NATIONAL
DAIRY
DEVELOPMENT
BOARD

OPERATIONAL GUIDELINES FOR

ENHANCING CATTLE FEED PLANT PERFORMANCE

National Dairy Development Board,
Anand

FOREWORD

Cattle Feed Plants (CFPs) play a vital role in supporting the dairy sector by ensuring the availability of quality feed, which directly impacts productivity and profitability from dairy farming. With the growing demand for safe, nutritionally balanced, and cost-effective feed, enhancing the operational efficiency of these plants has become essential to sustain their viability and competitiveness.

The Indian compound feed market is witnessing steady growth, driven by the country's large livestock population and the rising demand for milk and other animal-based products. While BIS Type II feed continues to dominate, there is a growing shift toward specialized feeds such as calf starter, growth meal, pregnancy feed, and buffalo feed, reflecting the industry's evolving focus on targeted nutrition to improve animal performance.

Currently, around 70 cooperative cattle feed plants in India produce nearly 5 million metric tons of feed annually. However, these plants face persistent challenges in balancing efficiency, quality, and affordability. Operational performance is influenced by multiple factors including raw material quality, feed formulation, particle size, moisture control, mixing accuracy, conditioning processes, equipment maintenance, etc.

This document, Guidelines for Enhancing Cattle Feed Plant Performance, has been prepared as a practical reference for plant managers, technical staff, and other stakeholders. Based on field visits, industry practices, and operational experiences, the guidelines present strategies for process optimization, waste reduction, energy conservation, and quality assurance. By strengthening operational systems, adopting appropriate technologies, and building technical capacities, these guidelines aim to support cattle feed plants in achieving higher productivity, sustainability, and resilience.

It is hoped that this document will help identify opportunities for improvement, encourage adoption of best practices, and enable the Cooperative cattle feed industry to remain competitive and impactful.

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1. Introduction

The Indian compound feed market is witnessing significant growth driven by a substantial livestock population and rising demand for animal products like milk and meat. The cattle feed industry is largely dominated by the production of BIS Type II feed, though there is a growing shift toward specialized feeds tailored for various categories of animals - such as calf starter, growth meal, pregnancy feed, buffalo feed etc.

Compound cattle feed is manufactured in feed mills using grinding, mixing, and pelleting machinery, under strict quality control measures to ensure uniformity and nutrient standards. Plant efficiency is a crucial factor contributing significantly to the financial viability of a feed plant. Efficiency in feed mills is influenced by several factors, including the quality and particle size of raw materials, moisture content, nutrient composition/nutrient density, ingredient mixing accuracy, conditioning processes, equipment maintenance, feed formulation etc. These elements directly impact the quality of the feed produced and the overall productivity of the plants.

Commercial feed production facilities typically concentrate on sales, profit margins, distributor incentives, and customer service, whereas dairy cooperative feed production units concentrate primarily on producing high-quality feed in large quantities that adhere to standards, at lowest possible manufacturing cost. Additionally, cooperative feed mills are required to offer cattle feeds at a reasonable rate with a smaller profit margin.

There are about 70 cattle feed plants under dairy cooperatives that collectively produce around 5 million metric tons (MMT) of feed annually. However, these plants face various challenges in maintaining quality while delivering feed at an affordable price to producer members. Identifying and tracking Key Performance Indicators (KPIs) can provide multiple benefits, including increased accountability and visibility, better decision-making, improved performance, reduced waste, and increased revenues.

In order to develop KPIs for feed plants, initiatives have been taken to evaluate cattle feed plants and establish guidelines that can serve as benchmarks for future assessments. These guidelines aim to help feed mills meet industry standards more consistently and improve feed quality.

A few cattle feed manufacturing facilities under dairy cooperatives were visited to study various aspects of feed production and develop KPIs.

2. Procurement of feed raw materials

Feed raw materials play a significant role in compound feed businesses since they make up about 80-90% of the cost. Due to this fact it is important that the raw materials are sourced at least cost. A slight disruption in the supply chain of raw materials can impact operations. While procurement of feed raw materials from reputable and reliable suppliers help to maintain a steady production, there are many factors to consider when procuring specific feed raw materials. There are different ways of procuring raw materials, and which method one should choose will depend on various factors including preference of the feed mills.

Procurement in feed manufacturing sector refers to the method of purchasing raw materials from an external source. Raw material procurement process involves researching, selecting, ordering, and paying for raw materials required for feed manufacturing. Identifying and selecting vendors, negotiating prices and terms, and awarding contracts are some steps in the procurement process. Raw material selection involves several factors that include cost, quality, availability, and delivery time.

2.1 Seven steps for procurement of feed raw materials

Let us take a look at the 7 steps in the procurement process of feed raw