraints. Linear programming is a computational method of selecting, allocating and evaluating limited resources with linear, algebraic constraints to obtain an optimal solution for a linear, algebraic objective function.

2.4.5.2 Application of linear programming in optimizing agricultural problems

Moatasem *et al.*, (2011) used linear programming technique to formulate least cost balanced ration for white eggs layers at the different stages of rearing and production periods using local feed ingredients. The main goal of their study was to reduce the cost of white eggs production in Jordan. The feed ingredients used were: yellow corn, barley, soybean, wheat bran, concentrate, premix (vitamin/mineral complex), salt, lysine, limestone, soya oil, methionine, and dicalcium phosphate. The researchers constructed Linear Programming (LP) models which were designed to reflect various feedstuff combinations used in the diet formulation, current market prices, nutrient composition and range of inclusion to obtain a least-cost ration for egg layers according to the available feedstuffs in Jordan. The objective of the models was to minimize cost of producing a particular diet after satisfying a set of constraints. The variables in the models were the ingredients while the cost of each ingredient and the nutrient value of each ingredient was the parameter. The results produced using LP technique revealed that the 0-6 weeks of age ration cost was the least compared to the other six ration combinations. It was 310.374 JDs. The 18 weeks to pre-layer ration was the highest in cost. It was 325.001 JDs. The other rations according to hens age were 312.923, 316.778, 323.129, 315.678, and 315.314 JDs for 6-12 weeks, 12-18 weeks, 80 grams/ day feed consumption, 100 grams/

day feed consumption, and 120 grams/ day feed consumption respectively. These costs were lower by nearly 25-45 JDs/ton than those imposed on the producers by the market. The results confirmed the fact that linear programming is a very important technique to allocate the available feedstuffs in a least cost layer ration formulation. The variation in the cost is a result of the variation in the nutrient requirements of the laying hens according to the stage of production. Each stage requires certain level of combined nutrients in the used feedstuffs.

Further, Nath and Talukdar (2014) applied linear programming technique in determining the optimum combination of feed ingredients required for providing a balanced ration for fish in Kamrup District of Assam – India. The aim of their study was cost minimization, due to the fact that controlling feed costs is a critical aspect to the sustainability of the fish Industry. The results of their study found that 22.98 kg of rice bran, 3.96 kg of wheat bran, 15.32 kg of fish meal and 57.72 kg of til cake are the required quantities for the mixture of 100 kg which satisfies the minimum nutrient content requirement of fish. The optimal cost of the 100 kg mixture was found to be ₹1426.57.

Additionally, Al-Deseit (2009), conducted a study on the economic use of the local feedstuffs to formulate least cost rations for broilers using Linear Programming (LP) technique to investigate, analyze and indicate how best the available local ingredients could be combined effectively and efficiently to formulate least-cost ration for broilers. Specifically, a linear programming technique was employed to determine the most efficient way of combining these locally available ingredients. Mathematical models were constructed by taking into consideration nutrient requirements of the broilers, nutrient composition of the available ingredient and any other restriction factor of the available ingredients for the formulation. The result of the study showed that the least cost ration for starter broiler produced by linear programming model consisted of 68.0% yellow corn, 25.07% soybean, 4% wheat bran, 0.5% fish meal, 0.5% Cadiphosphate, 0.1% lysine, 0.32% methoinine, 0.3% limestone, 0.3% NaCl, 0.5% ready premix, 0.4% soya oil and 0.01% vitamins and mineral mix. For the finisher ration the results showed that the ration consisted of 67.5% yellow corn, 20.45% soybean, 5% wheat bran, 0.25% fish meal, 1.5% cadiphosphate, 0.25%

lysine, 0.35% methoinine, 0.3% limestone, 0.5% NaCl, 3% ready premix, 0.75% soya oil and 0.15% vitamins and mineral mix.

Linear Programming Technique has gained grounds in warehouse problems, caterer problems, personnel problems, advertising media selection problems, crude oil refining and gasoline blending, manpower planning, allocation of aircraft to different routes, water quality management, traffic light control etc. It has also made a considerable impact on agricultural, livestock and animal husbandry research in recent years. That signifies how linear programming is a powerful tool in solving agribusiness and farm management problems (Nath and Talukdar, 2014).

2.4.5.3 Assumptions of linear programming

According to Lewis (2008) and Kapoor (2002) the basic assumptions for all linear programming models are; linearity (proportionality), deterministic (or certainty), additively, divisibility and non – negativity.

Linearity (Proportionality): The basic requirement of a linear programming problem is that both the objective function and constraints must be expressed in terms of linear equations or inequalities. The contribution of any variable to the objective function or constraints is proportional to that variable. This concept is analogous to the fact that if the number of machines in a plant is increased, the production in the plant also proportionately increases – of course if all other factors such as raw materials remain constant. Such a relationship, where there is a corresponding increment in a certain variable for every increment in another variable is called linear and can be graphically represented in the form of a straight line.

Deterministic (or certainty): This assumption means that all parameters i.e. all coefficients in the objective function and the constraints are known with certainty. Realistically, however, coefficients and parameters are often the result of approximation. It is realistically not possible to have a situation where the parameters will remain constant forever. Because of this fact, the inclusion of sensitivity analysis in any linear programming problem is important. Sensitivity analysis provides the range within which the linear programming solution holds true.

Additivity: The value of the objective function for the given values of decision variables and the total sum of resources used must be equal to the sum of the contributions earned from each decision variable.

Divisibility: Decision variables can be fractions. However, by using a special technique called integer programming, we can bypass this condition.

Non-negativity: It is usually assumed that variables will take only non – negative values. This is particularly so because in the really life is impossible to have a negative quantity of a certain resource.

2.4.5.4 General requirements of linear programming problem

Certain basic requirements are necessary before linear programming can be employed for optimization problems. According to Kapoor (2002) five requirements elaborated below must be fulfilled for linear programming to be applied.

The first requirement is the identification of the decision variables: The decision variables refer to raw materials, products, resources, projects, services *etc.* that are competing with one another for sharing given limited resources. These variables are usually inter-related in terms of utilization of resources and need simultaneous solutions. The relationship among them should be linear.

The second requirement is a well-defined objective function: A linear programming problem must have a clearly defined objective function. The objective function may aim at profit maximization or cost minimization, depending on the nature of the problem. The objective function should be expressed as a linear function of decision variables.

The third requirement is the presence of constraints or restrictions: There must be limitations or constraints on the use of limited resources which are to be allocated among various competitive activities. Examples of constraints may include production capacity, labor, time, machines, raw materials, space, market, etc. These constraints must be capable of being expressed as linear equalities or inequalities in terms of decision variables. The solution of a linear programming model must satisfy these constraints.

The fourth requirement is the presence of alternative courses of action: There must be alternative courses of action which results to the same optimum solution. It must be possible for example to make a selection between various combinations of the productive factors such as men, machines, material, markets *etc.* and still make the same level of optimum profit or cost.

The fifth and last requirement is the non – negativity restriction: All decision variables must assume non – negative values. This is because it is impossible to have a negative value of a physical quantity.

2.4.5.5 Specific requirements for applying linear programming technique in poultry feed formulation

According to Oladokun and Jonhson (2012) the necessary requirements for applying linear programming technique in poultry feed formulation are; identification of the available feed ingredients and their associated prices, determination of nutrient composition of the available feed ingredients and determination of nutrient requirement of the class of poultry that will be fed the formulated feed. The availability of these information will make it possible to formulate a linear programming model aiming at poultry feed formulation. The following sections give a detailed explanation of each requirement.

Identification of the available feed ingredients and their associated prices: These ingredients are the ones that are used as raw materials in poultry feed formulation. In the linear programming model, these ingredients are the *decision variables* and their prices are the coefficients of decision variables. Ravindran and Blair (1991) classify ingredients according the main nutrient which they supply in the feed. According to Ravindran and Blair (1991) the commonly used energy sources are maize, barley, oats, sorghum and pearl millet. Protein sources are of two types; the plant proteins and animal proteins. Commonly used plant proteins are groundnuts – in form of deoiled groundnut cake, mustard (rapeseed) – in form of deoiled mustard cake and soya beans – in form of deoiled soya cake (Ravindran and Blair, 1992). Deoiling is done so as to reduce the oil content in the feed. Commonly used animal proteins are meat meal and fish meal (Ravindran and Blair, 1993). Commonly used mineral sources include Dicalcium phosphate (DCP), Limestone powder (LSP) and Oyster shell (Moreson, 1988).

Determination of nutrient composition of the available feed ingredients: The nutrient content in each ingredient that is used in poultry feed formulation must be known. These nutrient contents form the coefficients of the constraint equations in the linear programming model. According to NRC (1994) major nutrients found in various ingredients that are used in formulation of poultry feeds include protein, fats (or ether extracts), fibre, calcium, phosphorus, lysine, methionine and metabolizable energy (M.E.). Each ingredient contains a certain amount of these nutrients. The duty of the scientist is to ensure that the final feed formulated comprises of the recommended amount of each nutrient for a particular class of poultry. The application of linear programming technique helps the scientist to accomplish this role (Moatasem *et al.*, 2011).

Determination of nutrient requirements of poultry: Each class of poultry has a specific requirement of certain nutrients. Poultry feeds are formulated on the bases of the requirements of bird in that particular class. Moatasem *et al.*, (2011) points the most commonly formulated chicken feeds as chicks mash, grower's mash, layers mash, broiler starter and broiler finisher. In recent developments in poultry management however, Venkateshwara Hatcheries Pvt Ltd provides a more intensive poultry management plan which categorizes broilers into three groups instead of the traditional two. According to Venkateswara Hatcheries (2010), broiler management stages comprises of pre – starter, starter and finisher. Layers on the other hand comprises of chicks, growers layer I, layer II and layer III. Each class has its own nutritional requirements. The recommended levels of each nutrient for each class of chicken forms the right hand side of the constrain equation in the linear programming model developed for feed formulation.

2.4.5.6 The general model of a linear programming problem

A linear programming model can be formulated using various notations with an inclusion of different decision variables depending on the nature of the problem that is to be optimized. However, each linear programming model must basically contain two parts; the objective function which is to be optimized and the constraints under which the objective function is to be optimized. Kapoor (2002) give a generalized form of a linear programming problem with n decision variables and m constraints in the following form:

Optimize (Maximize or Minimize) $Z = C_1X_1 + C_2X_2 + \dots\dots\dots + C_nX_n$

Subject to the linear constraints:

$$a_{11}x_1 + a_{12}x_2 + \dots\dots + a_{1n}x_n\ (\leq, =, \geq)\ b_1$$
$$a_{21}x_1 + a_2x_2 + \dots\dots + a_{2n}x_n\ (\leq, =, \geq)\ b_2$$
$$\vdots \qquad \vdots \qquad \vdots$$
$$a_{m1}x_1 + a_{m2}x_2 + \dots\dots + a_{mn}x_n\ (\leq, =, \geq)\ b_m$$

and $\qquad x_1, x_2, \dots\dots\dots, x_n \geq 0$

Where;

- X_1, X_2, ...,X_n are the decision variables whose values are to be determined.
- The linear function Z is the objective function which is to be maximized or minimized
- The inequalities are the constraints of the linear programming problem
- The constant coefficients c_j (j = 1, 2, ..., n) are the per unit contribution (profit or cost) of decision variable x_j to the value of the objective function
- The coefficients a_{ij} (i = 1, 2, ..., m; j = 1, 2, ..., n) are the technological or substitution coefficients. They represent the amount of resources consumed per unit of a variable x_j
- b_i(i = 1,2, ..., m) is the constant representing the requirement or availability of the i^{th} constraint.
- The expressions (≤, =, ≥) means only one of the relationships in the set (≤, =, ≥) will hold for a particular constrain (Kapoor, 2002).

Applying linear programming model in animal feed formulation, Saxena (2011) presented the general linear programming model for formulating animal feed where n ingredients are available and m nutrients are required in a particular animal feed. Adapting the model to cost minimization while ensuring balanced status of the nutrients in the feed, as is the case with all animal feed formulation activities, the model is presented as follows:

Minimize $Z = \sum_{j=1}^{n} CjXj$

Subject to; $\sum_{=1}^{n} aijXj \quad \leq, =, \geq bi, \quad i = 1, 2, \ldots, m$

$X_j \geq 0, \qquad j = 1, 2, \ldots n$

Where;

C_j = Price of the j^{th} ingredient
X_j = Quantity of the j^{th} ingredient that is to be included
a_{ij}= Quantity of nutrient i in the j^{th} ingredient
b_i= Quantity of nutrient i recommended for a particular class of animals

Therefore, linear programming is a powerful technique that can be efficiently applied in animal feed formulation

3. METHODOLOGY

3.1 Overview

This chapter presents the methodology that was used in the study. It covers the conceptual framework governing the study, description of the study area, type and sources of data that have been used, sampling procedure and sample size, questionnaire and data collection process, analytical models that have been applied in the study and statistical software that have been used in data analysis.

3.2 Conceptual framework

The conceptual framework displays a pictorial representation of the relationship existing among important variables that are involved in the decision and the general process of formulating chicken feeds at farm level as shown in figure 3.

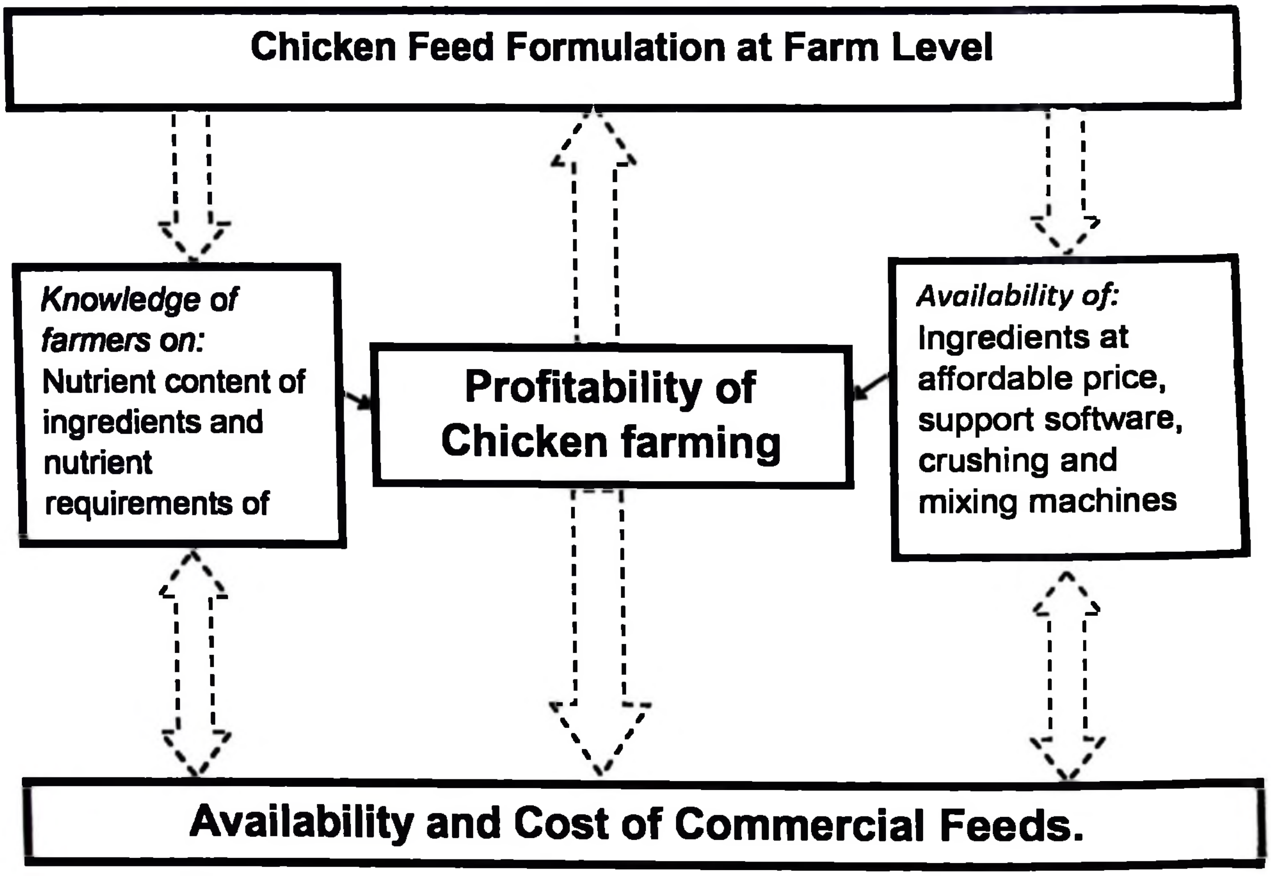
The conceptualization holds that, chicken feed formulation at farm level is dependent on three key aspects: the knowledge of farmers, availability of necessary materials and support technology and prices of commercial chicken feeds. These three factors are the determinants of the central issue – chicken farming profitability.

In analyzing the knowledge aspect, farmers have to be assessed in terms of their level of understanding of the nutrient content of various ingredients that are used in chicken feed formulation. Concurrently with knowing the nutrient content in ingredients, farmers should also have knowledge on the nutrient requirements for various classes of chicken including pre-starter, starter, finisher, chicks, growers and layers. Further, aspects relating to availability of materials and support technology have to be closely analyzed by assessing whether the ingredients that are needed as raw materials in feed formulation are available and of course at affordable price. Additionally, availability of support technology in terms of soft wares that are necessary in the course of balancing the proportion of the ingredients being mixed is important. More over crushing and mixing machines have to be available as these processes cannot be done manually.

The bottom line of chicken feed formulation at farm level is the price of available commercial feeds. If the available commercial feeds are cheaper than the farm formulated feeds, then feed formulation at farm level is economically unjustifiable.

Central to the whole phenomenon i.e. chicken feed formulation at farm level is the profitability issue. All the depicted factors will at the end of a day affect profitability of the farm. The conceptual framework of the study is summarized in Figure 2.

Figure 2: Conceptual framework

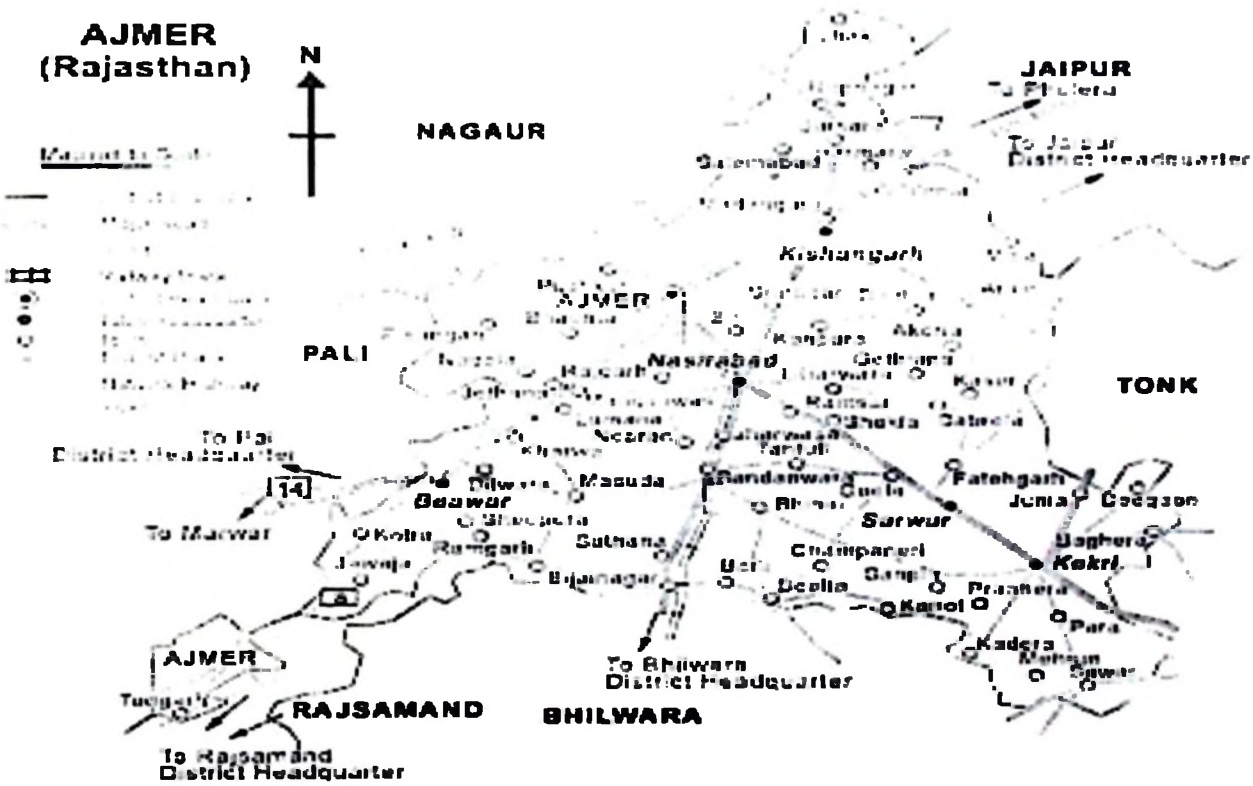


3.3 The study area

3.3.1 Location

The study was conducted in Ajmer district of Rajasthan which is located in the northern part of India. The district lies between latitudes 25° 38′ and 26° 58′ North of Equator and between the longitudes 73° 54′ and 75° 22′ East of Greenwich. The district covers an area of 8,360 km^2. Ajmer district borders, Rajsamand and Bhilwara districts in the South; in the East it borders Tonk district; in the West it borders Pali district, in the North it borders Nagaur district and in the North- East it borders Jaipur district. Figure 3 below shows map of Ajmer district indicating its borders.

Figure 3: Map of Ajmer district



3.3.2 Demography

According to the 2011 India census, Ajmer district has a population of *2,584,913*, which was made up of *1,325,911* males and 1,259,002 females. Ajmer district had an average literacy rate of 70.46 percent, male literacy being 83.93% and female literacy 56.42%
(https://en.wikipedia.org/wiki/Ajmer).

3.4 Justification of the study area

The study area was purposefully selected due to the fact that it is the most popular district in the state in poultry farming. The district has the highest number of poultry farms in the state. Dadheech and Vyas (2012), highlighted that Ajmer is the most popular district in Rajasthan state, as far as poultry farming is concerned. The authors further pointed out that the district has a total number of 250 poultry farms, with 2,500,000 birds including 1,200,000 layers which produce about 700,000 eggs daily. While Dadheech and Vyas (2012) reported about Ajmer district having a total of 250 poultry farms, State Poultry Training Institute (2015) reports that the total number of poultry farms in Ajmer district sums to 619. This is a tremendous increase in the number of farms! An increase of about 147.6% in a span of about three years only! This shows how significant and vibrant the poultry sector is in the district. That being the case, Ajmer district highly qualified to be a study area.

3.5 Data sources

Both primary and secondary data were solicited in this study. The survey covered collection of both qualitative and quantitative data. Secondary data were collected from various electronic sources, mainly *Indiastat.com*. Further, reports at the State Poultry Training Institute government of Rajasthan which is located in Ajmer contributed significantly to accessing secondary data. Primary data were sought from sampled poultry farms.

3.6 Sampling procedure and sample size

As pointed earlier, a purposeful sampling technique was employed in selection of the study district. According to State Poultry Training Institute (SPTI) government of Rajasthan data, Ajmer district currently has a total of 619 poultry farms. Of the 619 poultry farms found in the district about 75 percent are dealing with egg production, while about 25 percent are dealing with broiler production. Hence a proportionate simple random sampling technique was adopted. Of the twenty (20) farms which were to be sampled, 15 (75%) were layer farms and 5 (25%) were broiler farms. Then from each category the representative farms were randomly selected (Chawla, 2011 and Malhotra, 2009). Due to critical financial limitations in this research, the study had to concentrate on a total sample of 20 farms.

3.7 Instrumentation and data collection process

The major survey instrument that was employed in data collection was enumerator – administered structured questionnaire. The enumerator asked questions as they appeared in the questionnaire and recorded the responses accordingly. The technique enhanced the accuracy of the answers recorded. Due to language barrier, the field assistant who is conversant with Hindi language – the language spoken by respondents was hired to assist in interviewing the farmers. The interviewer recorded the answers as given by respondents. Question sections in the questionnaire were organized in accordance to the objectives of the research. The interviews included: Housing and facilities related to housing, feeds and feeding practices, water and watering practices, light and lighting practices, role of natural substances and herbs in poultry disease control and feed formulation from locally available ingredients.

3.8 Detailed strategy for attaining objectives

As pointed earlier, this study was guided by three specific objectives under mentioned; to study the chicken management practices, to study the feeding management practices and to formulate balanced least cost chicken feeds from locally available ingredients for different chicken classes. The following section provides a detailed account on how each objective was attained.

3.8.1 Objective one: To study the chicken management practices

This objective aimed at obtaining a general picture of chicken management practices in Ajmer district. Two popular commercial chicken breeds were considered in this objective. According to expert opinion, Vencobb 400 is the most popular broiler breed in India while BV300 is the most popular layer breed in the country. Aspects that were considered include; housing management, feeding management, lighting management and watering management. Both primary and secondary data were used in executing this objective. From the solicited data, charts and tables have been plotted to show the overall picture of poultry farming in the district.

3.8.2 Objective two: To study the feeding management practices with respect to least cost formulations

Feeds account to over 70 % in chicken production costs (Afolayan, 2008). It follows therefore that feeding is a critical aspect in poultry farming if profit is to be realized (Singh, 2011). This objective specifically explored feeding management practices that are being practiced by farmers in the district, the emphasis being cost aspect. Consideration was done on feeding practices done at different stages of chicken growth and production for popular broiler and layer breeds as pointed in objective one above. Aspects of consideration were type of feed fed i.e. commercial or own formulated feed and costs involved. Both primary and secondary data were solicited to accomplish this objective. The cost of each feeding practice was compared to the alternative least cost formulation.

3.8.3 Objective three: To formulate balanced least cost chicken feeds from locally available ingredients for different poultry classes

Objective three was the anchor point of this study. Its execution involved;

- Identification of the locally available ingredients and their prices. These ingredients are the ones that have been used as raw materials in least cost poultry feed formulation. In the Linear Programming model, these ingredients were used as the *decision variables i.e. the Xs*. The prices of each ingredient were used as the coefficients of decision variables i.e. the coefficients of the Xs.

  The ingredients that were identified include; energy sources, protein sources and mineral sources.
- Specification of the nutrient content in each identified ingredient was done through laboratory analysis of the ingredient samples taken from the study area. The nutrient contents in each ingredient have been used as the coefficients of the constraint equations.
- Determination of the nutrient requirement for each class of chicken including; chicks, growers, layer I, layer II, layer III, pre – starter, broiler starter and broiler finisher using scientifically established chicken feeding guide tables. It means how much of each type of nutrient e.g. protein, fats, energy *etc.* is recommended for each class of chicken. The recommended

quantities of each nutrient have been used to form the right hand side of the constraint equations.

- Developing Linear Programming Models on the bases of locally available ingredients, market prices of the ingredients, nutrient contents of the ingredients, and nutrient requirements for each stage of chicken.
- Having developed the models, appropriate Linear Programming Solvers were used to obtain the balanced least cost combination of the ingredients that are required for each stage of chicken.

3.8.3.1 The Generalized LP Model for chicken feed formulation:

$$Minimize \sum_{j=1}^{n} CjXj \ldots\ldots \quad (j = 1,2,3, \ldots . n)$$

Subject to;

$$\sum_{j=1}^{n} XJ \qquad = \qquad Q \ldots\ldots \; Demand\ constraint$$

$$\sum_{j=1}^{n} aij \geq biL \sum_{j=1}^{n} XJ \ldots\ldots Nutrient \quad constraint$$

$Xj \geq 0$ for j = 1, 2, 3, ...n .... Non negativity constraints

Where;

C_j = Price of the j^{th} ingredient

X_j = Quantity of the j^{th} ingredient that is to be included

a_{ij} = Quantity of nutrient i in the j^{th} ingredient

b_{iL} = Minimum quantity of nutrient i recommended for a particular stage of chicken.

3.8.3.2 Detailed Explanation of the LP model as is applied to this research

3.8.3.2.1 The Objective function

$$Minimize \sum_{j=1}^{n} CjXj \ldots\ldots (j = 1,2,3 \ldots n)$$

Xj: Represented the ingredients whose quantities were to be determined by the LP technique.

There were a total of 14 ingredients, coded as;

X_1 = Maize, X_2 = Pearl millet, X_3 = Deoled rice bran, X_4 = Deoiled soya cake, X_5 = Deoliel mustard cake, X_6 = Deoiled groundnut cake, X_7 = Marble grits, X_8 = Salt, X_9 = Vitamin and mineral premixes, X_{10} = Vegetable oil, X_{11} = Limestone powder (L.S.P.), X_{12} = Dicalcium phosphate (D.C.P.), X_{13} = Lysine and X_{14} = Methionine.

Cj: Represented the per kilogram market prices of the ingredients expressed in Indian rupees. These were parameters in the objective function equation

The parameters for each coded ingredient were as follows;

X_1 = 15.00, X_2 = 13.00, X_3 = 8.00. X_4 = 28.00, X_5 = 15.00, X_6 = 21.00, X_7 = 1.00, X_8 = 15.00, X_9 = 150.00, X_{10} = 90.00, X_{11} = 1.25, X_{12} = 50.00, X_{13} = 110, X_{14} = 250

3.8.3.2.2 The constraints

Optimization was done under a series of constraints which took the form:

$$\sum_{j=1}^{n} aij \geq biL \sum_{j=1}^{n} Xj$$

The constraints that were involved in all the eight stages of chicken studied are illustrated using the layer I stage as follows;

$X_1+X_2+X_3+X_4+X_5+X_6+X_7+X_8+X_9+X_{10}+X_{11}+X_{12}+X_{13}+X_{14}$ >= 100 - Demand constraint in kilograms

$0.1145x_1+0.1243x_2+0.1657x_3+0.4536x_4+0.3551x_5+0.4113X_6+0.78X_{13}+0.95X_{14}$ $\geq 0.18\sum_{i=1}^{14} Xi$ - Protein requirement for a particular stage of chicken

$0.0268x_1+ 0.0459x_2+0.005x_3+0.0024x_4+0.009x_5+0.0064x_6 +1X_{10} \geq 0.033\sum_{i=1}^{14} Xi$ - Ether extract requirement for a particular stage of chicken

$0.037x_1+0.0199x_2+0.1177x_3+0.1061x_4+0.1095x_5+0.1794x_6 \leq 0.06\sum_{i=1}^{14} Xi$ – Crude fibre requirement for a particular stage of chicken

$0.0003x_1+0.0004x_2+0.0037x_3+0.0036x_4+0.0072x_5+0.0031x_6+0.33x_7+0.33X_{11}+0.23X_{12}=0.038\sum_{i=1}^{14} Xi$ – Calcium requirement for a particular stage of chicken

$0.003x_1+0.007x_2+0.015x_3+0.0067x_4+0.011x_5+0.0067x_6+0.17X_{12} \geq 0.0076\sum_{i=1}^{14} Xi$ - Phosphorus requirement for a particular stage of chicken

$0.001x_1+0.0021x_3+0.0029x_4+0.0025x_5+0.0020x_6+0.17X_{12} \geq 0.0046\sum_{i=1}^{14} Xi$ - Available Phosphorus requirement for a particular stage of chicken

$0.002x_1+0.0014x_2+0.0129x_3+0.0038x_4+0.0051x_5+0.0047x_6+0.17X_{12} \geq 0.003\sum_{i=1}^{14} Xi$ -Phytic Phosphorus requirement for a particular stage of chicken

$0.0024x_1+0.0042x_2+0.0064x_3+0.029x_4+0.006x_5+0.016x_6+0.98X_{13} \geq 0.0088\sum_{i=1}^{14} Xi$ - Lysine requirement for a particular stage of chicken

$0.0018x_1+0.0024x_2+0.003x_3+0.0064x_4+0.0038x_5+0.0042x_6+0.98X_{14} \geq 0.004\sum_{i=1}^{14} Xi$ - Methionine requirement for a particular stage of chicken

$3300x_1+2640x_2+1450x_3+2300x_4+1900x_5+2400x_6+8500X_{10}+3900X_{13}+4500X_{14} \geq 2500\sum_{i=1}^{8} Xi$ - Metabolizable Energy requirement for a particular stage of chicken

$40 \leq X_1 \leq 60$ – Maize inclusion level as scientifically specified for a particular chicken stage

$10 \leq X_2 \leq 20$ – Pearl millet inclusion level as scientifically specified for a particular chicken stage

$5 \leq X_3 \leq 10$ – Deoiled rice bran inclusion level as scientifically specified for a particular chicken stage

$10 \leq x_4 \leq 15$ – Deoiled soya cake inclusion level as scientifically specified for a particular chicken stage

$5 \leq x_5 \leq 7$ – Deoiled mustard cake inclusion level as scientifically specified for a particular chicken stage

$5 \leq x_6 \leq 15$ – Deoiled groundnut cake inclusion level as scientifically specified for a particular chicken stage

$6 \leq x_7 \leq 9$ – Marble grits inclusion level as scientifically specified for a particular chicken stage

$X_8 = 0.3$ – Salt inclusion level as scientifically specified for a particular chicken stage

$X_9 = 0.05$ – Premix inclusion level as scientifically specified for a particular chicken stage

$X_{10} <= 0.5$ - Maximum vegetable oil inclusion level for a particular chicken stage

$X_{11} >= 1$ - Minimum L.S.P. inclusion level for a particular chicken stage

$X_{11} <= 2$ - Maximum L.S.P. inclusion level for a particular chicken stage

$X_{12} <= 2$ - Maximum D.C.P. inclusion level for a particular chicken stage

$X_{13} <= 0.25$ – Maximum inclusion level of Lysine for a particular chicken stage

$X_{14} <= 0.25$ – Maximum inclusion level of Methionine for a particular chicken stage

$X_i \geq 0$ for i= 1, 2...14 – Non negativity constraint.

3.9 Software for data analysis

Several types of software were used in data analysis depending on the nature of data. The software used included Excel, SPSS and Linear Programming Solvers.

3.10 Data analysis

3.10.1 Data analysis for objective one

Data analysis for objective one involved plotting of charts and establishment of tables to show the overall picture of poultry farming in Ajmer district.

3.10.2 Data analysis for objective two

Data analysis for objective two involved calculation of various aspects related to chicken feeding practices and associated costs in the district and comparing the costs of the practices which are in use with the least cost formulation developed from this study.

3.10.3 Data analysis for objective three

The LP Solvers were applied in solving the LP models so as to obtain least cost feed formulations. Sensitivity analysis was done to indicate limits in which the given solutions apply.

4. RESULTS AND DISCUSSION

This chapter presents and discusses the results under the following main sections;

i. Socio – economic characteristics of poultry farmers in Ajmer district
ii. Chicken management practices.
iii. Feeding management practices with respect to least cost formulations.
iv. Balanced least cost chicken feed formulation

4.1Socio – economic characteristics of poultry farmers

Researchers address various aspects when studying socio –economic characteristics of poultry farmers. Jatto (2012) addressed gender, age, education level, experience, marital status, main occupation of the farmer, involvement of the farmer in cooperative societies and contact with extension services. Similarly, Okoli (2004) addressed marital status, age of the farmer, education level, area of academic specialization, experience in poultry farming, labor employment, involvement in other occupations and capital sources. In studying socio – economic characteristics of poultry farmers, the current research considered gender, marital status, age of the farmer, education level, area of academic specialization, experience in poultry farming, farm management personnel, initial investment, current level of investment, total farm capacity, capacity utilization, labor requirement, labor availability, labor cost, type of poultry project dealing with, age of the farm and flock size.

4.1.1 Gender

The result of the study shows that 100 per cent of the sampled farms were managed by males. This high level of male dominance in farm management may be because culture and traditions play crucial roles in deciding who is to do what in the process of proving livelihoods of the people in the household. Putting it in another way, males are considered as bread winners while females have to take care of children and other household activities. The implication of male dominance in farm management is that productivity is expected to be high because males have tendency to be more labor efficient, especially in harsh activities involved in field work. Taking labor efficiency into concern, these findings are supported by Reddy (2008) that three women are equivalent to two men. Table 5 summarizes gender distribution in farm management.

Table 5: Gender of farm managers

Gender	Frequency	Percent	Valid Percent	Cumulative Percent
Male	20	100.0	100.0	100.00

Source: Survey data, 2015

4.1.2 Marital status

The results show that 95% of the farmers were married. This shows that the respondents are responsible people according to the societal norms and therefore are likely to have some experience of life. It is also generally accepted that married people, especially men have better settled minds which is an important attribute towards efficiency in work. Further, marriage means availability of family labor which can contribute to farm production. The findings are in line with the results of Oluwatayo (2008) that married farmers tend to have large family to compliment family labor to enhance production and reduce the cost of hired labor. Table 6 summarizes the marital status of farmers.

Table 6: Marital status of sample farmers

Marital status	Number of farmers	Percent	Valid Percent	Cumulative Percent
Married	19	95.0	95.0	95.0
Unmarried	1	5.0	5.0	100.0
Total	20	100.0	100.0	

Source: Survey data, 2015

4.1.3 Age of the farmer

The results show that majority of the farmers were relatively young and are still in their active age. The mean age of the farmers was 45 years, the minimum age was 27, the maximum age was 72 and range was 45. The implication is that younger farmers are likely to adopt new innovation faster than the older ones. The results also imply that poultry farming is likely to be sustainable in Ajmer district as more young people are involved in this business. The results supported by Adegbite *et al.*, (2006), who found that the most active people in entrepreneurial activities were found within the age range of 25 to 44 years. This implies that there are prospects of poultry industry further growing in the study area due involvement of young people in the business. Table 7 shows the age distribution of farmers in the study area.

Table 7: Age of the sample farmers

Age group	Number of farmers	Per cent	Cumulative per cent
Below 35	5	25	25
36 - 50	11	55	80
Above 50	4	20	100
Total	20	100	100

Source: Survey data, 2015

4.1.4 Education level

The result shows that majority of the poultry farmers had informal education, meaning that they are less educated. The distribution of respondents' education wise was: Informal education - 40%, 8th class – 5%, 10th class - 25%, 12th class – 5% and graduates - 25%. The low level of education might be affecting the bargaining power and decision making of the farmers in one way or another. These findings are contrary to Okoli (2004) who found that the level of education of commercial poultry farmers was high, hence influencing their resource allocation ability, innovation adoption rate and bargaining power. The results are further contrary to the findings of Bhande (2006) who reported that 54.17 per cent of broiler farmers in Bangalore had attained secondary education. However, Dev (2012) reported that generally the education level of small and marginal farmers in India is low, a fact which is in line with the findings of this research. Table 8 shows the education level of farmers in the study area.

Table 8: Education level of sample farmers

Education level	Number of farmers	Percent	Valid Percent	Cumulative Percent
Informal	8	40.0	40.0	40.0
8th	1	5.0	5.0	45.0
10th	5	25.0	25.0	70.0
12th	1	5.0	5.0	75.0
Graduation	5	25.0	25.0	100.0
Total	20	100.0	100.0	

Source: Survey data, 2015

4.1.5 Area of academic specialization

The results show that 100% of farmers dealing with poultry farming are from academic areas other than agriculture and livestock. This implies that either graduates of agro –livestock related courses are poorly oriented that they fail to link classroom knowledge with actual field practical or are lacking finances that could help them invest in poultry farming. These finding are in line with Okoli (2004) that graduates from agro – livestock related courses lack practical orientation that is important for future investment and self-employment in the agro – livestock field. The implication is that programs like Agri Clinics and Agribusiness Centre can advise agriculture graduates to explore investment possibilities in poultry farming which is a growing and lucrative sector in India. Table 9 shows the area of academic specialization of farmers in the study area.

Table 9: Area of academic specialization of sample farmers

Specialization	Number of farmers	Percent	Valid Percent	Cumulative Percent
Others	20	100.0	100.0	100.0
Agric.	0	0.00	0.00	0.00

Source: Survey data, 2015

4.1.6 Experience in poultry farming

The results show that the experience of farmers ranged from 1 to 30 years, with the mean being about 11years. Further the years of experience were positively skewed, with the skewness value beings 2.24. This implies that most farmers had higher experiences in poultry farming (Chawla and Sondh, 2009). The business implication is that farmers will be more efficient and more likely to earn high profits in the business. The findings support Oluwatayo (2008), that farmers with more experience would be more efficient, have better knowledge of climatic conditions and market situation and are thus, expected to run a more efficient and profitable enterprise. The results are also supported by the findings of Onyebinama (2004), that previous experience in farm business management enable farmers to set realistic time and cost targets, allocate, combine and utilize resources efficiently and identify production risks.Table 10 shows the level of experience among farmers in poultry farming the study area.

Table 10: Experience of poultry owners in poultry farming

Years of experience	Number of farmers	Per cent	Cumulative per cent
Up to 5	5	25	25
6 - 10	8	40	65
Above 10	7	35	100

Source: Survey data, 2015

4.1.7 Farm management personnel

The results show that 90% of farmers are owner managers, while 10% of the farmers hire management personnel. This implies that farmers in the study area are operating at a micro, small or medium scale hence is uneconomical for them to employ a farm manager. The results further show that the rate of labor employment ranged from 2 to 25 employees per farm. According toKushnir (n.d), on the bases of level of labor employment, these firms are mainly operating at micro and small scale level. According toKushnir (n.d), firms are divided into the following categories: micro (1 to 4 employees), small (5 to 9 employees), medium (10 to 99 employees), and large (100 or more employees). Similarly, Okoli

(2004) found that 68 percent of poultry farmers employed 1 to 5 workers per farm. That being the case, farms in the study area operates within micro, small and medium scale levels. Table 11 shows farm management approaches in the study area.

Table 11: Farm management approach

Type of manager	Number of farmers	Percent	Valid Percent	Cumulative Percent
Owner	18	90.0	90.0	90.0
Hired	2	10.0	10.0	100.0
Total	20	100.0	100.0	

Source: Survey data, 2015

4.1.8 Initial investment in rupees

The results show that the initial investment of farmers ranged from ₹ 200, 000 to ₹2,500,000 with the mean being ₹767500.According to the provision of Micro, Small & Medium Enterprises Development (MSMED) Act, 2006 of the Government of India, the Micro, Small and Medium Enterprises (MSME) are classified based on the level of investment as follows:

Micro enterprises: Investment does not exceed twenty-five lakh rupees (≤ 2,500,000)

Small enterprises: Investment is more than twenty-five lakh rupees but does not exceed five crore rupees (2,500,000 – 50,000,000)

Medium enterprises: Investment is more than five crore rupees but does not exceed ten crore rupees (50,000,000 – 100,000,000)

Large enterprises: Investment is more than ten crore rupees (above 100,000,000).

In accordance to this system of classification, Ajmer poultry farmers started operating their projects at micro level.

Table 12: Initial investment statistics

Statistic (N = 20)	Value (₹)
Mean	767,500.00
Minimum	200,000.00
Maximum	2,500,000.00
Range	2,300,000.00

Source: Survey data, 2015

4.1.9 Current level of investment in rupees

The results show that the current level of investment of farmers ranged from ₹ 500,000 to ₹ 200,000,000, with the mean being 15,870,000. According to the provision of Micro, Small & Medium Enterprises Development (MSMED) Act, 2006 of the Government of India, system of project classification, the mean level of investment value has increased from rupees767, 500.00 to 15,870,000.00, hence shifting farmers from micro level of operation to small scale level of operation. This hints that the poultry sector is growing in the area. Further, 70 percent of farmers reported to be doing some development activities such as house construction and buying cars from the profit which they get from poultry farming. The results are supported by Okoli (2004) who found that 76.4 percent of poultry farmers invested in house construction and buying other tangible assets using the money they acquired from poultry farming.

Table 13: Paired Samples Statistics for initial and current level of investment

Investment stage	Mean	N	Std. Deviation	Std. Error Mean
Initial investment	767,500.00	20	698169.599	156115.468
Current value	15,870,000.00	20	43653686.165	9761260.973

Source: Computation from survey data, 2015

4.1.10 Total farm capacity (Number of birds that can be accommodated at a time)

Farm capacity was considered as the total number of birds that the farm can accommodate at a time. The result shows that farm capacities ranged from 1500 to 100000 birds at a time. The mean capacity was 19965 birds. Comparing farmers in terms of projects they are dealing with i.e. broiler or layer farming, the mean farm capacity of broiler farmers was significantly lower than the mean capacity of layer farmers ($z = -2.841$, $p = 0.002$). It means layer farmers are comparatively wealthier and larger than broiler farmers. These results are supported by Dadheech and Vyas (2012) who commended that layer farming is more profitable than broiler farming.

Table 14: Comparison of total farm capacity project wise

Poultry project	N	Mean Rank	Sum of Ranks
Layers farming	15	12.67	190.00
Broiler farming	5	4.00	20.00
Total	20		

Source: Computation from survey data, 2015

Table 15: Test statistics for total farm capacity project wise comparison

Test Statistics	Total capacity
Mann-Whitney U	5.000
Wilcoxon W	20.000
Z	-2.841
Asymp. Sig. (2-tailed)	.004
Exact Sig. [2*(1-tailed Sig.)]	.002[b]

Source: Computation from survey data, 2015

4.1.11 Capacity utilization

The results show that capacity utilization ranged from 53% to 100%. Of the total farmers sampled, only 35% makes full utilization of the farm capacities. The rest of the farmers operate below capacities of their farms. Further analysis showed that the farm capacity utilized was significantly lower than the total capacity (t =

3.206, p = .005). These results are supported by Dadheech and Vyas (2012) who observed that the demand of eggs and chicken meat in India is low during summer season and high during winter season, consequently farmers reduce the stocking rate i.e. the number of birds kept during summer and increases the number during winter. The fact that the survey was conducted during summer season tells why there was low capacity utilization. The implication is that farmers need to be assisted with processing technology so as to increase the shelf life of poultry products.

Table 16: Percentage of capacity not used

Statistics (N = 20)	Value
Mean	16.55%
Skewness	0.646
Std. Error of skewness	0.512
Minimum	0%
Maximum	47%

Source: Computation from survey data, 2015

Table 17: Paired samples statistics for total capacity and capacity used

Variable	Mean	N	Std. Deviation	Std. Error Mean
Total capacity	19965.00	20	22934.650	5128.344
Capacity used	15660.00	20	18185.489	4066.399

Source: Computation from survey data, 2015

Table 18: Paired samples test for total capacity and capacity used

Pair	Mean	Std. Deviation	Std. Error Mean	t-value	p-value
Total capacity & Capacity used	4305	6004.864	1342.728	3.206	0.005

4.1.12 Labor requirement and Availability

The results show that the minimum labor requirement per farm was 2 and the maximum was 25. This is obvious that labor requirement is dependent on farm size. Further, there was a 1.00 correlation between labor requirement and labor availability in the study area (p = .000). It means labor is readily available. Whatever quantity is needed; it can be supplied. 100% of farm owners claimed to experience no problems related to labor availability. This implies that the unemployment is still a problem in the country and that poultry sector can contribute to employment creation. This result is supported by the statistics provided by the Ministry of Labor and Employment, Government of India (2014) retrieved at www.tradingeconomics.com. It is reported that the unemployment rate in the country is 4.9 per cent.

4.1.13 Labor cost

The labor cost incurred per farm ranged from ₹ 0 to ₹ 250000. The mean labor cost was ₹ 25000. Considering the costs project wise, farmers dealing with broiler farming didn't incur labor costs in running their projects. 100% of the broiler farmers incurred no direct labor costs in running the project. This implies that broiler farmers use family labor in running the projects. This might further be attributed by the fact that they are comparatively less wealth than layer farmers. That being the case, the costs of labor in running broiler projects was significantly lower than the cost of running a layer project (z = -2.927, p = .003).Jatto (2012) pointed out that it is a common phenomenon for poultry farmers to run farm operations by using family labor.

4.1.14 Main occupation

The results show that poultry farming is the main occupation to all farmers that are engaged in it in the study area. This indicates that poultry farming is not a part time job in the study area and that all farmers depend on the business as the major means of livelihood. This further explains the reason why poultry sector is very efficient in the study area. Farmers are taking it seriously as an employment. The results are supported by Kaulich (2012) who suggested that by becoming more specialized, the allocation of resources becomes more efficient.

4.1.15 Cooperative society

The results show that all farmers in the study area have no affiliation to any cooperative society or any other organ that gives them a common voice. The implication of this result is that farmers are likely to have low bargaining power when it comes to marketing of their products. This might also lead to lacking some important current information which they could be sharing had there been any cooperatives. The results are supported by SPTI (2015) who stated that poultry farmers in Ajmer are having a low bargaining power because there is no organ that mobilizes them and gives them a collective bargaining power when selling their products. Considering what is happening in other parts of the world, the results are contrary to the observations of Jatto (2012) who found that majority of poultry farmers were participating in cooperative societies and enjoying access to credit facilities, information on current innovations and a collective bargaining power.

4.1.16 Extension services

The result indicated that all farmers had close contact with private extension services. The feed suppliers were also offering extension services. This tells why the poultry sector is very active in the study area. It is because there is a mutual relationship between farmers and feed companies. Feed companies need farmers as their market. Farmers need companies as their input source. This symbiotic relationship entails sustainability. These results are supported byHanson and Dare (2014) who found that some input suppliers bundle extension and credit services together as their strategy to sell their inputs. This tendency improves efficiency of the farmers and credibility of input companies. The results also showed that most farmers had less connection to the public extension services as compared to the private extension services; a fact which is supported by Jatto (2012) who found that majority of poultry farmers had no contacts with pubic extension services.

4.1.17 Type of poultry project

There are several alternatives of poultry projects that one can engage in. Such projects include layer farming, broiler farming, chicks' production (hatchery), feed formulation and many others such as manure production and feathers. However, the results show that 75% of the farmers deal with layer farming while 25% deal with broiler farming. This implies that layer farming is a lucrative business. This might be attributed by the fact that most Indians living in the northern part of the country particularly Rajasthan are vegetarians. This life style reduces the market of chicken meat. Being a perishable product, meat cannot be stored for a long time under room temperature; special cold rooms are needed for preservation and transportation a fact that many broiler farmers can't afford. Compared to chicken meat, the shelf life of eggs is long – hence enhanced marketability.

Other projects such as chick production in terms of a hatchery and feed formulation are in fact more profit making than even egg production. However, establishment of these projects requires a substantial capital investment, as well as technical and scientific knowledge – qualities which most lay farmers lack. Asked to arrange chicken projects in order of profitability, starting from the most profitable to the least profitable, most farmers listed the projects in order of; hatchery, feed formulation, layer farming and broiler farming. This means in addition to profitability of the type of poultry project, financial muscles of the farmer decides which project he should engage in. This fact is proven by the reality that in Ajmer district, while there are 465 layer farms and 154 broiler farms, there are only 4 parent stocks for chicks' production and 6 feed mills for feed formulation (SPTI, 2015). Only few with sufficient capital, knowledge and technology can successfully invest in parent stocks and feed mills.

4.1.18 Age of the farm

While age of the farmer, experience in poultry farming and age of the farm appears to be closely related, each one of them has its own meaning and implication. Age of the farm means for how long has the farm been in operation. The results show that the age of farms ranged from 1 year to 25 years. The mean age was 10 years and the modal age was 10 years as well. This implies that poultry farming is both a mature and sustainable business in the study area.

4.1.19 Flock size

The number of chicken that were presently available during the time of research ranged from 1500 to 80000. The mean number stood at 15595. Further analysis showed that layer farms had significantly higher number of birds kept than broiler farms ($z = -2.752$, $p < 0.01$). As pointed earlier, this implies that layer farming is more lucrative than broiler farming. According to TNAU(n.d.), larger size units are more economical than smaller ones under commercial conditions. A unit of 2000 layers is usually considered as economical for commercial egg production. In the case of broilers, a unit intake of 250 chicks per week is usually considered as viable. Considering the flock size project wise, the mean flock size in layer farms was 19467 birds. This size is significantly higher than the minimum size of 2000 layer birds that is considered to be commercially economical for egg production (TNAU, n.d.).

Table 19: One-sample statistics for flock size in layer farms

Variable	N	Mean (birds)	Std. Deviation	Std. Error Mean
Flock size in layer farms	15	19466.67	19563.511	5051.277

Table 20: One-sample test for flock size in layer farms

Test Value = 2000

Variable	t-value	p-value	Mean difference
Flock size in layer farms	3.458	0.004	17466.667

Source: Computation from survey data, 2015

On the part of broiler farms, the mean flock size was found to be 3980 birds. This size is significantly higher than the minimum size of 250 broiler birds that is considered to be commercially viable for a broiler project (TNAU, n.d.)

Table 21: One-sample statistics for flock size in broiler farms

Variable	N	Mean	Std. Deviation	Std. Error Mean
Flock size in broiler farms	5	3980.00	3490.988	1561.217

Table 22: One-sample test for flock size in broiler farms

Test Value = 250

Variable	t-value	p-value	Mean difference
Flock size in broiler farms	2.389	.075	3730.000

Source: Computation from survey data, 2015

These results are supported by Dadheech and Vyas (2012) who highlighted that Ajmer is the most popular district in Rajasthan state, as far as poultry farming is concerned. The authors further pointed out that the district had a total number of 250 poultry farms by then. The results are further supported by State Poultry Training Institute (2015) which reported that Ajmer district is currently having a total number of 619 poultry farms. The significantly larger flock mean sizes in comparison to the minimum acceptable limits, tells why Ajmer is the most popular district in poultry farming in Rajasthan state. This fact further underscores that poultry farming is a profitable business. Having explored the socio – economic characteristics of poultry farmers in the study area, the next section dived deeply on chicken management practices as practiced by farmers in the study area.

4.2 Chicken management practices

This section presents the results of chicken management practices as practiced by farmers in the study area. In each management aspect, a comparison is made with the standard management specifications.

4.2.1 Chicken rearing system

As summarized in table 23, the results show that 70% of the farmers have adopted the cage system and the remaining 30% have adopted the deep litter system. None of the farmers are practicing neither the free range nor the house and run system. Looking at the matter project wise, 100% of broiler farmers have adopted the deep litter system while 93.3% of layer farmers have adopted the cage system. Only 6.7% of layer farmers have gone for deep litter system. Comparatively, the layer farmers who have adopted the deep litter system are smaller farmers as compared to those who have adopted the cage system. As pointed earlier, project wise comparison shows that layer farmers are wealthier than broiler farmers. This has the following implications; first, cage system requires a large capital investment as compared to deep litter system, second, cage system is an efficient way of commercial egg production as compared to deep litter system and lastly, Ajmer layer farmers are business minded. These results are firstly supported by Savory (2004) who pointed out that worldwide, approximately 80 percent of commercial egg production is done in battery cages. The results are further supported by Gerzilov (2012) who found that the layers that were kept in cages exhibited an average egg laying capacity of 336.1 eggs per hen, the egg laying capacity was over 90 % from 25 to 50 weeks of age, the mortality was the lowest - 5.35 % and feed conversion ratio per egg was the highest - 155.9 g. On contrast, the layers reared in the deep litter system were characterized with the lowest yield of eggs per hen - 330.5 eggs, the egg laying capacity was over 90 % from 26 to 61 weeks of age, the mortality was the highest - 9.43 % and feed conversion ratio per egg was 151g. Further, TNAU (n.d) describes the cage system as a super intensive system of chicken rearing with its advantages being greater number of birds is reared per unit of area, facilitating correct maintenance of records, easy identification of poor producers and prompt culling, control of vices of poultry such as cannibalism and egg eating, ensuring production of clean eggs, removal of stress factors, easy control of parasitic diseases like *coccidiosis* and worm infestation, minimum feed wastage, an ideal system for the area of moderated climate conditions where temperatures are not extreme, higher egg production per bird than it is in deep litter system and better feed efficiency and egg weight in caged birds than the laying flock under deep litter system. These benefits might be the reasons that attract most layer farmers to adopt the cage system as opposed to deep litter system in the study area.

Table 23: Chicken rearing system adopted

System	Number of farmers	Percent
Deep litter	6	30
Cage system	14	70
Free range	0	0
House and run	0	0
Total	**20**	**100**

Source: Survey data, 2015

4.2.2 Space management in cage system

This section considered aspects related to cage size and number of birds placed in each cage.

4.2.2.1 Cage size

The results as presented in table 24 show that the cage sizes ranged from 1320 cm^2 to 1400 cm^2. The mean size was 1339 cm^2. These results deviate from the recommendations of TNAU (n.d.) which proposes that the standard cage size should be 1463 cm^2. In this regard the cage sizes practiced by farmers are significantly smaller than standard cage size ($p<0.001$). This implies that farmers are trying to reduce costs of materials which are used to construct the cages.

Table 24: One-sample statistics for cage size

Variable	N	Mean	Std. Deviation	Std. Error Mean
Cage size	14	1338.5714	27.76471	7.42043

Source: Computation from survey data, 2015

4.2.2.2 Number of laying birds placed in each cage.

The results indicate that 78 percent of farmers place four laying birds in each cage. The remaining 22 percent place three laying birds per cage. The number of birds per cage is significantly higher ($p < 0.05$) compared to the standard provided by TNAU (n.d.) of 1, 2 or maximum 3 birds per cage, the mean being 3 birds per cage.

Table 25: One-sample statistics for layers in cage

Variable	N	Mean (birds)	Std. Deviation	Std. Error Mean
Number of layers in a cage	14	3.78	.441	.147

Source: Computation from survey data, 2015

Table 26: One sample test for number of layers in a cage

Variable	t-value	p-value	Mean Difference
Number of layers in a cage	5.292	.001	.778

Source: Computation from survey data, 2015

Considering the average cage size of 1339cm^2 practiced in the study area and the four birds per cage that is predominantly practiced, it means each laying bird is provided a space of about 335cm^2. This space is small compared to the standard space provided of 450 – 525cm^2 per laying bird proposed by TNAU(n.d.) and 550cm^2 per laying bird which is proposed by the European Union (Canadian Coalition for Farm Animals, 2005). What is generally seen here is that, farmers have small cages compared to the standard cages while at the same time they place a larger number of birds as compared to the proposed standard. The standard cages are larger and at the same time the number of birds placed is less. This implies that farmers are trying to minimize construction material costs by constructing small cages and at the same time maximize the number of birds kept by placing many of them in one cage. However, this is against animal welfare principles (Savory, 2004).

4.2.3 Space management in deep litter system

Space provision for chicken in deep litter system is quite different from that done in cage system. The deep litter system provides a freer environment for both layer and broiler chicken (Savory, 2004). This section provides results of the study in space provision for both layer and broiler chicken in deep litter system.

4.2.3.1 Space of laying birds in deep litter system

The results of the study show that layer farmers who have adopted deep litter system provide a living space of 2.0 square feet per laying bird. These results are supported by Pištěková (2006) who proposed that each broiler require one square foot of floor space while a layer requires 2.0 square feet of floor space under deep-litter system of rearing. The authors further clarify that the size of the house depends on the number of birds to be reared. The results are also supported by McPhee (2002) who suggests that chicken should be given a plenty of space for movement and exercise as well as areas to nest and perch. McPhee (2002) further explain that chicken also need somewhere to eat and drink. Concerning the floor space, the author suggested that a house of about 1 meter square gives plenty of space for a flock of 5 or 6 hens. This implies that each hen is provided an allowance of about 2 square feet. Hence as far as floor space is concerned, layer farmers who have adopted deep litter system are doing the right practice.

4.2.3.2 Space of broiler birds in deep litter system

The results in table 27 show that broiler farmers provide an average floor space of 1.2 square feet per bird. This space allowance does not significantly differ from Pištěková (2006) and TNAU (n.d.) who proposes a floor space of 1 square foot per broiler bird. That being the case, broiler farmers are doing the right practice in as far as floor space provision is concerned.

Table 27: One-sample statistics for space of broiler birds in deep litter system

Variable	N	Mean (birds)	Std. Deviation	Std. Error Mean
Area of boiler in deep litter	5	1.200	.2739	.1225

Table 28: One sample test for space of broiler birds in deep litter system

Variable	t-value	p-value	Mean Difference
Space of broiler in deep litter	1.633	.178	.2000

Source: Computation from survey data, 2015

4.2.4 Feeding space management

4.2.4.1 Type of feeders

The results in table 29 show that 30 percent of the farmers use round industrially made plastic feeders. These feeders are specifically designed for chicken feeding. Further observation showed that this 30 per cent was comprised of all farmers who had adopted the deep litter system. These farmers have comparatively smaller number of birds – mean number being birds 3983 as compared to those who have adopted the cage system whose mean is 16920 birds. The remaining 70 per cent of farmers have adopted the long feeders which are semi – automatic, and these are the ones who practice cage system and have a large number of chicken. These results are supported by Maas (2006) who commented that if there are only few chickens, hand-filled feeders are the best, otherwise automatic feeders will be best for large flocks of chicken. Maas (2006) further comments that feeders can either be rectangular or round shaped. The authors further underscored that it is important to ensure that there are enough feeders which are evenly distributed in the whole building to avoid chicken from scrambling for feed. The fact that farmers with many birds have gone for long semi – automatic feeders and those with few birds have gone for round feeders which are manually filled implies that the extension services are efficient in the study area and that farmers are receptive to innovations.

Table 29: Type of feeders used

Feeder type	Number of farmers	Percent	Valid Percent	Cumulative Percent
Round	6	30.0	30.0	30.0
Rectangular	14	70.0	70.0	100.0
Total	20	100.0	100.0	

Source: Computation from survey data, 2015

4.2.4.2 Space of birds feeding in a round feeder

A sufficient space must be provided to each bird to provide freedom during feeding. The results from the survey show that the mean feeding space provided to each bird in a round feeder is 4.67cm. This space is significantly higher than the standard space of 4cm which is proposed by Venkateshwara Hatcheries (2010) and McPhee (2002) who proposed that when circular feeders are used, there should be at least 4 cm feeding space per bird ($p < 0.05$). The implication is that farmers are doing the right practice. This is because Venkateshwara Hatcheries and McPhee gave the minimum limit and farmers are operating above the minimum limit. Moreover, Maas (2006) commented a space of 5cm per bird in a round feeder. Hence farmers in Ajmer district are doing the right management practice in as far as feeding space in round feeders is concerned.

Table 30: One-sample statistics for space of birds feeding in round feeder

Variable	N	Mean (birds)	Std. Deviation	Std. Error Mean
Space of birds feeding in round feeder	6	4.67	.516	.211

Source: Computation from survey data, 2015

Table 31: One-sample test for space of birds feeding in round feeder

Test Value = 4

Variable	t-value	p-value	Mean Difference
Space of birds feeding in round feeder	3.162	.025	.667

Source: Computation from survey data, 2015

4.2.4.3 Space of birds feeding in a rectangular feeder

The results in table 32 show that the space provided to each bird ranged from 10 to 12 cm. The mean space was 10.93cm. Further analysis show that the space provided to each bird by farmers is significantly larger than the space recommended by Venkateswara Hatcheries (2010) of 10cm per bird ($p < 0.01$). The space in practice is also larger compared to McPhee (2002) who proposed that each laying bird should be given a space of 8 cm at the feeding trough. However, compared to Maas (2006), whose propositions are a space of 12cm per bird feeding in a trough, the space provided by farmers is small. Generally speaking, farmers are doing the right practice because the space they provide is within the acceptable ranges i.e. 8cm – 12cm space per bird.

Table 32: One-sample statistics for space of birds in long feeder

Variable	N	Mean (Inches)	Std. Deviation	Std. Error Mean
Space of birds feeding in long feeder	14	10.93	.961	.248

Source: Computation from survey data, 2015

Table 33: One-sample test for space of birds in long feeder

Test Value = 10

Variable	t-value	p-value	Mean Difference
Space of birds feeding in long feeder	3.761	0.002	0.933

Source: Computation from survey data, 2015

4.2.4.4 Type of drinkers

The results of the study as summarized in table 34 show that 30 percent of the farmers use round industrially made plastic drinkers. These drinkers are specifically designed for chicken watering. Further observation shows that this 30 per cent was comprised of all farmers who had adopted the deep litter system. These farmers have comparatively smaller number of birds – mean number being birds 3983 as compared to those who have adopted the cage system whose mean is 16920 birds. The 70 per cent of farmers have adopted the pipe systems which are the ones who practice cage system and have a large number of chickens. The results are supported by McPhee (2002) who comment that round drinkers are appropriate for small flocks of chicken while long automatic pipes are appropriate for large flocks of chicken especially in cage system.

Table 34: Type of drinkers

Drinker type	Number of farmers	Percent	Valid Percent	Cumulative Percent
Round	6	30.0	30.0	30.0
Pipes	14	70.0	70.0	100.0
Total	20	100.0	100.0	

Source: Computation from survey data, 2015

4.2.4.5 Space of birds in a round drinker

The results of the survey show that farmers provide a drinking space of 8cm per bird in a round drinker. This result is in line with McPhee (2002) who also advices a space of 8cm per bird in a round drinker.

4.2.4.6 Space of birds in pipe drinkers

The results of the study show that there was a provision of two nipples in each cage of four birds. This means a ratio of two birds per nipple. This ratio of birds per nipple is recommended by McPhee (2002) as the right practice. This implies that farmers are working closely with consultants to acquire best farming practices.

4.2.4.7 Quantity of feed provided to pre starter birds

Of the sampled farms, two had birds at a pre starter stage. The results of the study show that the average quantity of feed provided to pre starter birds was 255g per bird per stage (i.e. 0 – 10 days). This quantity is small when compared with the quantity of 300 g per bird per stage that was proposed by Toledo (2011) who proposed that the pre-starter diets containing 22 and 25% crude protein have to be supplied to pre starter birds at an amount of 300 g. In their study they found that the use of the pre-starter diet with higher nutritional levels and the nutritive solution enhanced broiler performance. Toledo (2011) further reported that feeding pre starter boiler with high nutritional levels at the rate of 300 g resulted in better broiler performance and uniformity. Therefore, farmers should strive to attain the level of 300g of feed per bird per stage.

4.2.4.8 Quantity of feed provided to starter birds

Of the sampled farms, two had birds at a starter stage. The results of the study show that the average quantity of feed provided to starter birds was 775g per bird per stage (i.e. 11 – 21 days). This quantity is small when compared with the quantity of 1000g (1kg) per bird per stage that was proposed by Manitoba (n.d) who commended that starter bird should have consumed feed at the quantity of 1 kg per bird by the end of the stage. Manitoba (n.d.) further commented that best feeds for broiler chicken are those which are commercially prepared for the stages of pre starter, starter and finisher. The author further underscored the importance of following feed supplier's and veterinarian's recommendations in the course of using the commercial feeds. According to Khare (n.d), broiler starter should be in form of small granules which can easily be picked up by chicks when feeding. Khare (n.d) further insisted that, a bird requires 1 kg of starter feed to shift to finisher feed. The author further explained that this quantity of feed is sufficient enough to provide all required nutrients so as to get faster and maximum weight gain. Farmers therefore, should strive to attain the level of 1 kilogram of feed per bird per stage.

4.2.4.9 Quantity of feed provided to finisher birds

Of the sampled farms, one had birds at a finisher stage. The results of the study show that the quantity of feed provided to finisher birds was 1.7 kg per bird per stage (22 – 45 days). This quantity is larger than the quantity of 1.5 kg per bird per stage, that was proposed by Manitoba (n.d) who commended that finisher bird should have consumed feed at the quantity of 1.5 kg per bird by the end of the stage. However, the quantity of feed provided at each stage of the bird depends on the nature of the formulation. That's why Manitoba (n.d) insists on strictly following manufacturer's instructions. According to Khare (n.d), finisher broiler should consume a quantity of 1 kg finisher feed after having consumed 1 kg of starter feed till the point of disposal of the birds. The author's recommendation is based on feeds that are designed at a very high energy level with well-balanced protein - energy ratio to enable the birds get faster and maximum weight gain. The finisher feeding practice in terms of quantity of feed provided to birds being at higher level compared to the available recommendations implies that farmers are working closely with their feed suppliers and are practicing what the feed manufacturers recommend.

4.2.4.10 Quantity of feed provided to Chicks

Chicks are infant chicken at the age of 0 – 2 months which are meant for eggs production. The subsequent performance in terms egg laying is highly dependent on how they are managed at chick stage, especially feeding (VH, 2010). The results from the survey show that farmers provide an average quantity of 2.00540 kg of feeds per bird in a chick stage. This amount does not differ significantly with standards provided ($p>0.05$). VH (2010) recommends a cumulative amount of 2.002 kg per bird at the end of the chick stage. On the other hand, DAHLFVS – Government of Sikkim (n.d) recommends that a cumulative amount of 2.65 kg should be consumed by each chick by the end of this stage. The fact that the quantity of feed supplied by farmers to each bird i.e. 2.00540 kg is closer to the quantity proposed by Venkateswara Hatcheries of 2.002kg per bird per stage who is the breeder of the BV300, the breed which farmers keep in the research area, implies that farmers are doing the right practice in as far as breed management specification is concern.

Table 35: One-sample statistics for quantity of feed provided to chicks

Variable	N	Mean	Std. Deviation	Std. Error Mean
Quantity of feed provided to chicks	6	2.00540	.008414	.003763

Source: Computation from survey data, 2015

Table 36: One-sample test quantity of feed provided to chicks

Test value = 2.00

Variable	t-value	p-value	Mean Difference
Quantity of feed provided to chicks	1.435	.225	.005400

Source: Computation from survey data, 2015

4.2.4.11 Quantity of feed provided to growers

Of the sampled farmers, none of them had birds at the grower stage. Therefore, no data were collected about grower feeding practices.

4.2.4.12 Quantity of feed provided to layers

It was observed that 100 percent of layer farmers do not have different schedules for feeding layer I, layer II and layer III. Once chicken starts laying eggs, they are generally treated as layers, no differentiation. This implies that some of the latest innovations in chicken management are not well known to farmers. It was further observed that the average quantity of feed that farmers supplied to layer birds was 114.077g per bird per day. This quantity significantly differs ($p < 0.05$) with the standards provided by Rooney Feeds LTD (n.d.) of maximum 120g per bird per day. The amount in practice also differs with the propositions of Government of Sikkim, Department of livestock production (n.d.) which recommends that the quantity of feed supplied to each layer bird per day should be 125g. However, (www.ebay.com), proposes an amount of feed per layer, per day that ranges from 100g - 120g. This implies that what farmers are doing in terms of feed quantity supplied to layer birds is within the acceptable ranges. The perceived differences might be due to breed as well as feed manufacturers specifications.

Table 37: One-sample statistics for quantity of feed provided to layers

Variable	N	Mean (grams)	Std. Deviation	Std. Error Mean
Quantity of feed provided to layers	13	114.077	1.8467	.5122

Source: Computation from survey data, 2015

Table 38: One-sample test quantity of feed provided to layers

Test value = 120

Variable	t-value	p-value	Mean Difference
Quantity of feed provided to layers	-11.564	.000	-5.9231

Source: Computation from survey data, 2015

4.2.4.13 Quantity of water supplied to pre starter birds

Stressing on importance of water management, VH (2010) insisted that chickens comprises of 60 – 70 per cent water, and that a 10 per cent loss as a result of dehydration, excretion or both may result in serious physical or physiological disorder. That being the case, it is important to always have adequate clean and fresh water for chickens to drink whenever they wish. This is especially important at the chick stage. In the study area, farmers were found to be providing an average quantity of 3.45 litres of water per 100 birds per day. This amount of water is slightly higher than the amount recommended by VH (2010) of 3.30 litres of water per 100 birds per day. This implies that farmers are conscious with water management issues, especially in the light that they are operating in an arid zone of the country where birds are prone to dehydration.

4.2.4.14 Quantity of water supplied to starter birds

The results show that farmers provide an average quantity of 4.90 litres of water per 100 starter birds per day. This amount of water is slightly higher than the amount recommended by VH (2010) of 4.80 litres of water per 100 starter birds per day. This implies that farmers are conscious and implement right practices, knowing the importance of water in chicken management.

4.2.4.15 Quantity of water supplied to finisher birds

The results show that farmers provide an average quantity of 12.75 litres of water per 100 finisher birds per day. This amount of water is higher than the amount recommended by VH (2010) of 12.00 litres of water per 100 finisher birds per day. This implies that farmers are conscious and implement right practices, knowing the importance of water in chicken management.

4.2.4.16 Quantity of water supplied to chicks

The results show that farmers provide an average quantity of 14.70 litres of water per 100 birds in a chick stage per day. This amount of water is significantly higher ($p < 0.05$), than the amount recommended by VH(2010) of 14.40 litres of water per 100 chicks per day. This implies that farmers know the importance of the chick stage, as the subsequent performance of layer chicken is totally dependent on how the birds were handled at chick stage

Table 39: One-sample statistics for quantity of water provided to chicks

Variable	N	Mean (litres)	Std. Deviation	Std. Error Mean
Quantity of water provided chicks	6	14.733	.2944	.1202

Table 40: One-sample test quantity of water provided to chicks

Test value = 14.40

Variable	t-value	p-value	Mean Difference
Quantity of water provided to chicks	2.774	.039	.3333

Source: Computation from survey data, 2015

4.2.4.17 Quantity of water supplied to layers

The results show that farmers provide an average quantity of about 24.80 litres of water per 100 layer birds per day. This amount of water is significantly higher ($p < 0.05$), than the amount recommended by VH (2010) of 24.60 litres of water per 100 layer birds per day. This implies that farmers know the importance of drinking water in laying birds. The general observation is that, farmers are doing very well in the water management aspect. This might be contributed by the tradition of the people of Rajasthan, that the first thing when a guest arrives in a place is drinking water. They really know the importance of drinking water in living creatures. They even have a daily routine of providing drinking water to wild birds like pigeons! That shows how conscious they are in matters related to drinking water.

Table 41: One-sample statistics for quantity of water provided to layers

Variable	N	Mean (litres)	Std. Deviation	Std. Error Mean
Quantity of water provided chicks	13	24.885	.2193	.0608

Table 42: One-sample test quantity of water provided to layers

Test value = 24.60

Variable	t-value	p-value	Mean Difference
Quantity of water provided to chicks	4.680	.001	.2846

Source: Computation from survey data, 2015

4.2.4.18 Major sources of water

The result of the study shows that 100 per cent of farmers depend on ground water for management of their poultry farms. The results are supported by Dadheech and Vyas (2012) who also explained that the major source of water for poultry farmers in Ajmer district was ground water. This implies that ground water is a cheap and reliable source of water that can easily be afforded by poultry farmers. It further explains that poultry farmers are economic minded, which is a very important aspect for business efficiency.

Table 43: Major sources of water

Variable	Number of farmers	Valid percent	Cumulative percent
Ground water	20	100	100
Other sources	0	0	0

Source: Computation from survey data, 2015

4.2.4.19 Water treatment

The result of the study shows that 100 per cent of farmers regularly treat the ground water to ensure health security of the birds. The results are supported by Dadheech and Vyas (2012) who also explained that adequate research for proper control, prevention and treatment of infectious bacterial diseases such as *Colibacillosis, Coccidiosis* and *Necrotic Enteritis* are needed, as these diseases were still a problem in Ajmer district. Dadheech and Vyas (2012) further explained that these diseases originate from untreated ground water that was being provided to birds. The authors further insisted that farmers were incurring huge economic losses as a result of the diseases. The implication is that research findings are trickling down to the farmers. If Dadheech and Vyas (2012), recommended for water treatment, and in 2015 all farmers are treating water that is a great success. The results further imply that farmers in the study area are highly receptive to innovations.

Table 44: Water treatment

Variable	Number of farmers	Valid percent	Cumulative percent
Treating	20	100	100
Not treating	0	0	0

Source: Computation from survey data, 2015

4.2.4.20 Vaccination of birds.

The purpose of vaccination is to protect the flock against diseases VH (2010). Proven vaccines from reputable manufacturers should only be used for vaccination. The results of the study show that 100 per cent of farmers vaccinate birds at different stages according to experts' guidelines. The implication of this practice is that the mortality rate of the birds is low. This fact is supported by the fact that the flock sizes of both layer and broiler farmers are significantly higher than the minimum size of 2000 and 250 respectively that is considered to be commercially economical TNAU (n.d.).

Table 45: Vaccination of birds

Variable	Number of farmers	Valid percent	Cumulative percent
Vaccinating	20	100	100
Not vaccinating	0	0	0

Source: Computation from survey data, 2015

4.2.4.21 Light management

Light is an important aspect in chicken management as it influences the age of birds' sexual maturity. Moreover, feed consumption is highly influenced by the duration of day length. Natural light should be supplemented with artificial light as weather condition demands to ensure that chickens consume feeds and get warmed accordingly (VH, 2010). This section explored light management practices for both broiler and layer birds at different stages.

4.2.4.21.1 Light management for broiler birds

The results of the study show that farmers provide 12 hours of natural light and 12 hours of artificial light to broiler birds, making a total of 24 hours of light. These results are supported by VH (2010) who explains that most broiler farming in India is carried out in conventional open sided houses. VH (2010) further explained that as days are warm and nights are cool, most of the farmers are following no dark periods throughout the growing season. The author further noted that in many places light is used as a source of warmth as well. The fact that all sampled broiler farmers were keeping VENCOBB 400 breed which is produced by Venkateshwara Hatcheries and that they follow the lighting system advised by the breed developer, implies that farmers are receptive to innovations.

4.2.4.21.2 Light management for chicks

The results of the study show that farmers provide 12 hours natural light to chicks and 12 hours of artificial light making a total of 24 hours. This amount of light is similar to the amount proposed by VH (2010) of a total of 24 light hours per day to be provided to chicks. The implication is that farmers are following the scientific specification and chicks get sufficient time to eat feed during the night which is good for better growth.

4.2.4.21.3 Light management for layers

The results show that, farmers provide 12 hours natural light for layer birds and an average of 6 hours of artificial light making a total of 18 hours. The laying birds are provided the artificial light from 10.00 pm to 4.00 am. This time is higher than the time proposed by VH (2010) of a total of 15 light hours per day to be provided to layer birds. The implication is that layers get sufficient time to eat feed during the night which is good for better laying.

Table 46: One-sample statistics for light hours provided to layers

Variable	N	Mean (hours)	Std. Deviation	Std. Error Mean
Light hours provided to layers	13	18.0769	1.32045	.36623

Table 47: One-sample test for light hours provided to layers

Test value = 15

Variable	t-value	p-value	Mean Difference
Quantity of water provided to chicks	8.402	.000	3.07692

Source: Computation from survey data, 2015

4.2.4.22 Summary of the management practices

Table 46 summarizes the execution of chicken management practices as far as Ajmer farmers are concerned.

Table 48: Summary of the management practices

S/NO	Variable	Practice in field	Standard Practice	Gap	p-value
	Living space mgt:				
1	Cage size	1339 cm^2	1463 cm^2	-124 cm^2	0.000
2	No. of birds in@cage	4	3	-1	0.001

	Living space in deep litter system:				
3	Space of layer birds in deep litter system	2 ft^2	2 ft^2	0	-
4	Space of broiler birds in deep litter system	1.2 ft^2	1 ft^2	+0.2 ft^2	0.178
	Feeding space management:				
5	Space of @ bird feeding in a round feeder	4.67cm	4 cm	+0.67cm	0.025
6	Space of @ bird feeding in a rectangular feeder	10.93 cm	10 cm	+0.93 cm	0.002
	Drinking space:				
7	Space of @ bird in a round drinker	8 cm	8 cm	0	-
8	Space of birds in pipe drinkers	2 nipples/cage	2 nipples/cage	0	-
	Feed quantities:				
9	Quantity of feed provided to @ pre starter bird	255 g / stage	300 g / stage	-45 g	-
10	Quantity of feed provided to @ starter bird	700 g / stage	800 g / stage	-100 g	-
11	Quantity of feed provided to @ finisher bird	1.7 kg / stage	1.5kg / stage	+0.2 kg	-
12	Quantity of feed provided to @ Chick	2.00 kg/ stage	2.002 kg / stage	-0.002 kg	0.225
13	Quantity of feed provided to @ layer	114 g / bird /day	120 g / bird /day	-6 g	0.000

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4.2.4.21.3 Light management for layers

The results show that, farmers provide 12 hours natural light for layer birds and an average of 6 hours of artificial light making a total of 18 hours. The laying birds are provided the artificial light from 10.00 pm to 4.00 am. This time is higher than the time proposed by VH (2010) of a total of 15 light hours per day to be provided to layer birds. The implication is that layers get sufficient time to eat feed during the night which is good for better laying.

Table 46: One-sample statistics for light hours provided to layers

Variable	N	Mean (hours)	Std. Deviation	Std. Error Mean
Light hours provided to layers	13	18.0769	1.32045	.36623

Table 47: One-sample test for light hours provided to layers

Test value = 15

Variable	t-value	p-value	Mean Difference
Quantity of water provided to chicks	8.402	.000	3.07692

Source: Computation from survey data, 2015

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S/NO	Variable	Practice in field	Standard Practice	Gap	p-value
	Living space mgt:				
1	Cage size	1339 cm^2	1463 cm^2	-124 cm^2	0.000
2	No. of birds in@cage	4	3	-1	0.001

	Living space in deep litter system:			
3	Space of layer birds in deep litter system	2 ft^2	2 ft^2	0	-
4	Space of broiler birds in deep litter system	1.2 ft^2	1 ft^2	+0.2 ft^2	0.178
	Feeding space management:				
5	Space of @ bird feeding in a round feeder	4.67cm	4 cm	+0.67cm	0.025
6	Space of @ bird feeding in a rectangular feeder	10.93 cm	10 cm	+0.93 cm	0.002
	Drinking space:				
7	Space of @ bird in a round drinker	8 cm	8 cm	0	-
8	Space of birds in pipe drinkers	2 nipples/cage	2 nipples/cage	0	-
	Feed quantities:				
9	Quantity of feed provided to @ pre starter bird	255 g / stage	300 g / stage	-45 g	-
10	Quantity of feed provided to @ starter bird	700 g / stage	800 g / stage	-100 g	-
11	Quantity of feed provided to @ finisher bird	1.7 kg / stage	1.5kg / stage	+0.2 kg	-
12	Quantity of feed provided to @ Chick	2.00 kg/ stage	2.002 kg / stage	-0.002 kg	0.225
13	Quantity of feed provided to @ layer	114 g / bird /day	120 g / bird /day	-6 g	0.000

	Water quantities:				
14	Quantity of water supplied to pre starter birds	3.45 litres/100birds/day	3.30 litres/100birds/day	+0.15 litres	
15	Quantity of water supplied to starter birds	4.90 litres/100birds/day	4.80 litres/100birds/day	+0.100litres	
16	Quantity of water supplied to finisher birds	12.75 litres/100birds/day	12.00 litres/100birds/day	+0.75litres	
17	Quantity of water supplied to chicks	14.70 litres/100birds/day	14.40 litres/100birds/day	+0.30litres	0.039
18	Quantity of water supplied to layers	24.80 litres/100birds/day	24.60 litres/100birds/day	+0.20 litres	0.001
	Light Management:				
19	Light management for broiler birds	24 hours	24 hours	0	-
20	Light management for chicks	24 hours	24 hours	0	-
21	Light management for layers	18 hours	15 hours	+3hours	0.000

Source: Field Survey, 2015

4.3 Feeding management practices with respect to least cost formulations.

This objective specifically explored feeding management practices that were being practiced by farmers in the study area, the emphasis being cost aspect. Aspects of consideration were; type of feed fed i.e. commercial or own formulated feed and costs involved. Commercial feeds were further considered in terms of mash feeds, crumble feeds and concentrate feeds.

4.3.1 Type of feed used in the farm

The results of the study show that 100 per cent of farmers use commercial feeds to feed their chicken. These results are supported by Frame (2008), who suggests that farmers should feed their chicken on industrially made feeds, as such feeds are manufactured under standard expert conditions hence quality is assured. This implies that prices of feeds are affordable in the study area. If feeds were unaffordable, farmers would think other alternatives such as own feed formulation.

Table 49: Type of feed used

Feed type	Number of farmers	Valid percent	Cumulative percent
Commercial feed	20	100	100
Farm made feed	0	0	0

Source: Survey data, 2015

4.3.2 Type of commercial feed used in the farm

The results of the study show that 25 per cent of farmers used crumble feeds while 75 per cent used concentrate feeds. None of the farmers opted for mashes. Further observation shows that all broiler farmers adopted the readymade complete crumble feeds and none of them went for concentrate based complete feeds. On the other hand, all layer farmers went for concentrate based complete feeds and none of them went for readymade complete feeds. These results are supported by Mirghelenj and Golian (2009) who explained that feeding crumble or pelleted feeds significantly improves feed intake, body weight gain, feed conversion ratio and performance index in birds as compared to mash feeds. Further, crumble or pelleted feeds reduces the risk of respiratory diseases in birds. In the same way, Fanatico (2003) explains that the purpose of pelleting feed is to increase the intake. The bird can eat more at one time when fed crumbled or pelleted feed than when fed feed which is in mash form.

Table 50: Type of commercial feed used

Feed type	Number of farmers	Valid percent	Cumulative percent
Crumbs	5	25	25
Concentrate	15	75	100
Total	20	100	

Source: Computation from survey data, 2015

4.3.3 Satisfaction in terms of price of feed

The results of the study show that 100 per cent of farmers are satisfied with prices of commercial feeds. However, this might be due to the fact that feed dealers provide feeds in terms of credit and bundle it with other extension services. That being the case, farmers are bound. In any way they are forced to rely on feed dealers in running their farms. Furthermore, the price of concentrate based complete feed was found to be unrealistically low. A kilogram of the feed was rated at the cost of ₹ 15.16. The price of the concentrate was found to be ₹ 21.00 per kilogram. This level of cost is unrealistically low because the cost of deoiled soya cake alone was rated at ₹ 28.00 per kilogram. How comes for a concentrate which has gone through some industrial processes to be less costly than the raw material? Further researches need to be done on the production performance of the birds and the quality of the concentrate.

Table 51: Satisfaction in price and quality of commercial feeds

Satisfaction	Number of farmers	Percent
Satisfied	20	100
Unsatisfied	0	0

4.3.4 Prices of readymade complete commercial feeds

Table 52 summarizes the prices of readymade complete commercial feeds in the study area.

Table 52: Prices of readymade complete commercial feeds

Chicken stage	Average price (₹ /kg)

Pre starter feed	30.00
Starter feed	28.00
Finisher feed	27.00
Chick feed	26.00
Growers feed	24.00
Layers feed	20.00

Source: Survey data, 2015

The results of the study show that broiler feeds are costlier than layer feeds. Several reasons contribute to that. Firstly, compared to layers, broilers need high protein feeds so that they can reach their marketable age at around 42 – 45 days. On the other side proteins are costlier than energy. Therefore, feeds that demand more proteins will automatically be costly (Fanatico, 2003). Further the results of the study show that the younger the age of the birds, the costlier is the food. Here again, the reason is the same, younger birds need more protein than older one. That means their food has to be protein rich hence costlier (Fanatico, 2003). According to Fanatico (2003), starter rations are high in protein, which is an expensive feed ingredient. At the same time, grower and finisher rations are lower in protein since older birds require less. The author further clarifies that a starter diet is about 24% protein, grower diet 20% protein, and finisher diet 18% protein. On the other hand, Fanatico (2003) points out that layer diets generally have about 16% protein. Further observations show that the mean of broiler commercial feed is ₹28.30/kg, while that of commercial layer feed is ₹ 23.30/kg picturing the same point that broiler feeds are more costly as compared to layer feeds.

4.3.5 Prices of concentrate based complete feeds

The results of the study show that broiler farmers depend totally on readymade complete commercial feeds. Layer farmers go for concentrate based complete feeds where they do the mixing and then get the feed for their chicken. The implication is that broiler management requires a very keen consideration in feeding so that they grow and attain a marketable weight as early as 42 – 45 days. This can only be possible if a standardized feed is used in their feeding. On the part of layers, the farmer has an allowance of staying with the bird for about 1.5 years. This period is long enough to enable the farmer to adopt any other feeding schedule apart from readymade complete commercial feeds. The fact that all layer farmers opt for concentrate feeds, and not going for complete commercial feeds implies that concentrate feed are cheaper than complete commercial feeds. As pointed in table 52, while the price for complete commercial layer feed in the study area was ₹ 20 per kg, the price of concentrate based feed was ₹ 15.16 per kg. The concentrate feed was significantly less costly than the complete commercial feed ($p < 0.001$).

Table 53: Paired samples statistics for price of layer readymade complete commercial feed and price of concentrate based complete feed

Paired variables	Mean (₹)	N	Std. Deviation	Std. Error Mean
Price of commercial feed	20	15	0.834	0.215
Price of concentrate feed	15.16	15	.507	0.131

Source: Computation from survey data, 2015

Table 54: Paired sample test for price of layer readymade complete commercial feed and price of concentrate based complete feed

Paired variables	Mean (₹)	Standard Deviation	Standard Error Mean	t-value	p-value
Commercial feed & Concentrate feed	3.933	1.100	0.284	13.9	0.000

Source: Survey data, 2015

4.3.6 Formulation of farm based own feeds from locally available ingredients

The results of the study show that 100 per cent of farmers do not formulate feeds from locally available ingredients. Several reasons might be contributing to this. May be formulating own feeds is not economical. Further this abstinence might be caused by lack of technical knowhow as well as necessary technology. The situation seen in the study area is supported by Fanatico (2003) who explained that, preparing a balanced diet at farm level can be a complex and possibly a costly process, especially for producers with little background in nutrition. The author further insists that specialized knowledge is required about the nutrient requirements of chickens and the nutrients contained in feedstuffs. Fanatico (2003), underscores that ration-balancing of farm - made diets is important to achieve the right amounts of nutrients. If diets are not properly balanced, birds will suffer from nutritional diseases.

Table 55: Formulation of farm based own feed

Variable	Number of farmers	Percent	Cumulative percent
Formulating	0	0	0
Not formulating	20	100	100

Source: Survey data, 2015

4.3.7 Assessment of nutrient status of ingredients used in mixing

The results of the study show that 100 per cent of the farmers do not conduct any laboratory assessment of the nutrient status of the ingredients which they use in mixing with the concentrates. The implication is that feed mixing is done blindly and this might be affecting the quality of the resulting feed. These results are in contrast with Fanatico (2003) comments that feed ingredients need to be tested in laboratories to ascertain their nutrient status and that farmers have to work closely with nutrition experts in order to prepare best quality feeds. Or else they have to closely follow manufacturer's instructions on the mixing ratios, especially for those farmers who opt for concentrate feeds.

Table 56: Assessment of the nutrient status of ingredients

Variable	Number of farmers	Percent	Cumulative percent
Assessing	0	0	0
Not assessing	20	100	100

Source: Computation from survey data, 2015

4.3.8 Availability of feed formulation software

The results of the study show that 100 per cent of the farmers do not have any software that could assist in determining the proportions of various ingredients that have to be mixed. Farmers are determining the required proportions manually. The implication is that farmers are doing a tedious work and the quality of the feed might be negatively affected. Owing to the current advances in technology, especially the application of various software in industrial activities, there is a need for poultry farmers to be oriented towards using software in feed formulation. Olatunde and Moji (2008), insists on importance of having feed formulation software for poultry industries that are customized to locally available ingredients in a particular area rather than depending on feed formulas that are externally introduced.

Table 57: Availability of feed formulation software

Variable	Number of farmers	Percent	Cumulative percent
Available	0	0	0
Not available	20	100	100

Source: Survey data, 2015

4.3.9 Availability of crushing and mixing machines

The results of the study show that 100 per cent of the farmers who have adopted the concentrate based feeds have milling machines and mixers for crushing and mixing the ingredients. This implies that the work is done efficiently and they can manage to mix as much as feed as the farm demands. The results are supported by Fanatico (2003) who points out that a motorized machine is important in any poultry farm which chooses the option of farm mixed rations. Machines facilitate the processing of the feeds, hence efficiency of farm activities.

Table 58: Availability of crushing and mixing machines

Variable	Number of farmers	Percent	Cumulative percent
Available	20	100	100
Not available	0	0	0

Source: Survey data, 2015

4.3.10 Problems faced during feed formulation process

The results of the study show that 100 per cent of the farmers who have adopted the concentrate based feed face problems in knowing the nutrient content of the ingredients. This implies that there is a need of having a laboratory facility to assist farmers in assessing their ingredients so that they mix the feeds with perfect knowledge of the quality of raw materials the practice which will also enhance the quality of the resulting feeds. That the farmers experience is in line with Olatunde and Moji (2008) observations, that poultry feed formulation is a complex process that requires knowledge of nutrient quality of the ingredients, nutrient requirement of different stages of chicken and availability of facilities such as laboratories and software. Having these facilities and knowledge will help the feed formulation process to be done in an informed way hence end up having quality feeds.

Table 59: Problems faced during feed formulation

Problem	Number of farmers	Percent	Cumulative percent
Knowledge of nutrient content	20	100	100

Source: Survey data, 2015

4.4 Balanced least cost chicken feed formulation

This section addressed the aspect of balanced least cost chicken feeds formulation from locally available ingredients for different chicken classes. The execution involved: Identification of the locally available ingredients and their prices, specification of the nutrient content in each identified ingredient through laboratory analysis of the ingredient samples taken from the study area, determination of the nutrient requirement for each class of chicken including; pre – starter, broiler starter, broiler finisher, chicks, growers, layer I, layer II and layer III, using scientifically established chicken feeding guide tables, developing linear programming models (LPMs) on the bases of locally available ingredients, market prices of the ingredients, nutrient contents of the ingredients, and nutrient requirements for each stage of chicken and solving the developed linear programming models using LINDO LP solver to obtain the balanced least cost combination of the ingredients that are required for each stage of chicken.

4.4.1 Identification of the locally available ingredients

The ingredients that were identified include; energy sources, protein sources and mineral sources. The following list comprises of locally available ingredients and their market prices.

Table 60: Ingredients locally available in the study area

Ingredient	Price (₹ /kg)
Maize	15.00
Pearl millet	13.00
Deoiled rice bran	8.00
Deoiled Soya Cake	28.00
Deoiled Mustard Cake	15.00
Deoiled Groundnut Cake	21.00
Marble Stones (Grits)	1.00
Salt	15.00
Mineral and Vitamin premixes	150.00
Vegetable oil	90.00
Limestone powder	1.25
Dicalcium phosphate	50.00
Lysine	110.00
Methionine	250.00

Source: Survey data, 2015

In the LP model, these ingredients were used as the *decision variables i.e. the Xs,* while the price of each ingredient was used as the coefficient of a respective decision variable.

4.4.2 Specification of the nutrient content in the identified ingredients

The laboratory analysis of the ingredient samples was done and the results were as per table 61.

Table 61: Nutrient content in the identified ingredients

Ingredients	CP%	ME kcal/kg	EE%	CF%	Lysine%	Methionine %	Ca%	P%	AP %	PP%
Yellow maize	11.45	3300	2.68	3.70	0.24	0.18	0.03	0.30	0.10	0.20
Pearl millet	12.43	2640	4.59	1.99	0.42	0.24	0.04	0.70	0.00	0.70
Deoiled rice bran	16.57	1450	0.50	11.77	0.64	0.30	0.37	1.50	0.21	1.29
Deoiled soya cake	45.36	2300	0.24	10.61	2.90	0.64	0.36	0.67	0.29	0.38
Deoiled mustard cake	35.51	1900	0.90	10.95	0.60	0.38	0.72	1.10	0.25	0.85
Deoiled groundnut cake	41.13	2400	0.64	17.91	1.60	0.42	0.31	0.67	0.20	0.47
Marble stones	0.00	0.00	0.00	0.00	0.00	0.00	33.00	0.00	0.00	0.00

Source: Laboratory analysis, 2015

The nutrient contents in each ingredient were the coefficients in the constraint equations (Oladokun and Johnson, 2012)

Note: CP%, EE% and CF% represents analyzed values, the rest all are calculated values.

4.4.3 Recommended inclusion levels of feed ingredients for different stages of chicken

Table 62: Recommended inclusion levels of feed ingredients

Chicken stage	Maize %	Bajra%	D.O.R.B.%	DOSC%	DGNC%	DOMC%	Marble%	LSP%	DCP%	Wheat%	Fish%	Sunflower%
Pre starter	40 - 60	-	-	18 -26	5 - 15	1 -2	-	0 - 1	0 - 1	2 - 5	1 - 5	1 - 2
Broiler starter	40 - 60	10 - 20	-	15 - 20	5 - 15	1 - 2	-	0 - 1	0 - 1	2 - 5	1 - 5	1 - 2
Broiler finisher	40 - 60	10 - 20	-	12 - 20	5 - 15	2 - 5	-	0 - 1	0 - 1	2 - 5	1 - 5	1 - 2
Chicks	40 - 60	-	-	18 - 26	5 - 15	1 - 2	-	0 - 1	0 - 1	2 - 5	1 - 5	1 - 2
Growers	40 - 60	10 - 20	5 - 10	10 - 15	5 - 15	5 -7	-	0 - 1	0 - 1	2 - 5	1 - 5	1 - 2
Layer I	40 - 60	10 - 20	8 - 10	10 - 15	5 - 15	5 -7	6 - 9	1 - 2	0 - 1	2 - 5	1 - 5	1 - 2
Layer II	40 - 60	10 - 20	10 - 15	10 - 15	5 - 15	5 -7	6 - 9	1 - 2	0 - 1	2 - 5	1 - 5	1 - 2
Layer III	40 - 60	10 - 20	10 - 20	10 - 15	5 - 15	5 -7	6 - 9	1 - 2	0 - 1	2 - 5	1 - 5	1 - 2

Source: Panda and Mohapatra (1989), Cited by Kumar, S.(2011) Pg 135.

4.4.4 Determination of the nutrient requirement for various stages of chicken

The nutrient requirements for various stages of chicken are as per table 63.

Table 63: Nutrient requirements for different stages of chicken

Chicken stage	Protein Min.%	E.E Min.%	C.F Max.%	Calcium Exact%	Phosphorus%	A.Phosphorus%	P.Phosphorus%	Lysine Min.%	Methionine Min.%	M.E Kcal/kg	Salt
Pre starter	22.50	3.50	4.00	1.00	0.86	0.45	0.36	1.30	0.55	2950	0.50
Broiler starter	22.00	4.20	*4.70*	*1.10*	*0.86*	*0.50*	*0.36*	*1.10*	*0.45*	2800	0.50
Broiler finisher	21.00	4.20	*4.70*	*1.10*	*0.86*	*0.50*	*0.36*	*1.00*	*0.43*	2800	0.50
Chicks	24.00	3.80	5.0	1.10	0.86	0.50	0.36	1.05	0.43	2700	0.50
Growers	17.50	3.30	7.00	1.00	0.90	0.50	0.40	0.75	0.35	2500	0.50
Layer I	18.00	3.30	*6.00*	*3.80*	*0.76*	*0.46*	*0.30*	*0.88*	*0.40*	2500	0.45
Layer II	16.00	3.30	7.00	3.80	0.76	0.42	0.34	0.75	0.34	2450	0.45
Layer III	16.00	3.30	7.50	4.00	0.76	0.40	0.36	0.70	0.30	2400	0.40

Source: Moreson (1998), American National Research Council (NRC) (1994) and Venkateshwara Hatcheries (2010)

The recommended quantities of each nutrient formed the right hand side of the constraint equations (Oladokun and Johnson,2012.

The overall ingredients that were used in feed formulation and their codes are as listed in table 64. These ingredients are the decision variables.

Table 64: List of ingredients

Ingredient code	Ingredient represented
X_1	Quantity of maize
X_2	Quantity of pearl millet (Bajra)
X_3	Quantity of deoiled
X_4	Quantity of deoiled soya cake
X_5	Quantity of deoiled mustard cake
X_6	Quantity of deoiled groundnut cake
X_7	Quantity of marble grits
X_8	Salt
X_9	Premix
X_{10}	Vegetable oil
X_{11}	Limestone powder (L.S.P)
X_{12}	Dicalcium phosphate (D.C.P)
X_{13}	Lysine
X_{14}	Methionine

Source: Survey data, 2015

4.4.5 Linear programming model for pre starter feed formulation

Objective Function

Min Z =

$15X_1+28X_4+15X_5+21X_6+15X_8+150X_9+90X_{10}+1.25X_{11}+50X_{12}+110X_{13}+250X_{14}$

Subject to;

$X_1+X_4+X_5+X_6+X_8+X9+X_{10}+X_{11}+X_{12}+X_{13}+X_{14}=$ 100 – Demand constraint

$0.1145x_1+0.4536x_4+0.3551x_5+0.4113X_6+0.78X_{13}+0.95X_{14}\geq 0.225\sum_{i=1}^{14} Xi$ - Protein requirement

$0.0268x_1+0.0024x_4+0.009x_5+0.0064x_6+1X_{10}\geq 0.035\sum_{i=1}^{14} Xi$ - Ether extract requirement

$0.037x_1+0.1061x_4+0.1095x_5+0.1794x_6 \le 0.04\sum_{i=1}^{14} Xi$ – Crude fibre requirement

$0.0003x_1+0.0036x_4+0.0072x_5+0.0031x_6+0.33X_{11}+0.23X_{12}=0.011\sum_{i=1}^{14} Xi$ – Calcium

$0.003x_1+0.0067x_4+0.011x_5+0.0067x_6+0.17X_{12}\ge 0.0086\sum_{i=1}^{14} Xi$ - Phosphorus

$0.001x_1+0.0029x_4+0.0025x_5+0.0020x_6+0.17X_{12}\ge 0.0045\sum_{i=1}^{14} Xi$ - Available Phosphorus

$0.002x_1+0.0038x_4+0.0051x_5+0.0047x_6+0.17X_{12}\ge 0.0036\sum_{i=1}^{14} Xi$ -Phytic Phosphorus

$0.0024x_1+0.029x_4+0.006x_5+0.016x_6+0.98X_{13}\ge 0.013\sum_{i=1}^{14} Xi$ - Lysine

$0.0018x_1+0.0064x_4+0.0038x_5+0.0042x_6+0.98X_{14}\ge 0.0055\sum_{i=1}^{14} Xi$ - Methionine

$3300x_1+2300x_4+1900x_5+2400x_6+8500X_{10}+3900X_{13}+4500X_{14}\ge 2950\sum_{i=1}^{14} Xi$ - Metabolizable Energy

$40\le X_1\le 60$ – Maize inclusion level

$18\le x_4\le 26$ – Deoiled soya cake inclusion level

$1\le x_5\le 2$ – Deoiled mustard cake inclusion level

$5\le x_6\le 15$ – Deoiled groundnut cake inclusion level

$X_8 = 0.3$ – Salt restriction

$X_9 = 0.05$ – Premix restriction

$X_{10}>=1$- Minimum vegetable oil inclusion level

$X_{10}<=3$ - Maximum vegetable oil inclusion level

$X_{11}<=3$ - Maximum L.S.P inclusion level

$X_{12}<=3$ – Maximum D.C.P inclusion level

$X_{13}<=0.25$ – Lysine inclusion level

$X_{14}<=0.25$ – Methionine inclusion level

$Xi \ge 0$ for i= 1, 2...14 – Non negativity constraint

4.4.5.1 The pre starter analysis results

The formulated model was analyzed using LP solver and the results were as summarized in table 65. The results show the optimal quantity of each ingredient in kilograms and its value in Indian rupees.

Table 65: The pre starter model analysis results

Decision variable	Objective coefficient	Optimum solution	
Feed ingredient (X_i)	Price/Kg (₹)	Quantity (Kg)	Cost (₹)
Maize (X_1)	15.00	55.60	834.00
Deoiled soya cake (X_4)	28.00	26.00	728.00
Deoiled mustard cake (X_5)	15.00	1.00	15.00
Deoiled groundnut cake (X_6)	21.00	10.08	211.68
Salt (X_8)	15.00	0.30	4.50
Premixes (X_9)	150.00	0.05	7.50
Vegetable oil (X_{10})	90	2.70	243.00
L.S.P. (X_{11})	1.25	1.07	1.34
D.C.P. (X_{12})	50	2.50	125.00
Lysine (X_{13})	110	0.20	22.00
Methionine (X_{14})	250	0.20	50.00
Total		100kg	₹ 2267.90

As summarized in table 65, 100kg of pre starter feed can be formulated at the cost of ₹ 2267.90 at farm level. This entails a cost of ₹22.68 per kilogram of feed. The commercial complete feed for pre starter was found to be ₹ 30.00 per kilogram. The proposed optimal solution reduces feed cost by 24.40%. Though transportation and processing of the raw materials may somewhat add to the feed cost, the overall picture is that farm made pre starter feeds are less costly than complete commercial feeds. None of the sampled farmers in the study area practiced concentrate based pre starter feeds. Hence no comparison was done between the proposed optimal feed and the concentrate based feed. Sensitivity analysis for pre starter feed formula was as presented in table 66. The sensitivity analysis shows the range of both the objective function coefficients and the right hand side of the constraint equations in which the optimum solution will remain unchanged.

4.4.5.2 The pre starter results sensitivity analysis

Table 66: Pre starter sensitivity analysis

Decision Variable	Current Objective Coefficient	Allowable increase	Allowable decrease
X_1: Maize	15.00	7.90	Infinity
X_4: Soya cake	28.00	8.80	Infinity
X_5:Mustard cake	15.00	Infinity	12.58
X_6: Groundnut cake	21.00	53.96	4.45
X_8: Salt	15.00	Infinity	Infinity
X_9: Premixes	150.00	Infinity	Infinity
X_{10}: Veg. oil	90.00	1080.34	60.02
X_{11}: L.S.P.	1.25	87.28	1338.90
X_{12}:D.C.P.	50.00	324.12	60.86
X_{13}:Lysine	110.00	1174.46	Infinity
X_{14}:Methionine	250.00	7234.07	221.00

Constraint	Current RHS	Allowable increase	Allowable decrease	Dual Price
1	100.00	1.37	0.36	40.15
2	22.50	0.59	Infinity	0.00
3	3.50	0.87	Infinity	0.00
4	4.00	2.73	Infinity	0.00
5	1.10	0.11	0.36	-125.46
6	0.86	0.06	0.14	-360.56
7	0.45	0.14	Infinity	0.00
8	0.36	0.34	Infinity	0.00
9	1.30	0.02	0.02	-1290.71
10	0.55	0.01	0.02	-225.76
11	295000.00	1260.21	4549.95	-0.02

12	40.00	15.65	Infinity	0.00
13	60.00	Infinity	4.34	0.00
14	18.00	8.00	Infinity	0.00
15	26.00	2.55	176	8.80
16	1.00	1.00	1.00	-12.58
17	2.00	Infinity	1.00	0.00
18	5.00	5.08	Infinity	0.00
19	15.00	Infinity	4.91	0.00
20	0.30	0.36	0.30	-55.15
21	0.05	0.36	0.05	-190.15
22	1.00	1.74	Infinity	0.00
23	3.00	1.07	Infinity	0.00
24	0.00	Infinity	0.25	0.00
25	2.00	1.07	Infinity	0.00
26	0.00	Infinity	1.92	0.00
27	2.70	2.58	Infinity	0.00
28	3.00	Infinity	0.41	0.00
29	0.25	0.03	0.02	1174.46
30	0.25	Infinity	0.01	0.00

Source: Computation from survey data, 2015

4.4.6 Linear programming model for starter feed formulation

Objective Function

Min Z =

$$15X_1+13X_2+28X_4+15X_5+21X_6+15X_8+150X_9+90X_{10}+1.25X_{11}+50X_{12}+110X_{13}+250X_{14}$$

Subject to;

$$X_1+X_2+X_4+X_5+X_6+X_8+X_9+x_{10}+x_{11}+x_{12}+x_{13}+x_{14} = 100$$

$$0.1145x_1+0.1243x_2+0.4536x_4+0.3551x_5+0.4113X_6+0.78X_{13}+0.95X_{14} \geq 0.22\sum_{i=1}^{14} Xi$$

- Protein requirement

$0.0268x_1+0.0459x_2+0.0024x_4+0.009x_5+0.0064x_6+1X_{10}\geq 0.042\sum_{i=1}^{14} Xi$ - Ether extract requirement

$0.037x_1+0.0199x_2+0.1061x_4+0.1095x_5+0.1794x_6 \leq 0.047\sum_{i=1}^{14} Xi$ – Crude fibre requirement

$0.0003x_1+0.0004x_2+0.0036x_4+0.0072x_5+0.0031x_6+0.33X_{11}+0.23X_{12}=0.011\sum_{i=1}^{14} Xi$ – Calcium

$0.003x_1+0.007x_2+0.0067x_4+0.011x_5+0.0067x_6+0.17X_{12}\geq 0.0086\sum_{i=1}^{14} Xi$ - Phosphorus

$0.001x_1+0.0029x_4+0.0025x_5+0.0020x_6+0.17X_{12}\geq 0.005\sum_{i=1}^{14} Xi$ - Available Phosphorus

$0.002x_1+0.0014x_2+0.0038x_4+0.0051x_5+0.0047x_6+0.17X_{12}\geq 0.0036\sum_{i=1}^{14} Xi$ -Phytic Phosphorus

$0.0024x_1+0.0042x_2+0.029x_4+0.006x_5+0.016x_6+0.98X_{13}\geq 0.011\sum_{i=1}^{14} Xi$ - Lysine

$0.0018x_1+0.0024x_2+0.0064x_4+0.0038x_5+0.0042x_6+0.98X_{14}\geq 0.0045\sum_{i=1}^{14} Xi$ - Methionine

$3300x_1+2640x_2+2300x_4+1900x_5+2400x_6+8500X_{10}+3900X_{13}+4500X_{14}\geq 2800 \sum_{i=1}^{14} Xi$ - Metabolizable Energy

$40\leq X_1\leq 60$ – Maize inclusion level

$10\leq X_2\leq 20$ – Pearl millet inclusion level

$15\leq x_4\leq 20$ – Deoiled soya cake inclusion level

$1\leq x_5\leq 2$ – Deoiled mustard cake inclusion level

$5\leq x_6\leq 15$ – Deoiled groundnut cake inclusion level

$X_8 = 0.3$ – Salt restriction

$X_9 = 0.05$ – Premix restriction

$X_{10}<=2.5$- Maximum vegetable oil inclusion level

$X_{11}<=3$ - Maximum L.S.P. inclusion level

$X_{12}<=3$ - Maximum D.C.P. inclusion level

$X_{13}<=0.25$ – Lysine inclusion level

$X_{14}<=0.25$ – Methionine inclusion level

$X_i \geq 0$ for i= 1, 2...14 – Non negativity constraint

4.4.6.1The starter analysis results

The formulated model was analyzed using LP solver and the results were as summarized in table 80. The results show the optimal quantity of each ingredient in kilograms and its value in Indian rupees.

Table 67: Starter model results

Decision variable	Objective coefficient	Optimum solution	
Feed ingredient (X_i)	Price/Kg (₹)	Quantity (Kg)	Cost (₹)
Maize (X_1)	15.00	40.00	600.00
Pearl millet (X_2)	13.00	19.30	250.90
Deoiled soya cake (X_4)	28.00	17.30	484.40
Deoiled mustard cake (X_5)	15.00	2.00	30.00
Deoiled groundnut cake (X_6)	21.00	15.00	315.00
Salt (X_8)	15.00	0.30	4.50
Premixes (X_9)	150.00	0.05	7.50
Vegetable oil (X_{10})	90	2.08	187.20
L.S.P. (X_{11})	1.25	1.30	1.63
D.C.P. (X_{12})	50	2.20	110.00
Lysine (X_{13})	110	0.17	18.70

Methionine (X_{14})	250	0.15	37.50
Total		100Kg	₹ 2050.19

Source: Computation from survey data, 2015

As per table 67, 100kg of starter feed can be formulated at the cost of ₹ 2050.19 at farm level. This entails a cost of ₹ 20.50 per kilogram of feed. The commercial complete feed for starter was found to be rupees 28.00 per kilogram. The proposed optimal solution reduces feed cost by 26.80%. Though transportation and processing of the raw materials may somewhat add to the feed cost, the overall picture is that farm made starter feeds are less costly than complete commercial feeds. None of the sampled farmers in the study area practiced concentrate based starter feeds. Hence no comparison was done between the proposed optimal feed and the concentrate based feed. Sensitivity analysis for starter feed formula was as presented in table 68. The sensitivity analysis shows the range of both the objective function coefficients and the right hand side of the constraint equations in which the optimum solution will remain unchanged.

4.4.6.2 The starter results sensitivity analysis

Table 68: Starter sensitivity analysis

Decision Variable	Current Objective Coefficient	Allowable increase	Allowable decrease
X_1: Maize	15.00	Infinity	4.10
X_2:Pearl millet	13.00	3.88	24.84
X4: Soya cake	28.00	33.27	4.15
X_5:Mustard cake	15.00	6.64	Infinity
X_6: Groundnut cake	21.00	3.72	Infinity
X_8: Salt	15.00	Infinity	Infinity
X_9: Premixes	150.00	Infinity	Infinity
X_{10}: Veg. oil	90.00	1313.49	82.17
X_{11}: L.S.P.	1.25	69.52	555.06
X_{12}:D.C.P.	50.00	635.12	48.51

X_{13}:Lysine	110.00	347.38	67.27
X_{14}:Methionine	250.00	2000.52	200.57

Constraint	Current RHS	Allowable increase	Allowable decrease	Dual Price
1	100.00	0.43	0.75	-2.37
2	22.50	0.82	0.19	-46.65
3	3.50	0.39	0.29	-87.62
4	4.00	1.91	Infinity	0.00
5	1.10	0.24	0.14	3.4
6	0.86	0.01	Infinity	0.00
7	0.45	0.13	0.01	-284.75
8	0.36	Infinity	0.10	0.00
9	1.30	0.07	0.15	-72.6
10	0.55	0.09	0.14	-207.44
11	295000.00	1802.36	Infinity	0.00
12	40.00	1.67	0.60	-4.10
13	60.00	Infinity	20.00	0.00
14	10.00	9.35	Infinity	0.00
15	20.00	Infinity	0.64	0.00
16	15.00	2.31	Infinity	0.00
17	20.00	Infinity	2.68	0.00
18	1.00	1.00	Infinity	0.00
19	2.00	2.58	2.99	6.64
20	5.00	0.75	0.30	0.00
21	15.00	2.5	2.99	3.72
22	0.30	0.75	0.30	-12.62
23	0.05	0.75	0.05	-147.62
24	0.00	2.08	Infinity	0.00
25	2.50	Infinity	0.41	0.00
26	0.00	1.36	Infinity	0.00
27	1.50	Infinity	0.13	0.00
28	0.00	2.20	Infinity	0.00
29	2.40	Infinity	0.19	0.00

30	0.25	Infinity	0.07	0.00
31	0.25	Infinity	0.09	0.00

Source: Computation from survey data, 2015

4.4.7 Linear programming model for finisher feed formulation

Objective Function

Minimize $15X_1+13X_2+28X_4+15X_5+21X_6+15X_8+150X_9+90X_{10}+1.25X_{11}+50X_{12}+110X_{13}+250X_{14}$

Subject to;

$X_1+X_2+X_4+X_5+X_6+X_8+X_9+X_{10}+X_{11}+X_{12}+X_{13}+X_{14} = 100$

$0.1145x_1+0.1657x_3+0.4536x_4+0.3551x_5+0.4113X_6+0.78X_{13}+0.95X_{14} \geq 0.21\sum_{i=1}^{14} Xi$ - Protein requirement

$0.0268x_1+0.0459x_2 0.0024x_4+0.009x_5+0.0064x_6+1X_{10} \geq 0.042\sum_{i=1}^{14} Xi$ - Ether extract requirement

$0.037x_1+0.0199x_2+0.1061x_4+0.1095x_5+0.1794x_6 \leq 0.047\sum_{i=1}^{14} Xi$ – Crude fibre requirement

$0.0003x_1+0.0004x_2+0.0037x_3+0.0036x_4+0.0072x_5+0.0031x_6+0.33X_{11}+0.23X_{12}=0.038\sum_{i=1}^{14} Xi$ – Calcium

$0.003x_1+0.007x_2++0.0067x_4+0.011x_5+0.0067x_6+0.17X_{12} \geq 0.0086\sum_{i=1}^{14} Xi$ - Phosphorus

$0.001x_1+0.0029x_4+0.0025x_5+0.0020x_6+0.17X_{12} \geq 0.005\sum_{i=1}^{8} Xi$ - Available Phosphorus

$0.002x_1+0.0014x_2+0.0038x_4+0.0051x_5+0.0047x_6+0.17X_{12} \geq 0.0036\sum_{i=1}^{14} Xi$ -Phytic Phosphorus

$0.0024x_1+0.0042x_2+0.029x_4+0.006x_5+0.016x_6+0.98X_{13} \geq 0.01\sum_{i=1}^{14} Xi$ - Lysine

$0.0018x_1+0.0024x_2+0.0064x_4+0.0038x_5+0.0042x_6+0.98X_{14}\geq 0.004\sum_{i=1}^{14} Xi$ - Methionine

$3300x_1+2640x_2+2300x_4+1900x_5+2400x_6+8500X_{10}+3900X_{13}+4500X_{14}\geq 2800 \sum_{i=1}^{14} Xi$ - Metabolizable Energy

$40\leq X_1\leq 60$ – Maize inclusion level

$10\leq X_2\leq 20$ – Pearl millet inclusion level

$12\leq x_4\leq 20$ – Deoiled soya cake inclusion level

$2\leq x_5\leq 5$ – Deoiled mustard cake inclusion level

$5\leq x_6\leq 15$ – Deoiled groundnut cake inclusion level

$X_8 = 0.3$ – Salt restriction

$X_9 = 0.05$ – Premix restriction

$X_{10}>=1$ - Minimum vegetable oil inclusion level

$X_{10}<=3$ - Maximum vegetable oil inclusion level

$X_{11}<=3$ - Maximum L.S.P. inclusion level

$X_{12}<=3$ - Maximum D.C.P. inclusion level

$X_{13}<=0.25$ – Lysine inclusion level

$X_{14}<=0.25$ – Methionine inclusion level

$Xi \geq 0$ for i= 1, 2...14 – None negativity constraint

4.4.7.1 The finisher model analysis results

The formulated model was solved through LP solver and the results were as summarized in table 69.

Table 69: Finisher model results

Decision variable	Objective coefficient	Optimum solution	
Feed ingredient (X_i)	Price/Kg (₹)	Quantity (Kg)	Cost (₹)
Maize (X_1)	15.00	40.70	610.50
Pearl millet (X_2)	13.00	20.00	260.00
Deoiled soya cake (X_4)	28.00	12.00	336.00
Deoiled mustard cake (X_5)	15.00	5.00	75.00
Deoiled groundnut cake (X_6)	21.00	15.40	323.40
Salt (X_8)	15.00	0.30	4.50
Premixes (X_9)	150.00	0.05	7.50
Vegetable oil (X_{10})	90	2.00	180.00
L.S.P. (X_{11})	1.25	1.80	2.25
D.C.P. (X_{12})	50	2.20	110.00
Lysine (X_{13})	110	0.19	20.90
Methionine (X_{14})	250	0.12	30.00
Total		100kg	₹ 1966.80

Source: Computation from survey data, 2015

As shown in table 69, 100kg of finisher feed can be formulated at the cost of ₹ 1966.80 at farm level. This entails a cost of ₹ 19.67per kilogram of feed. The commercial complete feed for finisher was found to be ₹ 27.00 per kilogram. The proposed optimal solution reduces feed cost by 27.10%. Though transportation and processing of the raw materials may somewhat add to the feed cost, the overall picture is that farm made finisher feeds are less costly than complete commercial feeds. None of the sampled farmers in the study area practiced concentrate based finisher feeds. Hence no comparison was done between the proposed optimal feed and the concentrate based feed. Sensitivity analysis for finisher feed formula was as presented in table 70. The sensitivity analysis shows the range of both the objective function coefficients and the right hand side of the constraint equations in which the optimum solution will remain unchanged.

4.4.7.2 The finisher results sensitivity analysis

Table 70: Finisher sensitivity analysis

Decision Variable	Current Objective Coefficient	Allowable increase	Allowable decrease
X_1: Maize	15.00	0.95	4.26
X_2:Pearl millet	13.00	4.01	0.70
X_4: Soya cake	28.00	Infinity	4.87
X_5:Mustard cake	15.00	0.61	Infinity
X_6: Groundnut cake	21.00	4.39	0.77
X_8: Salt	15.00	Infinity	Infinity
X_9: Premixes	150.00	Infinity	Infinity
X_{10}: Veg. oil	90.00	32.34	58.70
X_{11}: L.S.P.	1.25	Infinity	Infinity
X_{12}:D.C.P.	50.00	Infinity	Infinty
X_{13}:Lysine	110.00	68.11	68.02
X_{14}:Methionine	250.00	1238.87	199.52

Row	Current RHS	Allowable Increase	Allowable Decrease	Dual Price
1	100.00	1.15	1.84	-1.25
2	21.00	0.32	1.14	-25.90
3	4.20	0.21	0.93	0
4	4.70	1.80	Infinity	0
5	3.80	Infinity	2.52	0
6	0.86	0.02	Infinity	-286.76
7	0.50	0.12	0.02	0
8	0.36	Infinity	0.10	-80.59
9	1.00	0.03	0.18	-217.45
10	0.40	0.12	0.11	-0.003
11	280000	6432.95	1863.43	0
12	40.00	0.77	Infinity	0
13	60.00	Infinity	19.22	0
14	10.00	10.00	Infinity	1.92
15	20.00	1.20	4.32	-4.63

16	12.00	8.00	4.08	0
17	20.00	Infinity	8.00	0
18	2.00	3.00	Infinity	2.45
19	5.00	6.34	3.00	2.74
20	5.00	10.46	Infinity	0
21	20.00	Infinity	4.53	0
22	0.30	1.84	0.30	-13.75
23	0.05	1.84	0.05	-148
24	1.00	1.01	infinity	0
25	3.00	Infinity	0.98	0
26	0.00	1.84	Infinity	0
27	3.00	Infinity	1.15	0
28	0.00	2.24	Infinity	0
29	3.00	Infinity	0.75	0
30	0.25	Infinity	0.05	0
31	0.25	Infinity	0.12	0

Source: Computation from survey data, 2015

4.4.8 Linear programming model for chick feed formulation

Objective Function

Min $Z = 15X_1+28X_4+15X_5+21X_6+15X_8+150X_9+90X_{10}+1.25X_{11}+50X_{12}+110X_{13}+250X_{14}$

Subject to;

$X_1+X_4+X_5+X_6+X_8+X_9+X_{10}+X_{11}+X_{12}+X_{13}+X_{14} = 100$

$0.1145x_1+0.4536x_4+0.3551x_5+0.4113X_6+0.78X_{13}+0.95X_{14} \geq 0.24\sum_{i=1}^{14} Xi$ - Protein requirement

$0.0268x_1+ 0.0024x_4+0.009x_5+0.0064x_6+1X_{10} \geq 0.0314\sum_{i=1}^{14} Xi$ - Ether extract requirement

$0.037x_1+0.1061x_4+0.1095x_5+0.1794x_6 \leq 0.05\sum_{i=1}^{14} Xi$ – Crude fibre requirement

$0.0003x_1+0.0036x_4+0.0072x_5+0.0031x_6+0.33X_{11}+0.23X_{12}=0.011\sum_{i=1}^{14} Xi$ – Calcium

$0.003x_1+0.0067x_4+0.011x_5+0.0067x_6+0.17X_{12}\geq 0.0086\sum_{i=1}^{14} Xi$ - Phosphorus

$0.001x_1+0.0029x_4+0.0025x_5+0.0020x_6+0.17X_{12}\geq 0.005\sum_{i=1}^{14} Xi$ - Available Phosphorus

$0.002x_1+0.0038x_4+0.0051x_5+0.0047x_6+0.17X_{12}\geq 0.0036\sum_{i=1}^{14} Xi$ -Phytic Phosphorus

$0.0024x_1+0.029x_4+0.006x_5+0.016x_6+0.98X_{13}\geq 0.0105\sum_{i=1}^{14} Xi$ - Lysine

$0.0018x_1+0.0064x_4+0.0038x_5+0.0042x_6+0.98X_{14}\geq 0.0043\sum_{i=1}^{14} Xi$ - Methionine

$3300x_1+2300x_4+1900x_5+2400x_6+8500X_{10}+3900X_{13}+4500X_{14}\geq 2700\sum_{i=1}^{14} Xi$ – Metabolizable Energy

$40\leq X_1\leq 60$ – Maize inclusion level

$18\leq x_4\leq 26$ – Deoiled soya cake inclusion level

$1\leq x_5\leq 2$ – Deoiled mustard cake inclusion level

$5\leq x_6\leq 15$ – Deoiled groundnut cake inclusion level

$X_8 = 0.3$ – Salt restriction

$X_9 = 0.05$ – Premix restriction

$X_{10}<=2.5$ - Maximum vegetable oil inclusion level

$X_{11}<=3$ - Maximum L.S.P. inclusion level

$X_{12}<=3$ - Maximum D.C.P. inclusion level

$X_{13}<=0.25$ – Lysine inclusion level

$X_{14}<=0.25$ – Methionine inclusion level

$Xi \geq 0$ for i= 1, 2...14 – Non negativity constraint

4.4.8.1 The chick analysis results

The analysis of the formulated model produced the optimal solution as summarized in table 71.

Table 71: Chick analysis results

Decision variable	Objective coefficient	Optimum solution	
Feed ingredient (X_i)	Price/Kg (₹)	Quantity (Kg)	Cost (₹)
Maize (X_1)	15.00	52.40	786.00
Deoiled soya cake (X_4)	28.00	24.20	677.60
Deoiled mustard cake (X_5)	15.00	2.00	20.00
Deoiled groundnut cake (X_6)	21.00	15.00	315.00
Salt (X_8)	15.00	0.30	4.50
Premixes (X_9)	150.00	0.05	7.50
Vegetable oil (X_{10})	90	2.20	198.00
L.S.P. (X_{11})	1.25	2.10	2.63
D.C.P. (X_{12})	50	2.40	120.00
Lysine (X_{13})	110	0.00	0.00
Methionine (X_{14})	250	0.10	25.00
Total		100Kg	₹ 2175.50

Source: Computation from survey data, 2015

As shown in table 71, 100kg of chick feed can be formulated at the cost of ₹ 2175.50 rupees at farm level. This entails a cost of ₹ 21.75 per kilogram of feed. The commercial complete feed for chicks was found to be ₹26.00 per kilogram. The proposed optimal solution reduces feed cost by 16.35%. Though transportation and processing of the raw materials may somewhat add to the feed cost, the overall picture is that farm made chick feeds are less costly than complete commercial feeds. None of the sampled farmers in the study area practiced concentrate based chick feeds. Hence no comparison was done between the proposed optimal feed and the concentrate based feed. Sensitivity analysis for chick feed formula was as presented in table 72. The sensitivity analysis shows the range of both the objective function coefficients and the right hand side of the constraint equations in which the optimum solution will remain unchanged.

4.4.8.2 The chick results sensitivity analysis

Table 72: Chick sensitivity analysis

Variable	Current Coefficient	Allowable Inc.	Allowable Dec.
X_1:Maize	15.00	12.86	40.18
X_4:DOSC	28.00	36.66	5.96
X_5:DOMC	15.00	10.32	Infinity
X_6:DGNC	21.00	5.24	Infinity
X_8:Salt	15.00	Infinity	Infinity
X_9:Premix	150.00	Infinity	Infinity
X_{10}:Veg. Oil	90.00	3495.13	79.93
X_{11}:LSP	1.25	67.08	2514.20
X_{12}:DCP	50.00	594.46	46.80
X_{13}:Lysine	110.00	Infinity	72.73
X_{14}:Methionine	250.00	2752.68	203.40

Row	Current RHS	Allowable Inc.	Allowable Dec.	Dual Price
1	100.00	4.63	4.96	-7.15
2	24.00	0.58	0.39	-38.60
3	3.80	0.26	2.14	-82.84
4	5.00	Infinity	0.35	0
5	1.10	0.62	0.37	17.90
6	0.86	0.09	0.07	-276.23
7	0.50	0.07	Infinity	0
8	0.36	0.33	Infinity	0
9	1.05	0.03	Infinity	0
10	0.43	0.13	0.10	-210.37
11	270000	18151.59	Infinity	0
12	40	12.47	infinity	0
13	60	Infinity	7.52	0
14	18	6.26	Infinity	0

15	26	Infinity	1.70	0
16	1	1.00	Infinity	0
17	2	2.03	1.00	10.32
18	5	10.00	1.97	5.24
19	15	3.21	0.30	-7.84
20	0.30	4.96	0.05	-142.84
21	0.05	4.96	Infinity	0
22	0.00	2.22	0.27	0
23	2.50	Infinity	Infinity	0
24	0.00	1.12	1.87	0
25	3.00	Infinity	Infinity	0
26	0.00	2.45	Infinity	0
27	3.00	Infinity	0.54	0
28	0.25	Infinity	0.25	0
29	0.25	Infinity	0.13	0

Source: Computation from survey data, 2015

4.4.9 Linear programming model for growers feed formulation

Objective Function

Minimize Z =

$15X_1+13X_2+8X_3+28X_4+15X_5+21X_6+15X_8+150X_9+90X_{10}+1.25X_{11}+50X_{12}+110X_{13}+250X_{14}$

Subject to;

$X_1+X_2+X_3+X_4+X_5+X_6+X_8+X_9+X_{10}+X_{11}+X_{12}+X_{13}+X_{14} = 100$

$0.1145x_1+0.1243x_2+0.1657x_3+0.4536x_4+0.3551x_5+0.4113X_6+0.78X_{13}+0.95X_{14} \geq 0.175\sum_{i=1}^{14} Xi$ - Protein requirement

$0.0268x_1+0.0459x_2+0.005x_3+0.0024x_4+0.009x_5+0.0064x_6+1X_{10} \geq 0.033\sum_{i=1}^{14} Xi$ - Ether extract requirement

$0.037x_1+0.0199x_2+0.1177x_3+0.1061x_4+0.1095x_5+0.1794x_6 \leq 0.07\sum_{i=1}^{14} Xi$ – Crude fibre requirement

$0.0003x_1+0.0004x_2+0.0037x_3+0.0036x_4+0.0072x_5+0.0031x_6+0.33X_{11}+0.23X_{12}=0.011\sum_{i=1}^{14} Xi$ – Calcium

$0.003x_1+0.007x_2+0.015x_3+0.0067x_4+0.011x_5+0.0067x_6+0.17X_{12}\geq0.009\sum_{i=1}^{14} Xi$ - Phosphorus

$0.001x_1+0.0021x_3+0.0029x_4+0.0025x_5+0.0020x_6+0.17X_{12}\geq0.005\sum_{i=1}^{14} Xi$ - Available Phosphorus

$0.002x_1+0.0014x_2+0.0129x_3+0.0038x_4+0.0051x_5+0.0047x_6+0.17X_{12}\geq0.004\sum_{i=1}^{14} Xi$ -Phytic Phosphorus

$0.0024x_1+0.0042x_2+0.0064x_3+0.029x_4+0.006x_5+0.016x_6+0.98X_{13}\geq0.0075\sum_{i=1}^{14} Xi$ - Lysine

$0.0018x_1+0.0024x_2+0.003x_3+0.0064x_4+0.0038x_5+0.0042x_6+0.98X_{14}\geq0.0035\sum_{i=1}^{14} Xi$ - Methionine

$3300x_1+2640x_2+1450x_3+2300x_4+1900x_5+2400x_6+90X_{10}+1.25X_{11}+50X_{12}+110X_{13}+250X_{14}\geq2500\sum_{i=1}^{8} Xi$ - Metabolizable Energy

$40\leq X_1\leq60$ – Maize inclusion level

$10\leq X_2\leq20$ – Pearl millet inclusion level

$5\leq X_3\leq10$ – Deoiled rice bran inclusion level

$10\leq x_4\leq15$ – Deoiled soya cake inclusion level

$5\leq x_5\leq7$ – Deoiled mustard cake inclusion level

$5\leq x_6\leq15$ – Deoiled groundnut cake inclusion level

$X_8 = 0.3$ – Salt restriction

$X_9 = 0.05$ – Premix restriction

$X_{10}<=1$ - Maximum vegetable oil inclusion level

$X_{11}<=3$ - Maximum L.S.P. inclusion level

$X_{12}<=3$ - Maximum D.C.P. inclusion level

X_{13}<=0.25 – Lysine inclusion level

X_{14}<=0.25 – Methionine inclusion level

$X_i \geq 0$ for i= 1, 2...14 – Non negativity constraint

4.4.9.1 The grower analysis results

The formulated model was analyzed using LP solver and the results were as shown in table 73.

Table 73: Growers analysis results

Decision variable	Objective coefficient	Optimum solution	
Feed ingredient (X_i)	Price/Kg (₹)	Quantity (Kg)	Cost (₹)
Maize (X_1)	15.00	43.50	652.50
Pearl millet (X_2)	13.00	20.00	260.00
D.O.R.B (X3)	8.00	10.00	80.00
Deoiled soya cake (X_4)	28.00	10.00	280.00
Deoiled mustard cake (X_5)	15.00	7.00	105.00
Deoiled groundnut cake (X_6)	21.00	5.00	105.00
Salt (X_8)	15.00	0.30	4.50
Premixes (X_9)	150.00	0.05	7.50
Vegetable oil (X_{10})	90	0.30	27.00
L.S.P. (X_{11})	1.25	1.20	1.50
D.C.P. (X_{12})	50	2.20	110.00
Lysine (X_{13})	110	0.08	8.80
Methionine (X_{14})	250	0.08	20.00
Total		100Kg	₹ 1674.70

Source: Computation from survey data, 2015

As shown in table 73, 100kg of growers feed can be formulated at the cost of ₹ 1674.70 at farm level. This entails a cost of ₹ 16.75 per kilogram of feed. The commercial complete feed for growers was found to be rupees 24.00 rupees per kilogram. The proposed optimal solution reduces feed cost by 30.20%. Though transportation and processing of the raw materials may somewhat add to the feed cost, the overall picture is that farm made growers feeds are less costly than complete commercial feeds. None of the sampled farmers in the study area practiced concentrate based grower feeds. Hence no comparison was done between the proposed optimal feed and the concentrate based feed. Sensitivity analysis for grower feed formula was as presented in table 74. The sensitivity analysis shows the range of both the objective function coefficients and the right hand side of the constraint equations in which the optimum solution will remain unchanged.

4.4.9.2 The growers' results sensitivity analysis

Table 74: Growers' results sensitivity analysis

Variable	Current Coefficient	Allowable Inc.	Allowable Dec.
X_1:Maize	15.00	5.83	0.66
X_2:Pearl millet	13.00	2.91	Infinity
X_3:D.O.R.B	8.00	5.91	Infinity
X_4:DOSC	28.00	Infinity	10.75
X_5:DOMC	15.00	0.64	infinity
X_6:DGNC	21.00	Infinity	5.82
X_8:Salt	15.00	Infinity	Infinity
X_9:Premix	150.00	Infinity	Infinity
X_{10}:Veg. Oil	90.00	157.86	75.92
X_{11}:LSP	1.25	65.47	44.27
X_{12}:DCP	50.00	501.47	45.61
X_{13}:Lysine	110.00	395.58	98.44
X_{14}:Methionine	250.00	2273.11	238.23

Row	Current RHS	Allowable Increase	Allowable Decrease	Dual Price
1	100.00	10.87	3.40	-11.30
2	17.50	0.85	infinity	0.00
3	3.30	0.58	0.38	78.69
4	7.00	infinity	1.08	0.00
5	1.10	0.56	0.42	30.43

6	0.90	0.07	Infinity	-268.83
7	0.50	0.13	0.07	0.00
8	0.40	0.32	Infinity	-100.70
9	0.75	0.15	0.08	-243.56
10	0.35	0.16	0.08	0.00
11	250000.00	13435.24	Infinity	0.00
12	40.00	3.55	Infinity	0.00
13	60.00	Infinity	16.44	0.00
14	10.00	10.00	Infinity	2.91
15	20.00	3.60	10.00	0.00
16	5.00	5.00	Infinity	5.91
17	10.00	3.53	5.00	-10.75
18	10.00	3.20	2.71	0.00
19	15.00	Infinity	5.00	0.00
20	5.00	2.00	Infinity	0.64
21	7.00	3.65	2.00	-5.82
22	5.00	3.56	3.01	0.00
23	15.00	Infinity	10.00	-3.69
24	0.30	3.40	0.05	-138.69
25	0.05	0.34	0.05	0.00
26	0.00	0.39	Infinity	0.00
27	1.00	Infinity	0.60	0.00
28	0.00	2.22	Infinity	0.00
29	3.00	Infinity	0.77	0.00
30	0.25	Infinity	0.16	0.00
31	0.25	Infinity	0.16	0.00

Source: Computation from survey data, 2015

4.4.10 Linear programming model for layer I feed formulation

Objective Function

Min Z =

$15X_1+13X_2+8X_3+28X_4+15X_5+21X_6+1X_7+15X_8+150X_9+90X_{10}+1.25X_{11}+50X_{12}+110X_{13}+250X_{14}$

Subject to;

$$X_1 + X_2 + X_3 + X_4 + X_5 + X_6 + X_7 + X_8 + X_9 + X_{10} + X_{11} + X_{12} + X_{13} + X_{14} = 100$$

$0.1145x_1+0.1243x_2+0.1657x_3+0.4536x_4+0.3551x_5 + 0.4113X_6+0.78X_{13}+0.95X_{14} \geq 0.18\sum_{i=1}^{14} Xi$ - Protein requirement

$0.0268x_1+ 0.0459x_2+0.005x_3+0.0024x_4+0.009x_5+0.0064x_6 +1X_{10} \geq 0.033\sum_{i=1}^{14} Xi$ - Ether extract requirement

$0.037x_1+0.0199x_2+0.1177x_3+0.1061x_4+0.1095x_5+0.1794x_6 \leq 0.06\sum_{i=1}^{14} Xi$ – Crude fibre requirement

$0.0003x_1+0.0004x_2+0.0037x_3+0.0036x_4+0.0072x_5+0.0031x_6+0.33x_7+0.33X_{11}+0.23X_{12}=0.038\sum_{i=1}^{14} Xi$ – Calcium

$0.003x_1+0.007x_2+0.015x_3+0.0067x_4+0.011x_5+0.0067x_6+0.17X_{12} \geq 0.0076\sum_{i=1}^{14} Xi$ - Phosphorus

$0.001x_1+0.0021x_3+0.0029x_4+0.0025x_5+0.0020x_6+0.17X_{12} \geq 0.0046\sum_{i=1}^{14} Xi$ - Available Phosphorus

$0.002x_1+0.0014x_2+0.0129x_3+0.0038x_4+0.0051x_5+0.0047x_6+0.17X_{12} \geq 0.003\sum_{i=1}^{14} Xi$ -Phytic Phosphorus

$0.0024x_1+0.0042x_2+0.0064x_3+0.029x_4+0.006x_5+0.016x_6+0.98X_{13} \geq 0.0088\sum_{i=1}^{14} Xi$ - Lysine

$0.0018x_1+0.0024x_2+0.003x_3+0.0064x_4+0.0038x_5+0.0042x_6+0.98X_{14} \geq 0.004\sum_{i=1}^{14} Xi$ - Methionine

$3300x_1+2640x_2+1450x_3+2300x_4+1900x_5+2400x_6+8500X_{10}+3900X_{13}+4500X_{14} \geq 2500 \sum_{i=1}^{8} Xi$ - Metabolizable Energy

$40 \leq X_1 \leq 60$ – Maize inclusion level

$10 \leq X_2 \leq 20$ – Pearl millet inclusion level

$5 \leq X_3 \leq 10$ – Deoiled rice bran inclusion level

$10 \leq x_4 \leq 15$ – Deoiled soya cake inclusion level

$5 \le x_5 \le 7$ – Deoiled mustard cake inclusion level

$5 \le x_6 \le 15$ – Deoiled groundnut cake inclusion level

$6 \le x_7 \le 9$ – Marble grits inclusion level

$X_8 = 0.3$ – Salt restriction

$X_9 = 0.05$ – Premix restriction

$X_{10} <= 0.5$ - Maximum vegetable oil inclusion level

$X_{11} >= 1$ - Minimum L.S.P. inclusion level

$X_{11} <= 2$ - Maximum L.S.P. inclusion level

$X_{12} <= 2$ - Maximum D.C.P. inclusion level

$X_{13} <= 0.25$ – Lysine inclusion level

$X_{14} <= 0.25$ – Methionine inclusion level

$X_i \ge 0$ for i= 1, 2...14 – Non negativity constraint

4.4.10.1 The layer I analysis results

The analysis of the formulated layer I model produced results that are shown in table 88.

Table 75: Layer I model analysis results

Decision variable	Objective coefficient	Optimum solution	
Feed ingredient (X_i)	Price/Kg (₹)	Quantity (Kg)	Cost (₹)
Maize (X_1)	15.00	48.00	720.00
Pearl millet (X_2)	13.00	15.30	198.90
D.O.R.B (X3)	8.00	8.00	64.00
Deoiled soya cake (X_4)	28.00	11.10	310.80
Deoiled mustard cake (X_5)	15.00	0.00	0.00
Deoiled groundnut cake (X_6)	21.00	5.00	105.00

Marble grits (X_7)	1.00	9.00	9.00
Salt (X_8)	15.00	0.30	4.50
Premixes (X_9)	150.00	0.05	7.50
Vegetable oil (X_{10})	90	0.00	0.00
L.S.P. (X_{11})	1.25	1.00	1.25
D.C.P. (X_{12})	50	1.6	80.00
Lysine (X_{13})	110	0.25	27.50
Methionine (X_{14})	250	0.16	40.00
Total		100kg	₹ 1574.80

Source: Computation from survey data, 2015

As shown in table 75, 100kg of layer I feed can be formulated at the cost of ₹ 1574.80 at farm level. This entails a cost of ₹ 15.75 per kilogram of feed. The commercial complete feed for layer I was found to be ₹ 20.00 per kilogram. The proposed optimal solution reduces feed cost by 21.30%.

It was observed that 100 per cent of the sampled layer farmers in the study area practiced concentrate based complete feed. The price of concentrate based layer I feed averaged at ₹ 15.16 per kg. Hence compared to concentrate based commercial feeds, the proposed optimal feed was found to be about 3.9% more costly. Though 15.75 cost of farm based own feed is a bit costlier than 15.16 concentrate based complete feed, farm based feed is more advantageous than commercial because the farmer will be assured of quality. Farm based feed will pay him in terms of health and productivity of the birds. This is especially true because the type and quantities of ingredients included in the concentrate are not shown on the bag of the commercial feed. Hence no one can exactly tell the quality of the commercial feed. Farmers are therefore encouraged to make their own feeds at farm level. Sensitivity analysis for layer I feed formula was as presented in table 76. The sensitivity analysis shows the range of both the objective function coefficients and the right hand side of the constraint equations in which the optimum solution will remain unchanged.

4.4.10.2 The layer I results sensitivity analysis

Table 76: Layer I results sensitivity analysis

Variable	Current Coefficient	Allowable Increase	Allowable Decrease
X_1:Maize	15.00	0.53	2.72
X_2:Pearl millet	13.00	2.01	0.33
X_3:D.O.R.B	8.00	0.94	Infinity
X_4:DOSC	28.00	3.06	13.53
X_5:DOMC	15.00	Infinity	4.12
X_6:DGNC	21.00	Infinity	1.43
X_7:Marble grits	1.00	0.25	Infinity
X_8:Salt	15.00	Infinity	Infinity
X_9:Premix	150.00	Infinity	Infinity
X_{10}:Veg. Oil	90.00	Infinity	41.96
X_{11}:L.S.P.	1.25	71.88	0.25
X_{12}:D.C.P.	50.00	230.68	50.14
X_{13}:Lysine	110.00	553.92	Infinity
X_{14}:Methionine	250.00	3251.56	229.44

Row	Current RHS	Allowable Increase	Allowable Decrease	Dual Price
1	100.00	0.78	0.43	10.77
2	18.00	Infinity	1.79	0.00
3	3.30	Infinity	1.20	0.00
4	6.00	Infinity	2.20	0.00
5	3.80	0.29	0.02	-36.44
6	0.76	0.01	0.22	-308.20
7	0.46	Infinity	0.07	0.00
8	0.30	0.26	Infinity	0.00
9	0.88	0.05	0.03	-660.93
10	0.40	0.08	0.16	-234.32
11	250000.00	1651.60	2660.22	-0.01
12	40.00	8.02	Infinity	0.00
13	60.00	Infinity	11.97	0.00

14	10.00	5.34	Infinity	0.00
15	20.00	Infinity	4.65	0.00
16	8.00	1.90	1.66	0.94
17	10.00	Infinity	2.00	0.00
18	10.00	1.17	Infinity	0.00
19	15.00	Infinity	3.82	0.00
20	5.00	Infinity	5.00	0.00
21	7.00	Infinity	7.00	0.00
22	5.00	2.51	5.00	0.00
23	15.00	Infinity	10.00	-1.43
24	6.00	3.00	Infinity	0.00
25	9.00	0.04	0.95	0.00
26	0.30	0.43	0.05	0.25
27	0.05	0.45	0.05	-25.77
28	0.00	0.00	Infinity	-160.77
29	0.50	Infinity	0.50	0.00
30	1.00	0.04	Infinity	0.00
31	2.00	Infinity	0.95	0.00
32	0.00	1.64	Infinity	0.00
33	2.00	Infinity	0.35	0.00
34	0.25	0.02	0.05	0.00
35	0.25	Infinity	0.08	0.00

Source: Computation from survey data, 2015

4.4.11 Linear programming model for layer II feed formulation

Objective Function

Min Z =

$$15X_1+13X_2+8X_3+28X_4+15X_5+21X_6+1X_7+15X_8+150X_9+90X_{10}+1.25X_{11}+50X_{12}+110X_{13}+250X_{14}$$

Subject to;

$$X_1+X_2+X_3+X_4+X_5+X_6+X_7+X_8+X_9+X_{10}+X_{11}+X_{12}+X_{13}+X_{14}=100$$

$0.1145x_1+0.1243x_2+0.1657x_3+0.4536x_4+0.3551x_5 + 0.4113X_6+0.78X_{13}+0.95X_{14} \geq 0.16\sum_{i=1}^{14} Xi$ - Protein requirement

$0.0268x_1+ 0.0459x_2+0.005x_3+0.0024x_4+0.009x_5+0.0064x_6 +1X_{10} \geq 0.033\sum_{i=1}^{14} Xi$ - Ether extract requirement

$0.037x_1+0.0199x_2+0.1177x_3+0.1061x_4+0.1095x_5+0.1794x_6 \leq 0.07\sum_{i=1}^{14} Xi$ – Crude fibre requirement

$0.0003x_1+0.0004x_2+0.0037x_3+0.0036x_4+0.0072x_5+0.0031x_6+0.33x_7+0.33X_{11}+0.23X_{12}=0.038\sum_{i=1}^{14} Xi$ – Calcium

$0.003x_1+0.007x_2+0.015x_3+0.0067x_4+0.011x_5+0.0067x_6+0.17X_{12} \geq 0.0076\sum_{i=1}^{14} Xi$ - Phosphorus

$0.001x_1+0.0021x_3+0.0029x_4+0.0025x_5+0.0020x_6+0.17X_{12} \geq 0.0042\sum_{i=1}^{14} Xi$ - Available Phosphorus

$0.002x_1+0.0014x_2+0.0129x_3+0.0038x_4+0.0051x_5+0.0047x_6+0.17X_{12} \geq 0.0034 \sum_{i=1}^{14} Xi$ -Phytic Phosphorus

$0.0024x_1+0.0042x_2+0.0064x_3+0.029x_4+0.006x_5+0.016x_6+0.98X_{13} \geq 0.0075\sum_{i=1}^{14} Xi$ - Lysine

$0.0018x_1+0.0024x_2+0.003x_3+0.0064x_4+0.0038x_5+0.0042x_6+0.98X_{14} \geq 0.0034 \sum_{i=1}^{14} Xi$ - Methionine

$3300x_1+2640x_2+1450x_3+2300x_4+1900x_5+2400x_6+8500X_{10}+3900X_{13}+4500X_{14} \geq 2450 \sum_{i=1}^{14} Xi$ - Metabolizable Energy

$40 \leq X_1 \leq 60$ – Maize inclusion level

$10 \leq X_2 \leq 20$ – Pearl millet inclusion level

$10 \leq X_3 \leq 15$ – Deoiled rice bran inclusion level

$10 \leq x_4 \leq 15$ – Deoiled soya cake inclusion level

$5 \leq x_5 \leq 7$ – Deoiled mustard cake inclusion level

$5 \leq x_6 \leq 15$ – Deoiled groundnut cake inclusion level

$6 \le x_7 \le 9$ – Marble grits inclusion level

$X_8 = 0.3$ – Salt restriction

$X_9 = 0.05$ – Premix restriction

$X_{10} <= 0.25$ - Maximum vegetable oil inclusion level

$X_{11} >= 1$ - Minimum L.S.P. inclusion level

$X_{11} <= 2$ - Maximum L.S.P. inclusion level

$X_{12} <= 2$ - Maximum D.C.P. inclusion level

$X_{13} <= 0.25$ – Lysine inclusion level

$X_{14} <= 0.25$ – Methionine inclusion level

$X_i \ge 0$ for i= 1, 2...14 – Non negativity constraint

4.4.11.1 The layer II analysis results

The formulated model was solved using LP solver and the results were as shown in table 77.

Table 77: Layer II model analysis results

Decision variable	Objective coefficient	Optimum solution	
Feed Ingredient (X_i)	Price/Kg (₹)	Quantity (Kg)	Cost (₹)
Maize (X_1)	15.00	44.20	663.00
Pearl millet (X_2)	13.00	18.20	236.60
D.O.R.B (X_3)	8.00	8.00	64.00
Deoiled soya cake (X_4)	28.00	7.10	198.80
Deoiled mustard cake (X_5)	15.00	5.00	75.00
Deoiled groundnut cake (X_6)	21.00	5.00	105.00
Marble grits (X_7)	1.00	8.80	8.80
Salt (X_8)	15.00	0.30	4.50
Premixes (X_9)	150.00	0.05	7.50
Vegetable oil (X_{10})	90	0.00	0.00
L.S.P. (X_{11})	1.25	1.00	1.25
D.C.P. (X_{12})	50	1.80	90.00

Lysine (X_{13})	110	0.20	22.00
Methionine (X_{14})	250	0.10	25.00
Total		100Kg	₹ 1509.60

Source: Computation from survey data, 2015

As shown in table 77, 100kg of layer II feed can be formulated at the cost of ₹ 1509.60 at farm level. This entails a cost of ₹ 15.10 per kilogram of feed. The commercial complete feed for layer II was found to be ₹ 20.00 per kilogram. The proposed optimal solution decreases feed cost by 24.50%. Though transportation and processing of raw materials may somehow add to the costs, still there are all indicators that farm made layer II feeds will be less costly than complete commercial layer II feeds.

However, considering the price of concentrate based layer II feeds of ₹ 15.16 per Kg, the farm based own feed will be 0.4% less costly than the concentrate based complete layer II feed. Given the assured quality of farm based own feed, farmers are advised to make their own farm based feed instead of going for concentrate based complete feed. Sensitivity analysis for layer II feed formula was as presented in table 78. The sensitivity analysis shows the range of both the objective function coefficients and the right hand side of the constraint equations in which the optimum solution will remain unchanged.

4.4.11.2 The layer II results sensitivity analysis

Table 78: The layer II results sensitivity analysis

Variable	Current Coefficient	Allowable Increase	Allowable Decrease
X_1:Maize	15.00	1.96	0.70
X_2:Pearl millet	13.00	0.51	1.28
X_3:D.O.R.B	8.00	3.31	Infinity
X_4:DOSC	28.00	30.83	4.54
X_5:DOMC	15.00	5.55	Infinity
X_6:DGNC	21.00	4.09	Infinity
X_7:Marble grits	1.00	0.25	2.88
X_8:Salt	15.00	Infinity	Infinity
X_9:Premix	150.00	Infinity	Infinity
X_{10}:Veg. Oil	90.00	Infinity	61.88

X_{11}:LSP	1.25	Infinity	0.25
X_{12}:DCP	50.00	89.21	50.39
X_{13}:Lysine	110.00	312.20	64.32
X_{14}:Methionine	250.00	2776.02	196.85

Row	Current RHS	Allowable Increase	Allowable Decrease	Dual Price
1	100.00	0.30	1.45	1.94
2	16.00	0.87	0.36	-38.84
3	3.30	Infinity	1.14	0.00
4	7.00	Infinity	3.13	0.00
5	3.80	0.05	0.10	-8.93
6	0.76	0.07	Infinity	0.00
7	0.42	0.02	0.04	-293.49
8	0.34	0.26	Infinity	0.00
9	245000	5311.00	1113.77	-69.23
10	40.00	4.22	Infinity	-203.18
11	60.00	Infinity	15.77	-0.004
12	10.00	8.26	Infinity	0.00
13	20.00	Infinity	1.73	0.00
14	8.00	2.00	0.66	0.00
15	10.00	Infinity	0.00	0.00
16	10.00	Infinity	2.84	3.31
17	15.00	Infinity	7.84	0.00
18	5.00	2.00	1.87	0.00
19	7.00	Infinity	2.00	0.00
20	5.00	4.50	3.15	5.55
21	15.00	Infinity	10.00	0.00
22	6.00	2.83	Infinity	4.09
23	9.00	Infinity	0.16	0.00
24	0.30	1.45	0.30	0.00
25	0.05	1.45	0.05	0.00
26	0.00	0.00	Infinity	-16.94
27	0.25	Infinity	0.25	-151.94

28	1.00	1.00	0.16	0.00
29	2.00	Infinity	1.00	0.00
30	0.00	1.85	Infinity	-0.25
31	2.00	Infinity	0.14	0.00
32	0.25	Infinity	0.04	0.00
33	0.25	Infinity	0.14	0.00

Source: Computation from survey data, 2015

4.4.12 Linear programming model for layer III feed formulation

Objective Function

Min Z =

$15X_1+13X_2+8X_3+28X_4+15X_5+21X_6+1X_7+15X_8+150X_9+90X_{10}+1.25X_{11}+50X_{12}+110X_{13}+250X_{14}$

Subject to;

$X_1+ X_2+X_3+X_4+X_5+X_6+X_7+X_8 +X_9+X_{10}+X_{11}+X_{12}+X_{13}+X_{14} = 100$

$0.1145x_1+0.1243x_2+0.1657x_3+0.4536x_4+0.3551x_5+0.4113X_6+0.78X_{13}+0.95X_{14}\geq 0.16\sum_{i=1}^{14} Xi$ - Protein requirement

$0.0268x_1+ 0.0459x_2+0.005x_3+0.0024x_4+0.009x_5+0.0064x_6+1X_{10} \geq 0.033\sum_{i=1}^{14} Xi$ - Ether extract requirement

$0.037x_1+0.0199x_2+0.1177x_3+0.1061x_4+0.1095x_5+0.1794x_6 \leq 0.075\sum_{i=1}^{14} Xi$ – Crude fibre requirement

$0.0003x_1+0.0004x_2+0.0037x_3+0.0036x_4+0.0072x_5+0.0031x_6+0.33x_7+0.33X_{11}+0.23X_{12}=0.04\sum_{i=1}^{14} Xi$ – Calcium

$0.003x_1+0.007x_2+0.015x_3+0.0067x_4+0.011x_5+0.0067x_6+0.17X_{12}\geq 0.0076\sum_{i=1}^{14} Xi$ - Phosphorus

$0.001x_1+0.0021x_3+0.0029x_4+0.0025x_5+0.0020x_6+0.17X_{12}\geq 0.004\sum_{i=1}^{14} Xi$ - Available Phosphorus

$0.002x_1+0.0014x_2+0.0129x_3+0.0038x_4+0.0051x_5+0.0047x_6+0.17X_{12}\geq 0.0036\sum_{i=1}^{14} Xi$ -Phytic Phosphorus

X_{11}:LSP	1.25	Infinity	0.25
X_{12}:DCP	50.00	89.21	50.39
X_{13}:Lysine	110.00	312.20	64.32
X_{14}:Methionine	250.00	2776.02	196.85

Row	Current RHS	Allowable Increase	Allowable Decrease	Dual Price
1	100.00	0.30	1.45	1.94
2	16.00	0.87	0.36	-38.84
3	3.30	Infinity	1.14	0.00
4	7.00	Infinity	3.13	0.00
5	3.80	0.05	0.10	-8.93
6	0.76	0.07	Infinity	0.00
7	0.42	0.02	0.04	-293.49
8	0.34	0.26	Infinity	0.00
9	245000	5311.00	1113.77	-69.23
10	40.00	4.22	Infinity	-203.18
11	60.00	Infinity	15.77	-0.004
12	10.00	8.26	Infinity	0.00
13	20.00	Infinity	1.73	0.00
14	8.00	2.00	0.66	0.00
15	10.00	Infinity	0.00	0.00
16	10.00	Infinity	2.84	3.31
17	15.00	Infinity	7.84	0.00
18	5.00	2.00	1.87	0.00
19	7.00	Infinity	2.00	0.00
20	5.00	4.50	3.15	5.55
21	15.00	Infinity	10.00	0.00
22	6.00	2.83	Infinity	4.09
23	9.00	Infinity	0.16	0.00
24	0.30	1.45	0.30	0.00
25	0.05	1.45	0.05	0.00
26	0.00	0.00	Infinity	-16.94
27	0.25	Infinity	0.25	-151.94

28	1.00	1.00	0.16	0.00
29	2.00	Infinity	1.00	0.00
30	0.00	1.85	Infinity	-0.25
31	2.00	Infinity	0.14	0.00
32	0.25	Infinity	0.04	0.00
33	0.25	Infinity	0.14	0.00

Source: Computation from survey data, 2015

4.4.12 Linear programming model for layer III feed formulation

Objective Function

Min Z =

$15X_1+13X_2+8X_3+28X_4+15X_5+21X_6+1X_7+15X_8+150X_9+90X_{10}+1.25X_{11}+50X_{12}+110X_{13}+250X_{14}$

Subject to;

$X_1+X_2+X_3+X_4+X_5+X_6+X_7+X_8+X_9+X_{10}+X_{11}+X_{12}+X_{13}+X_{14} = 100$

$0.1145x_1+0.1243x_2+0.1657x_3+0.4536x_4+0.3551x_5+0.4113X_6+0.78X_{13}+0.95X_{14}\geq 0.16\sum_{i=1}^{14} Xi$ - Protein requirement

$0.0268x_1+0.0459x_2+0.005x_3+0.0024x_4+0.009x_5+0.0064x_6+1X_{10}\geq 0.033\sum_{i=1}^{14} Xi$ - Ether extract requirement

$0.037x_1+0.0199x_2+0.1177x_3+0.1061x_4+0.1095x_5+0.1794x_6\leq 0.075\sum_{i=1}^{14} Xi$ – Crude fibre requirement

$0.0003x_1+0.0004x_2+0.0037x_3+0.0036x_4+0.0072x_5+0.0031x_6+0.33x_7+0.33X_{11}+0.23X_{12}=0.04\sum_{i=1}^{14} Xi$ – Calcium

$0.003x_1+0.007x_2+0.015x_3+0.0067x_4+0.011x_5+0.0067x_6+0.17X_{12}\geq 0.0076\sum_{i=1}^{14} Xi$ - Phosphorus

$0.001x_1+0.0021x_3+0.0029x_4+0.0025x_5+0.0020x_6+0.17X_{12}\geq 0.004\sum_{i=1}^{14} Xi$ - Available Phosphorus

$0.002x_1+0.0014x_2+0.0129x_3+0.0038x_4+0.0051x_5+0.0047x_6+0.17X_{12}\geq 0.0036\sum_{i=1}^{14} Xi$ -Phytic Phosphorus

$0.0024x_1+0.0042x_2+0.0064x_3+0.029x_4+0.006x_5+0.016x_6+0.98X_{13}\geq 0.007\sum_{i=1}^{14} Xi$ - Lysine

$0.0018x_1+0.0024x_2+0.003x_3+0.0064x_4+0.0038x_5+0.0042x_6+0.98X_{14}\geq 0.003\sum_{i=1}^{14} Xi$ - Methionine

$3300x_1+2640x_2+1450x_3+2300x_4+1900x_5+2400x_6+8500X_{10}+3900X_{13}+4500X_{14}\geq 2400 \sum_{i=1}^{14} Xi$ - Metabolizable Energy

$40\leq X_1\leq 60$ – Maize inclusion level

$10\leq X_2\leq 20$ – Pearl millet inclusion level

$10\leq X_3\leq 20$ – Deoiled rice bran inclusion level

$10\leq x_4\leq 15$ – Deoiled soya cake inclusion level

$5\leq x_5\leq 7$ – Deoiled mustard cake inclusion level

$5\leq x_6\leq 15$ – Deoiled groundnut cake inclusion level

$6\leq x_7\leq 9$ – Marble grits inclusion level

$X_8 = 0.3$ – Salt restriction

$X_9 = 0.05$ – Premix restriction

$X_{10}<=0.25$ - Maximum vegetable oil inclusion level

$X_{11}>=1$ - Minimum L.S.P. inclusion level

$X_{11}<=2$ - Maximum L.S.P. inclusion level

$X_{12}<=2$ - Maximum D.C.P. inclusion level

$X_{13}<=0.25$ – Lysine inclusion level

$X_{14}<=0.25$ – Methionine inclusion level

$Xi \geq 0$ for i= 1, 2...14 – Non negativity constraint

4.4.12.1 The layer III analysis results

The analysis of the layer III model produced the optimal solution results that are summarized in table 79.

Table 79: Layer III analysis results

Decision variable	Objective coefficient	Optimum solution	
Feed ingredient (X_i)	**Price/Kg (₹)**	**Quantity (Kg)**	**Cost (₹)**
Maize (X_1)	15.00	40.60	609.00
Pearl millet (X_2)	13.00	18.60	241.80
D.O.R.B (X_3)	8.00	8.00	64.00
Deoiled soya cake (X_4)	28.00	10.00	280.00
Deoiled mustard cake (X_5)	15.00	5.00	75.00
Deoiled groundnut cake (X_6)	21.00	5.00	105.00
Marble grits (X_7)	1.00	9.00	9.00
Salt (X_8)	15.00	0.30	4.50
Premixes (X_9)	150.00	0.05	7.50
Vegetable oil (X_{10})	90	0.00	0.00
L.S.P. (X_{11})	1.25	1.50	1.88
D.C.P. (X_{12})	50	1.70	85.00
Lysine (X_{13})	110	0.07	7.70
Methionine (X_{14})	250	0.05	12.50
Total		100kg	₹ 1506.50

Source: Computation from survey data, 2015

As shown in table 79, 100kg of layer III feed can be formulated at the cost of ₹1506.50 at farm level. This entails a cost of ₹15.10 per kilogram of feed. The commercial complete feed for layer III was found to be ₹20.00 per kilogram. The proposed optimal solution decreases feed cost by 24.50%. Though transportation and processing of raw materials may somehow add to the costs, still the likelihood is that farm made layer III feeds will be cheaper than readymade complete layer III feeds.

Considering the price of concentrate based layer III feeds of ₹15.16 per Kg, the farm formulated feed will be 0.4% less costly than the concentrate based layer III feed. Given the assured quality of farm based own feed, farmers are advised to make their own farm based feed instead of going for concentrate based complete feed. Sensitivity analysis for layer III feed formula was as presented in table 80. The sensitivity analysis shows the range of both the objective function coefficients and the right hand side of the constraint equations in which the optimum solution will remain unchanged.

4.4.12.2 The layer III results sensitivity analysis

Table 80: Layer III results sensitivity analysis

Variable	Current Coefficient	Allowable Increase	Allowable Decrease
X_1:Maize	15.00	1.29	2.05
X_2:Pearl millet	13.00	1.56	0.82
X_3:D.O.R.B	8.00	2.25	Infinity
X_4:DOSC	28.00	Infinity	11.92
X_5:DOMC	15.00	Infinity	3.12
X_6:DGNC	21.00	Infinity	6.63
X_7:Marble grits	1.00	0.25	Infinity
X_8:Salt	15.00	Infinity	Infinity
X_9:Premix	150.00	Infinity	Infinity
X_{10}:Veg. Oil	90.00	Infinity	59.92
X_{11}:LSP	1.25	69.35	0.25
X_{12}:DCP	50.00	150.95	48.28
X_{13}:Lysine	110.00	482.61	94.01
X_{14}:Methionine	250.00	3075.82	232.06

Row	Current RHS	Allowable Increase	Allowable Decrease	Dual Price
1	100.00	0.16	1.74	-3.90
2	16.00	0.77	Infinity	0.00
3	3.30	Infinity	1.21	0.00
4	7.50	Infinity	3.50	0.00
5	4.00	0.15	0.05	8.03
6	0.76	0.05	Infinity	-282.03
7	0.40	0.04	0.06	0.00
8	0.36	0.22	Infinity	-96.00
9	0.70	0.17	0.07	-236.98
10	0.30	0.17	0.05	-0.003
11	240000	5769.38	427.99	0.00
12	40.00	0.64	Infinity	0.00
13	60.00	Infinity	19.35	0.00
14	10.00	8.65	Infinity	0.00
15	20.00	Infinity	1.34	2.25

16	8.00	2.00	0.36	0.00
17	10.00	Infinity	2.00	-11.92
18	10.00	3.02	0.91	0.00
19	15.00	Infinity	5.00	-3.12
20	5.00	2.00	0.63	-6.63
21	7.00	Infinity	2.00	0.00
22	5.00	6.45	1.02	0.00
23	15.00	Infinity	10.00	0.25
24	6.00	3.00	Infinity	-11.09
25	9.00	0.51	0.48	-146.09
26	0.30	1.74	0.16	0.00
27	0.05	1.74	0.05	0.00
28	0.00	0.00	Infinity	0.00
29	0.25	Infinity	0.25	0.00
30	1.00	0.51	Infinity	0.00
31	2.00	Infinity	0.48	0.00
32	0.00	1.71	Infinity	0.00
33	2.00	Infinity	0.28	0.00
34	0.25	Infinity	0.17	0.00
35	0.25	Infinity	0.19	0.00

Source: Computation from survey data, 2015

4.4.13 Comparison among costs of readymade complete feeds, concentrate based complete feeds and farm based own feeds

This section summarized the cost aspect of chicken feeds by comparing the costs of readymade complete feeds, concentrate based complete feeds and farm based own feeds as shown in table 81;

Table 81: Price comparison among readymade complete feeds, concentrate based complete feeds and farm based own feeds.

Stage	Readymade complete feed	Farm based own feed	%cost up or down	Concentrate based complete feed	Farm based own feed	%cost up or down
Pre starter	30.00	22.68	24.40 low	NA	22.68	-
Starter	28.00	20.50	26.80 low	NA	20.50	-
Finisher	27.00	19.67	27.10 low	NA	19.67	-
Chick	26.00	21.75	16.35 low	NA	21.75	-
Grower	24.00	16.75	30.20 low	NA	16.75	
Layer I	20.00	15.75	21.30 low	15.16	15.75	3.9 high
Layer II	20.00	15.10	24.50 low	15.16	15.10	0.4 low
Layer III	20.00	15.10	24.50 low	15.16	15.10	0.4 low

Source: Computation from survey data, 2015

From the summary in table 81, it can be deduced that readymade complete feeds are significantly costlier than farm based own feeds ($p<0.05$). On the other hand, there is no significant difference between concentrate based complete feeds and farm based own feeds ($p>0.05$). Prices between concentrate based complete feeds and farm based own feeds are almost similar. Therefore, it is advised that farmers adopt farm based own feeds. These feeds are not only less costly, but also the quality of the feed is assured because the farmer is totally aware of the kind of ingredients included and the quantities as well. Farmers will benefit from the best productivity performance of the birds. Further it is advised that some more researches be conducted on production performance of the birds which are currently fed on concentrate based complete feeds. This is because the price of such feeds of ₹ 15.16 is unreasonably too low for the feed which has undergone industrial processing.

5. SUMMARY AND CONCLUSION

5.1 Overview

In view of the results from the study some major conclusions and recommendations can be drawn with regard to chicken feed formulation at farm level in Ajmer district of Rajasthan. However, the study faced some serious limitations which might have affected the results in one way or another.

5.2 Limitations of the study

5.2.1 Language barrier

There was a language barrier due to the fact that the researcher was a foreign student whose main communication is English language while farmers' main communication language is Hindi. That being the case mediation had to be done by someone who could speak both English and Hindi. Hence the researcher relied on secondary translated information. Though was not a big problem, to a certain extent it might have affected the results, especially the qualitative part.

5.2.2 Shortage of funds

There was a serious shortage of funds during execution of this research. The scholarship program allotted no money for research. The university supported with only a minute amount of money to pay the field translators. In fact, it is inconceivable how a PhD scholarship program can be designed without considering a research budget. As a matter of fact, PhD is all about research. If research is neglected or taken lightly, the whole concept of a particular PhD program is null and void. The prevailed critical shortage of funds might have affected the results in one way or another.

5.3 Summary

This section provides a brief summary of the research work as it was conducted under areas of introduction, methodology and results.

5.3.1 Introduction

The poultry industry in India is highly dynamic and rapidly expanding segment in livestock economy. The compounded annual growth rate is currently 13% and

15% for eggs and broilers respectively. Currently, the country holds the third position globally in egg production and fourth position globally in broiler production. Within Rajasthan state, Ajmer is the most popular district in chicken production. In the execution of this study, three objectives were addressed, namely; to study the chicken management practices, to study the feeding management practices and o formulate balanced least cost chicken feeds from locally available ingredients for different chicken stages.

5.3.2 Methodology

Apurposeful sampling technique was employed in selection of the study district. According to State Poultry Training Institute (SPTI) government of Rajasthan data, Ajmer district currently has a total of 619 poultry farms. Of the 619 poultry farms found in the district about 75 percent are dealing with egg production, while about 25 percent are dealing with broiler production. Hence a proportionate simple random sampling technique was adopted. Of the twenty (20) farms which were to be sampled, 15 (75%) were layer farms and 5 (25%) were broiler farms. Then from each category the representative farms were randomly selected (Chawla, 2011 and Malhotra, 2009). Due to critical financial limitations in this research, the study had to concentrate on a total sample of 20 farms. Linear programming models were formulated and solved through LP solvers to obtain the optimum ingredient combination for the eight stages of chicken which were considered. The cost of the optimum ingredient combination that was offered by the LP model was compared with the market price of the chicken feed at each stage as summarized in the results section.

5.3.3 Results

The results showed that chicken feed formulation at farm level is feasible. Compared to the commercial feeds, farm formulated feeds were found to reduce feed costs as follows;

- Pre starter feed – 24.40% cost reduction relative to readymade complete feed
- Starter feed – 26.80% cost reduction relative to readymade complete feed
- Finisher feed – 27.10% cost reduction relative to readymade complete feed

- Chick feed – 16.35% cost reduction relative to readymade complete feed
- Grower feed – 30.20% cost reduction relative to readymade complete feed
- Layer I feed – 21.30% cost reduction relative to readymade complete feed.
- Layer II feed – 24.50% cost reduction relative to readymade complete feed.
- Layer III feed – 24.50% cost reduction relative to readymade complete feed.

Comparing proposed farm based feed with the concentrate based complete feed, the results were;

- Layer I farm based own feed – 3.90% more costly than concentrate based complete feed
- Layer II farm based own feed – 0.4% less costly than concentrate based complete feed
- Layer III farm based own feed – 0.4% less costly than concentrate based complete feed

5.4 Conclusion

Based on the findings of the study, the following conclusion can be drawn;

i. Poultry farming is a significant, vibrant and rapidly growing subsector in India at large and Ajmer district in particular. Broiler and egg production grows at an annual rate of 13% and 15% respectively, placing India in the 3rd position in terms of egg production and 4th position in terms of broiler production globally (Mohanraj and Manivannan, 2012). District wise the growth rate in terms of number of farms is quite alarming, from 2012 to 2015 the number of poultry farms have increased by 147.6 per cent (Dadheech and Vyas 2012; SPTI, 2015)

ii. Generally, Ajmer poultry farmers are doing well in as far as the chicken management practices are concerned. The research considered 21 management aspects namely; Cage size, number of birds in each cage, Space of layer birds in deep litter system, Space of broiler birds in deep litter system, Space of birds feeding in a round feeder, Space of birds feeding in a rectangular feeder, Space of birds in a round drinker, Space of birds in pipe drinkers, Quantity of feed provided to pre starter birds, Quantity of feed provided to starter birds, Quantity of feed provided to finisher birds, Quantity of feed provided to Chicks, Quantity of feed provided to layers, Quantity of water supplied to pre starter birds, Quantity of water supplied to starter birds, Quantity of water supplied to finisher birds, Quantity of water supplied to chicks, Quantity of water supplied to layers, Light management for broiler birds, Light management for chicks and Light management for layers. Out of these factors, farmers were found to be doing in accordance to specified standard management practices in 15 factors, equivalent to 71 percent. Farmers had a negative gap in only 6 factors, equivalent to 29 per cent. The practices where they fell short were; Cage size – had smaller cages than standard ones, number of birds in each cage – had more birds than the recommended number, Quantity of feed provided to pre starter birds – provided less quantity than the recommended amount, Quantity of feed provided to starter birds - provided less quantity than the recommended amount, Quantity of feed provided to chicks - provided less quantity than the recommended amount and quantity of feed provided to layer I birds - provided less quantity than the recommended amount. That being the case it can generally be concluded that farmers are practicing standard chicken management practices.

iii. Basing on the research the following formulations were found to be least cost for each stage in question;

Pre starter feed

Decision variable	Objective coefficient	Optimum solution	
Feed ingredient (X_i)	Price/Kg (₹)	Quantity (Kg)	Cost (₹)
Maize (X_1)	15.00	55.60	834.00
Deoiled soya cake (X_4)	28.00	26.00	728.00
Deoiled mustard cake (X_5)	15.00	1.00	15.00
Deoiled groundnut cake (X_6)	21.00	10.08	211.68
Salt (X_8)	15.00	0.30	4.50
Premixes (X_9)	150.00	0.05	7.50

Vegetable oil (X_{10})	90	2.70	243.00
L.S.P. (X_{11})	1.25	1.07	1.34
D.C.P. (X_{12})	50	2.50	125.00
Lysine (X_{13})	110	0.20	22.00
Methionine (X_{14})	250	0.20	50.00
Total		100Kg	₹ 2267.90

Remarks: 24.40% less costly than readymade complete feed for this stage.

Starter feed

Decision variable	Objective coefficient	Optimum solution	
Feed ingredient (X_i)	**Price/Kg (₹)**	**Quantity (Kg)**	**Cost (₹)**
Maize (X_1)	15.00	40.00	600.00
Pearl millet (X_2)	13.00	19.30	250.90
Deoiled soya cake (X_4)	28.00	17.30	484.40
Deoiled mustard cake (X_5)	15.00	2.00	30.00
Deoiled groundnut cake (X_6)	21.00	15.00	315.00
Salt (X_8)	15.00	0.30	4.50
Premixes (X_9)	150.00	0.05	7.50
Vegetable oil (X_{10})	90	2.08	187.20
L.S.P. (X_{11})	1.25	1.30	1.63
D.C.P. (X_{12})	50	2.20	110.00
Lysine (X_{13})	110	0.17	18.70
Methionine (X_{14})	250	0.15	37.50
Total		100Kg	₹ 2050.19

Remarks: 26.80% less costly than readymade complete feed for this stage.

Finisher feed

Decision variable	Objective coefficient	Optimum solution	
Feed ingredient (X_i)	**Price/Kg (₹)**	**Quantity (Kg)**	**Cost (₹)**
Maize (X_1)	15.00	40.70	610.50
Pearl millet (X_2)	13.00	20.00	260.00
Deoiled soya cake (X_4)	28.00	12.00	336.00

Deoiled mustard cake (X_5)	15.00	5.00	75.00
Deoiled groundnut cake (X_6)	21.00	15.40	323.40
Salt (X_8)	15.00	0.30	4.50
Premixes (X_9)	150.00	0.05	7.50
Vegetable oil (X_{10})	90	2.00	180.00
L.S.P. (X_{11})	1.25	1.80	2.25
D.C.P. (X_{12})	50	2.20	110.00
Lysine (X_{13})	110	0.19	20.90
Methionine (X_{14})	250	0.12	30.00
Total		100Kg	₹ 1966.80

Remarks: 27.10% less costly than readymade complete feed for this stage.

Chick feed

Decision variable	**Objective coefficient**	**Optimum solution**	
Feed ingredient (X_i)	**Price/Kg (₹)**	**Quantity (Kg)**	**Cost (₹)**
Maize (X_1)	15.00	52.40	786.00
Deoiled soya cake (X_4)	28.00	24.20	677.60
Deoiled mustard cake (X_5)	15.00	2.00	20.00
Deoiled groundnut cake (X_6)	21.00	15.00	315.00
Salt (X_8)	15.00	0.30	4.50
Premixes (X_9)	150.00	0.05	7.50
Vegetable oil (X_{10})	90	2.20	198.00
L.S.P. (X_{11})	1.25	2.10	2.63
D.C.P. (X_{12})	50	2.40	120.00
Lysine (X_{13})	110	0.00	0.00
Methionine (X_{14})	250	0.10	25.00
Total		100Kg	₹ 2175.50

Remarks: 16.35% less costly than the readymade complete feed for this stage

Grower feed

Decision variable	**Objective coefficient**	**Optimum solution**	
Feed ingredient (X_i)	**Price/Kg (₹)**	**Quantity (Kg)**	**Cost (₹)**

Maize (X_1)	15.00	43.50	652.50
Pearl millet (X_2)	13.00	20.00	260.00
D.O.R.B (X_3)	8.00	10.00	80.00
Deoiled soya cake (X_4)	28.00	10.00	280.00
Deoiled mustard cake (X_5)	15.00	7.00	105.00
Deoiled groundnut cake (X_6)	21.00	5.00	105.00
Salt (X_8)	15.00	0.30	4.50
Premixes (X_9)	150.00	0.05	7.50
Vegetable oil (X_{10})	90	0.30	27.00
L.S.P. (X_{11})	1.25	1.20	1.50
D.C.P. (X_{12})	50	2.20	110.00
Lysine (X_{13})	110	0.08	8.80
Methionine (X_{14})	250	0.08	20.00
Total		100Kg	₹ 1674.70

Remarks: 30.20% less costly than readymade complete feed for this stage

Layer I feed

Decision variable	**Objective coefficient**	**Optimum solution**	
Feed ingredient (X_i)	**Price/Kg (₹)**	**Quantity (Kg)**	**Cost (₹)**
Maize (X_1)	15.00	48.00	720.00
Pearl millet (X_2)	13.00	15.30	198.90
D.O.R.B (X_3)	8.00	8.00	64.00
Deoiled soya cake (X_4)	28.00	11.10	310.80
Deoiled mustard cake (X_5)	15.00	0.00	0.00
Deoiled groundnut cake (X6)	21.00	5.00	105.00
Marble grits (X_7)	1.00	9.00	9.00
Salt (X_8)	15.00	0.30	4.50
Premixes (X_9)	150.00	0.05	7.50
Vegetable oil (X_{10})	90	0.00	0.00
L.S.P. (X_{11})	1.25	1.00	1.25
D.C.P. (X_{12})	50	1.6	80.00
Lysine (X_{13})	110	0.25	27.50

Methionine (X_{14})	250	0.16	40.00
Total		100Kg	₹ 1574.80

Remarks: 21.30% less costly than readymade complete feed for this stage, but 3.90% more costly than concentrate based complete feed.

Layer II feed

Decision variable	Objective coefficient	Optimum solution	
Feed ingredient (X_i)	Price/Kg (₹)	Quantity(Kg)	Cost (₹)
Maize (X_1)	15.00	44.20	663.00
Pearl millet (X_2)	13.00	18.20	236.60
D.O.R.B (X_3)	8.00	8.00	64.00
Deoiled soya cake (X_4)	28.00	7.10	198.80
Deoiled mustard cake (X_5)	15.00	5.00	75.00
Deoiled groundnut cake (X_6)	21.00	5.00	105.00
Marble grits (X_7)	1.00	8.80	8.80
Salt (X_8)	15.00	0.30	4.50
Premixes (X_9)	150.00	0.05	7.50
Vegetable oil (X_{10})	90	0.00	0.00
L.S.P. (X_{11})	1.25	1.00	1.25
D.C.P. (X_{12})	50	1.80	90.00
Lysine (X_{13})	110	0.20	22.00
Methionine (X_{14})	250	0.10	25.00
Total		100Kg	₹ 1509.60

Remarks: 24.50% less costly than readymade complete feed for this stage and 0.40% less costly compared to concentrate based complete feed.

Layer III feed

Decision variable	Objective coefficient	Optimum solution	
Feed ingredient (X_i)	Price/Kg (₹)	Quantity (Kg)	Cost (₹)
Maize (X_1)	15.00	40.60	609.00
Pearl millet (X_2)	13.00	18.60	241.80
D.O.R.B (X_3)	8.00	8.00	64.00
Deoiled soya cake (X_4)	28.00	10.00	280.00
Deoiled mustard cake (X5)	15.00	5.00	75.00

Deoiled groundnut cake (X_6)	21.00	5.00	105.00
Marble grits (X_7)	1.00	9.00	9.00
Salt (X_8)	15.00	0.30	4.50
Premixes (X_9)	150.00	0.05	7.50
Vegetable oil (X_{10})	90	0.00	0.00
L.S.P. (X_{11})	1.25	1.50	1.88
D.C.P. (X_{12})	50	1.70	85.00
Lysine (X_{13})	110	0.07	7.70
Methionine (X_{14})	250	0.05	12.50
Total		100Kg	₹ 1506.50

Remarks: 24.50% less costly than readymade complete feed for this stage and 0.40% less costly compared to concentrate based complete feed.

Summing up, on the bases of the preceding tables it can be concluded and recommended that for all stages of chicken from pre starter to layer III, farmers should adopt farm based own feed. By so doing, they will benefit from both economic point of view and nutritional point of view as well. Farm based own feeds are less costly but also farmers will be confident with the quality of feed and that will positively impact the production performance of their flocks.

5.5 Recommendations

Based on the findings of the study, the following recommendations are worth noting:

i. It was noted that 100 per cent of poultry farmers are not from agro – livestock background. This implies that either graduates of agro –livestock related courses are poorly oriented that they fail to link classroom knowledge with actual field practical or are lacking finances that could help them invest in poultry farming (Okoli, 2004). It is therefore recommended that programs like Agri Clinics and Agribusiness Centres should also target poultry farming as an area where agriculture graduates can invest, bearing in mind that the sector is both rapidly growing and very lucrative in Indian environment. Further, as a strategy towards instilling interest in poultry farming and livestock production at large among agriculture graduates, Swami Keshwanand Rajasthan Agricultural University should introduce livestock production programs. The university owns a very huge land area and so many idle buildings which could profitably be used for this purpose.

ii. It was further noted that most farmers operate below farm capacity during summer season. This is because during this time of the year the local demand of the eggs is low. Given the tremendous growth rate of poultry sector in Ajmer, it is recommended that egg processing plants should be established in the area. This will increase the shelf life of eggs, further promote export business and in turn raise the demand of the same. If the demand will be high throughout the year, farmers will fully utilize their farm capacities.

iii. In feeding practices, it was noted that some of the most current scientific developments in poultry nutrition are not known by farmers. For example, pre starter feeding technology is not known. Farmers till now still sticks to starter – fisher schedules, which is an old technology. Further to that, layer I, II and III differentiation in feeding schedules is not done. Farmers treat layers as a single group from the onset of laying to culling, while in the actual sense these three stages differ in terms of nutrient requirements. It is recommended that poultry nutritionists should have outreach programs for educating farmers in this aspect and other currents inventions, especially in popular areas like Ajmer. The government should facilitate the available scientists to disseminate knowledge. Having best knowledge which is not disseminated to farmers is as good as having none.

iv. Given the technology availability in India in terms of processing machines and the abundance of grains as raw materials for poultry feeds, coupled with the popularity of Ajmer in poultry farming, it is strongly advised that farmers should adopt feed formulation at farm level. The research result show that there is a possibility of reducing a significant level of production costs if farmers produce their own feeds, rather than rely on commercial feeds as they are doing now. Adoption of this approach will have a positive spillover effect – the demand of grains such as maize and pearl millet will increase, hence benefiting crop farmers and reducing grain wastage due to insufficiency of modem grain ware houses, there will be some kind of added employment generation to facilitate processing of feeds at the farm, also large commercial feed mills will focus more on the export market of poultry feeds. The net effect of this adoption to the country will be positive and never negative.

v. There is a need of having a laboratory facility for testing the quality of feed ingredients, especially at the State Poultry Training Institute (SPTI) which is located in Ajmer city. Farmers were found to be mixing ingredients blindly without knowing the nutrient content of each. This may have negative impact on the resulting feed quality. A reasonable testing fee may be established for farmers to pay hence make the laboratory a self-sustaining unit.

5.6 Areas for future research

Basing on the results of this study, the following areas are recommended for future researches;

i. Quality and nature of concentrates: It was observed that the price of concentrates was unreasonably low. A kilogram of concentrate was sold at the price of ₹ 21.00. This rate is lower than the price of deoiled soya cake which was sold at the rate of ₹28.00 per kilogram. Is surprising that the price of raw material is higher than the price of concentrate which has already gone through some industrial processing. The low price of concentrate resulted into unreasonably low concentrate based complete feeds. That being the case, it is recommended that future researches may be done to ascertain the nature and quality of concentrates.

ii. Connected to the quality and nature of concentrates issue, is the production performance. It is recommended that future researches be done to see whether the kind of feed used is affecting production performance in terms of optimum egg production, feed consumption, mortality and medicine costs.

iii. Lastly, it is recommended that studies on technology adoption behavior of poultry farmers in Ajmer can be studied to identify factors that affect technology adoption.

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Poultry Feed Formulation at Farm Level in Ajmer District of Rajasthan

ABSTRACT- Section

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Abstract

Poultry farming is a significant sector in Indian economy at large and Ajmer district in particular. Feeding is the costliest aspect in poultry farming. Feed costs accounts to over 70% of broiler and layer production costs. This report presents the result of study titled '**Poultry Feed Formulation at Farm Level in Ajmer District of Rajasthan**'. The research was guided by three objectives as follows; to study the chicken management practices in general, to study the feeding management practices in particular and to formulate balanced least cost chicken feeds from locally available ingredients for different chicken classes. The study found that farmers are doing well in chicken management practices. The research considered 21 management aspects namely; cage size, number of birds in each cage, space of layer birds in deep litter system, space of broiler birds in deep litter system, space of birds feeding in a round feeder, space of birds feeding in a rectangular feeder, space of birds in a round drinker, space of birds in pipe drinkers, quantity of feed provided to pre starter birds, quantity of feed provided to starter birds, quantity of feed provided to finisher birds, quantity of feed provided to chicks, quantity of feed provided to layers, quantity of water supplied to pre starter birds, quantity of water supplied to starter birds, quantity of water supplied to finisher birds, quantity of water supplied to chicks, quantity of water supplied to layers, light management for broiler birds, light management for chicks and light management for layers. Out of these factors, farmers were found to be doing in accordance to specified standard management practices in 15 factors, equivalent to 71%. Farmers had a negative gap in only 6 factors, equivalent to 29%. The practices where they fell short were; cage size – had smaller cages than standard ones, number of birds in each cage – had more birds than the recommended number, quantity of feed provided to pre starter birds – provided less quantity than the recommended amount, quantity of feed provided to starter birds - provided less quantity than the recommended amount,

quantity of feed provided to chicks - provided less quantity than the recommended amount and quantity of feed provided to layer I birds - provided less quantity than the recommended amount. Concerning the feeding management practices, the study found that feeding of pre starter, starter, finisher, chick and growers was totally dependent on readymade complete feeds. The feeding of laying birds was based on concentrate based complete feeds. Farmers were not formulating farm based own feeds. The concentrate based complete feed was found to cost ₹ 15.16per kilogram. Lastly the study found that by adopting the proposed farm based own feeds farmers would reduce feed costs in the following proportions;

- Pre starter feed – 24.40% cost reduction relative to readymade complete feed
- Starter feed – 26.80% cost reduction relative to readymade complete feed
- Finisher feed – 27.10% cost reduction relative to readymade complete feed
- Chick feed – 16.35% cost reduction relative to readymade complete feed
- Grower feed – 30.20% cost reduction relative to readymade complete feed
- Layer I feed – 21.30% cost reduction relative to readymade complete feed.
- Layer II feed – 24.50% cost reduction relative to readymade complete feed.
- Layer III feed – 24.50% cost reduction relative to readymade complete feed.

Comparing proposed farm based feed with the concentrate based complete feed, the results were;

- Layer I farm based own feed – 3.90% more costly than concentrate based complete feed
- Layer II farm based own feed – 0.4% less costly than concentrate based complete feed
- Layer III farm based own feed – 0.4% less costly than concentrate based complete feed

In all cases, farmers are advised to adopt the farm based own feeds as they will be exactly sure of the kind of ingredients included as well as the levels of inclusion, something which will benefit them in terms of production performance of the birds.

राजस्थान के अजमेर जिले में खेत स्तर पर कुकुट दाना निरूपण

सारांश अनुभाग

जोज़फ लोंगो
(पीएचडी स्कॉलर)

डॉ.राजेश शर्मा
(मुख्य सलाहकार)

सारांश

मुर्गीपालन का भारतीय अर्थव्यवस्था विशेष रूप से अजमेर जिले में एक महत्वपूर्ण क्षेत्र है। आहार/खिलाना मुर्गीपालन में सबसे महंगा पहलू है। दाना कि लागत, ब्रायलर और परत उत्पादन लागत का 70%से अधिक होती है। यह रिपोर्ट 'राजस्थान के अजमेर जिले में खेत स्तर पर पोल्ट्री दाना निरूपण "शीर्षक से अध्ययन के परिणाम प्रस्तुत करती है। अनुसंधान तीन उद्देश्यों द्वारा निर्देशित किया गया था; सामान्य रूप में चिकन प्रबंधन के तरीकों का अध्ययन करने के लिए विशेष रूप से खिला प्रबंधन के तरीकों का अध्ययन करने के लिए और कम से कम लागत का संतुलित चिकन अलग चिकन कक्षाओं के लिए स्थानीय स्तर पर उपलब्ध सामग्री से खिलाती तैयार करने के लिए । अध्ययन में पाया गया कि किसान चिकन प्रबंधन के तरीके अच्छी तरह से कर रहे हैं। अनुसंधान में 21प्रबंधन पहलुओं पर विचार किया; पिंजरे का आकार, प्रत्येक पिंजरे में पक्षियों की संख्या, डीप लिटर प्रणाली में परत पक्षियों की गजह, डीप लिटर प्रणाली में ब्रायलर पक्षियों की जगह, एक दौर फीडर में खिला पक्षियों की जगह, एक आयताकार फीडर में खिला पक्षियों के गजह, एक दौर वाली,पीने कि पाइप में पक्षियों की गजह,परी स्टार्टर पक्षियो के लिए प्रदान कि चारा कि मात्रा, स्टार्टर पक्षियों के लिए प्रदान कि चारा कि मात्रा,अंत पक्षियों के लिए प्रदान कि चारा कि मात्रा, चूजो के लिए प्रदान कि चारा कि मात्रा, परत पक्षियों के लिए प्रदान कि चारा कि मात्रा, प्री-स्टार्टर पक्षियों के लिए प्रदान पानी की मात्रा, चूजो के लिए प्रदान पानी कि मात्रा, परत पक्षियो के लिए प्रदान पानी कि मात्रा, ब्रायलर पक्षियों के लिए प्रकाश प्रबंधन, चूजो के लिए प्रकाश प्रबंधन, परत पक्षियों के लिए प्रकाश प्रबंधन ।

इन कारकों में से, किसान 15कारकों में यानि 71% के बराबर निर्धारित मानक के प्रबंधन के तरीकों के अनुसार कर रहें हो, पाए गए। किसानों को 6 कारकों, 29% के बराबर में ही नकारात्मक अंतर था। जिन क्रियाओ में उनको अभाव था वो हैं, पिंजरे का आकार - मानक पिंजरे की तुलना में छोटे पिंजरों, प्रत्येक पिंजरे में पक्षियों की संख्या- मानक संख्या से अधिक पक्षियों की उपस्थिति,प्री- स्टार्टर पक्षियों के लिए प्रदान फ़ीड कि मात्रा - सुझाई गई राशि से कम मात्रा, स्टार्टर पक्षियों के लिए प्रदान की फीड की मात्रा - अनुशंसित मात्रा से प्रदान की कम मात्रा, चूजो के लिए प्रदान की फीड की मात्रा - मानक राशि की तुलना में कम मात्रा और परत 1 पक्षियों के लिए फ़ीड की मात्रा प्रस्तावित मात्रा से कम मात्रा प्रदान कि गई।

खिला प्रबंधन के तरीको को मध्य नजर रखते हुए, अध्ययन ने पाया कि पूर्व स्टार्टर के खिला, खिला, अंत खिला, चूजा और उत्पादन पूरी तरह से बाजारू खिला पर निर्भर था। लयिंग-पक्षियों का चारा पूरी तरह से पूरा फ़ीड धयान केंद्रित आधारित था। किसान खेत आधारित खुद खिलाती तैयार नहीं कर रहें थे। धयान केंद्रित पूर्ण फ़ीड कि लागत 15.16रुपए प्रति किलोग्राम थी। अन्त में अध्ययन में पाया कि प्रस्तावित खेत आधारित खुद फ़ीड को अपनाने से किसान दाना लागत नीचें प्रस्तावित अनुपात में कम कर पायंगे।

- प्री-स्टार्टर फ़ीड - 24.40% तैयार पूरा फ़ीड के सापेक्षिक लागत में कमी।
- स्टार्टर फ़ीड - 26.80% तैयार पूरा फ़ीड के सापेक्षिक लागत में कमी।
- अंत फ़ीड - 27.10% तैयार पूरा फ़ीड के सापेक्षिक लागत में कमी।
- चूजा फ़ीड - 16.35% तैयार पूरा फ़ीड के सापेक्षिक लागत में कमी।
- उत्पादक फ़ीड - 30.20% तैयार पूरा फ़ीड के सापेक्षिक लागत में कमी।
- लेयर में फ़ीड - 21.30% तैयार पूरा फ़ीड के सापेक्षिक लागत में कमी।
- परत द्वितीय फ़ीड 24.50% तैयार पूरा फ़ीड के सापेक्षिक लागत में कमी।
- परत तृतीय फ़ीड - 24.50% तैयार पूरा फ़ीड के सापेक्षिक लागत में कमी।

सांद्र आधारित पूरा फ़ीड के साथ प्रस्तावित खेत आधारित फ़ीड की तुलना परिणाम थे;

- लेयर में खेत आधारित स्वयं फ़ीड - आधारित ध्यान केंद्रित पूर्ण फ़ीड से 3.90%ज्यादा महंगा
- परत द्वितीय खेत आधारित स्वयं फ़ीड - आधारित ध्यान केंद्रित पूर्ण फ़ीड से 0.4%कम महंगा
- परत तृतीय खेत आधारित स्वयं फ़ीड - आधारित ध्यान केंद्रित पूर्ण फ़ीड से 0.4%कम महंगा

सभी मामले में, किसानो को खेत आधारित खुद खिलाती को अपनाने कि सलाह दी जाती है, जिसके कि उन्हें अवययो के प्रकार की युक्तिऔर साथ ही शामिल किए जाने के स्तर का सही पता चले, जिससे पक्षियो का उत्पादन प्रदर्शन के मामले में लाभ होगा।

APPENDICES

Annexure 1: Questionnaire for collecting data from farmers

Chicken Feed Formulation at Farm Level in Ajmer District of Rajasthan

Questionnaire

Section A: Chicken Management Practices

1. What commercial chicken breeds do you currently have at your farm?

   i) Broiler breeds:..
   ii) Layer breeds ....

2. How many birds are there in each of the following stages?

Broilers

Stage	Number
Pre - starter	
Starter	
Finisher	

Layers

Stage	Number
Chicks	
Growers	
Layer I	
Layer II	
Layer III	
Parent stock	

3. How do you obtain chicks for your farm?

   i) Hatch your own chicks from parent stock ....
   ii) Buy from hatcheries ....

4. Which chicken rearing system have you adopted in your farm?

   i) Deep litter system ....
   ii) Cage system ....
   iii) Free range system ....
   iv) A combination of ....
   v) Others ....

5. How much space do you provide your birds in each stage of the birds?

Stage	Space
Pre - starter	
Starter	
Finisher	
Chicks	
Growers	
Layer I	
Layer II	
Layer III	

6. What facilities and materials are provided in your chicken house for the following purposes?

i) Bedding materials:

a) Type of bedding material ....

b) How much bedding materials per 1000 birds? .... kg

c) Do you do any turning of the bedding materials? Yes ( ), No ( )

d) How do you turn the bedding materials? ....

e) After how long do you change the bedding materials? ....

ii) Type of feeding equipments ....

iii) Are your feeding equipments automatic or manual?..

iv) How many birds feed in one feeder? ....

v) How much feed do you provide to your birds in each stage?

Stage	Age	Number of birds	Quantity of feed per bird	Body weight
Pre - starter	0 – 9 days			
Starter	10 – 20 days			
Finisher	21 – (40 – 50) days			
Chicks	0 – 2 months			
Growers	2 – 4 months			
Layer I	4 – 10 months			
Layer II	11 – 14 months			
Layer III	15 – 19 months			

vi) Type of watering equipments ....

vii) Are your drinkers automatic or manual?...

viii) How many birds drink in one drinker? ....

ix) How much water do you provide to your birds per day?

Stage	Quantity of water per 100 birds per day (Ltrs)
Pre - starter	
Starter	
Finisher	
Chicks	
Growers	
Layer I	
Layer II	
Layer III	

x) What are the major sources of water ....

xi) Is the water provided to birds treated?..

xii) How do you enhance the newly introduced chicks to eat and drink water?.

xiii) Do you vaccinate your chicks? Yes ( ), No ( )

xiv) Do you apply any natural substances in controlling some chicken diseases? Yes ( ), No ( ).

xv) What natural substances do you apply in controlling chicken diseases?

Substance	Preparation	Control for....

xvi) What hygienic measures do take to prevent disease introduction into your farm?

....

xvii) In case a disease is introduced, what measures do you take to prevent it from spreading?..
......

xviii) For how many hours do you provide light to the birds?

Type of chicken	Stage	Source of light	Natural light (hrs)	Artificial light (hrs)	Total
Broilers	Pre - starter				
	Starter				
	Finisher				
Layers	Chick				
	Grower				
	Layer I				
	Layer II				
	Layer III				

7. Do you produce the following chicken products at your farm?

a) Chicks: Yes ( ), No ( )
b) If you produce chicks, how do you market them?
c) Do you produce eggs at your farm? Yes ( ), No ( )
d) If you produce eggs how do you market them?
e) Where do you get the trays for egg storage and handling?
f) Which are the major markets of your eggs?
g) Do you produce broilers in your farm? Yes ( ), No ( )
h) If you produce broilers, do you slaughter or sell them alive?
i) Who are the major customers of your broilers?
j) Is there any opportunity for export market of your chicken products?
k) What are the export markets available?

Section B: Feeding Management Practices

8. Which type of feed do you use, is it commercial feed or own feed?
Please specify the details
....
....
....

Broiler

i) Pre-starter:

a) **Commercial feeds:**

S.No	Brand	Type: mash. crumbs, concentrate	If concentrate, then ratio of concentrate to other ingredients			Cost of feed per kg	Nutrient specification of feed on bag	Qnty fed per day (kg)	Satisfied or not. If not specify reasons.
			Ingred	Qnty	Rate				
			Conc.						

Note: Parameters of satisfaction:

- Price ....
- Nutrient specification on bag ....
- Quality of service offered by feed dealer ....

b) **Own feed:**

Type of ingredients used	Level of inclusion (kgs)	Cost of each ingredient per kg	Total quantity needed during rearing period	Qnty fed per day (kg)	Price variation in a season	Total cost of making 100kg of feed

Do you assess the nutrient status of your ingredients in the laboratory before using for feed formulation? Yes ( ), No ( )

ii) Broiler Starter

Commercial feeds:

S.No	Brand	Type: mash. crumbs, concentrate	If concentrate, then ratio of concentrate to other ingredients			Cost of feed per kg	Nutrient specification of feed on bag	Qnty fed per day (kg)	Satisfied or not. If not specify reasons.
			Ingred	Qnty	Rate				
			Conc.						

Note: Parameters of satisfaction:

- Price ....
- Nutrient specification on bag ....
- Quality of service offered by feed dealer ....

Own feed

Type of ingredients used	Level of inclusion (kgs)	Cost of each ingredient per kg	Total quantity needed during rearing period	Qnty fed per day (kg)	Price variation in a season	Total cost of making 100kg of feed

iii) Broiler finisher

Commercial feed

S.No	Brand	Type: mash. crumbs, concentrate	If concentrate, then ratio of concentrate to other ingredients			Cost of feed per kg	Nutrient specification of feed on bag	Qnty fed per day (kg)	Satisfied or not. If not specify reasons.
			Ingred	Qnty	Price				
			Conc.						

Note: Parameters of satisfaction:

- Price ....
- Nutrient specification on bag ....
- Quality of service offered by feed dealer ....

Own feed

Type of ingredients used	Level of inclusion (kgs)	Cost of each ingredient per kg	Total quantity needed during rearing period	Qnty fed per day (kg)	Price variation in a season	Total cost of making 100kg of feed

Layer BV 300

i) **Chicks**

Commercial feed

S.No	Brand	Type: mash. crumbs, concentrate	If concentrate, then ratio of concentrate to other ingredients			Cost of feed per kg	Nutrient specification of feed on bag	Qnty fed per day (kg)	Satisfied or not. If not specify reasons.
			Ingred	Qnty	Rate				
			Conc.						

Note: Parameters of satisfaction:

- Price ....
- Nutrient specification on bag ....
- Quality of service offered by feed dealer ....

Own feed

Type of ingredients used	Level of inclusion (kgs)	Cost of each ingredient per kg	Total quantity needed during rearing period	Qnty fed per day (kg)	Price variation in a season	Total cost of making 100kg of feed

ii) Growers

Commercial feeds

S.No	Brand	Type: mash. crumbs, concentrate	If concentrate, then ratio of concentrate to other ingredients			Cost of feed per kg	Nutrient specification of feed on bag	Qnty fed per day (kg)	Satisfied or not. If not specify reasons.
			Ingred	Qnty	Rate				
			Conc.						

Note: Parameters of satisfaction:

- Price ....
- Nutrient specification on bag ....
- Quality of service offered by feed dealer ....

Own feed

Type of ingredients used	Level of inclusion (kgs)	Cost of each ingredient per kg	Total quantity needed during rearing period	Qnty fed per day (kg)	Price variation in a season	Total cost of making 100kg of feed

iii) Layer I

Commercial feed

S.No	Brand	Type: mash. crumbs, concentrate	If concentrate, then ratio of concentrate to other ingredients			Cost of feed per kg	Nutrient specification of feed on bag	Qnty fed per day (kg)	Satisfied or not. If not specify reasons.
			Ingred	Qnty	Rate				
			Conc.						

Note: Parameters of satisfaction:

- Price ....
- Nutrient specification on bag ....
- Quality of service offered by feed dealer ....

Own feed

Type of ingredients used	Level of inclusion (kgs)	Cost of each ingredient per kg	Total quantity needed during rearing period	Qnty fed per day (kg)	Price variation in a season	Total cost of making 100kg of feed

iv) Layer II

Commercial feed

S.No	Brand	Type: mash. crumbs, concentrate	If concentrate, then ratio of concentrate to other ingredients			Cost of feed per kg	Nutrient specification of feed on bag	Qnty fed per day (kg)	Satisfied or not. If not specify reasons.
			Ingred	Qnty	Rate				
			Conc.						

Note: Parameters of satisfaction:

- Price ....
- Nutrient specification on bag ....
- Quality of service offered by feed dealer ....

Own feed

Type of ingredients used	Level of inclusion (kgs)	Cost of each ingredient per kg	Total quantity needed during rearing period	Qnty fed per day (kg)	Price variation in a season	Total cost of making 100kg of feed

Layer Skylark

I) Chicks

Commercial feed

S.No	Brand	Type: mash. crumbs, concentrate	If concentrate, then ratio of concentrate to other ingredients			Cost of feed per kg	Nutrient specification of feed on bag	Qnty fed per day (kg)	Satisfied or not. If not specify reasons.
			Ingred	Qnty	Rate				
			Conc.						

Note: Parameters of satisfaction:

- Price ....
- Nutrient specification on bag ....
- Quality of service offered by feed dealer ....

Own feed

Type of ingredients used	Level of inclusion (kgs)	Cost of each ingredient per kg	Total quantity needed during rearing period	Qnty fed per day (kg)	Price variation in a season	Total cost of making 100kg of feed

ii) Growers

Commercial feeds

S.No	Brand	Type: mash. crumbs, concentrate	If concentrate, then ratio of concentrate to other ingredients			Cost of feed per kg	Nutrient specification of feed on bag	Qnty fed per day (kg)	Satisfied or not. If not specify reasons.
			Ingred	Qnty	Rate				
			Conc.						

Note: Parameters of satisfaction:

- Price ....
- Nutrient specification on bag ....
- Quality of service offered by feed dealer ....

Own feeds

Type of ingredients used	Level of inclusion (kgs)	Cost of each ingredient per kg	Total quantity needed during rearing period	Qnty fed per day (kg)	Price variation in a season	Total cost of making 100kg of feed

iii) Layer I

Commercial feeds

S.No	Brand	Type: mash. crumbs, concentrate	If concentrate, then ratio of concentrate to other ingredients			Cost of feed per kg	Nutrient specification of feed on bag	Qnty fed per day (kg)	Satisfied or not. If not specify reasons.
			Inged.	Qnty	Rate				
			Conc.						

Own feeds

Type of ingredients used	Level of inclusion (kgs)	Cost of each ingredient per kg	Total quantity needed during rearing period	Qnty fed per day (kg)	Price variation in a season	Total cost of making 100kg of feed

iv) Layer II

Commercial feed

S.No	Brand	Type: mash. crumbs, concentrate	If concentrate, then ratio of concentrate to other ingredients			Cost of feed per kg	Nutrient specification of feed on bag	Qnty fed per day (kg)	Satisfied or not. If not specify reasons.
			Ingred	Qnty	Rate				
			Conc.						

v) Layer III

Commercial feeds

S.No	Brand	Type: mash. crumbs, concentrate	If concentrate, then ratio of concentrate to other ingredients			Cost of feed per kg	Nutrient specification of feed on bag	Qnty fed per day (kg)	Satisfied or not. If not specify reasons.
			Ingred	Qnty	Rate				
			Conc.						

Note: Parameters of satisfaction:

- Price ....
- Nutrient specification on bag ....
- Quality of service offered by feed dealer ....

Own feeds

Type of ingredients used	Level of inclusion (kgs)	Cost of each ingredient per kg	Total quantity needed during rearing period	Qnty fed per day (kg)	Price variation in a season	Total cost of making 100kg of feed

9. Do you also sell your own formulated feeds? Yes ( ), No ( )

10. How do you formulate your own feed, manually or any software available?...

11. How do you process the raw materials to get the feed? Do you have machine for that work?..

12. What type of problems do you face during feed formulation? ....

13. Specify the composition in terms of ingredients and the rate (price) of each ingredient in a 100kg feed of your current own formulations.

Ingredients	Inclusion (kg)	Rate (Price)

Section C: Balanced Least Cost Feed Formulation

14. What are the major sources of energy in feed?

Energy source	Price per kg

15. What are the major sources of protein in feed?

Protein source	Price per kg

16. What are the major mineral sources in feed?

Mineral source	Price per unit

17. What are the major vitamin sources in feed?

Vitamin source	Price per unit

18. What are the nutrient contents of ingredients mentioned in 13, 14, 15 and 16 above?

19. What are the nutrient requirements for different breeds of chicken and stages under consideration?

20. According to your views, of the following poultry projects which one is likely to be the most profitable?

i) Formulation and selling of poultry feeds ( )
ii) Hatching and selling of chicks ( )
iii)Broiler production ( )
iv)Egg production ( )

21. Name of the farm ....
Age of the manager..
Gender of farm manager..
Marital status..
Education level ....
Area of specialization...
Experience in the poultry field ....
Owner or hired manager ....
Initial investment ....
Current value of investment..
Market price of egg ....
Market price of broiler ....
Market price of chick ....
Annual profit ....
Labour requirement ....
Current labour available ....
Labour cost per month ....
Poultry projects dealing with:...

THANK YOU FOR YOUR COOPERATION

Annexure 2: Questionnaire for District Livestock Department

Chicken Feed Formulation at Farm Level in Ajmer District of Rajasthan

1. What commercial chicken breeds are commonly reared in the district?
   - i) Broiler breeds ....
   - ii) Layer breeds ....

2. How many chicken farms are there in the district? ....

3. About the existing chicken farms;
   - i) How many specialize in layers production? ....
   - ii) How many specialize in broilers production?..
   - iii) How many mixes broilers and layers...
   - iv) How many farms keep parent stocks?..

4. How many poultry feed processing firms are there in the district? ....

5. What are the major ingredients and there prices that the feed processing firms use?...

6. What is the contribution of the poultry sector in the district's income?.................

7. How significant/important is the poultry sector compared to other sectors of agriculture in the district? ....

8. Is there export market for poultry from Ajmer? ....

9. What are the export markets?..

10. How does the District Livestock Department assist farmers in the export business of poultry products?..

11. What are the major challenges of poultry industry in the district?..............................

THANK YOU FOR YOUR COOPERATION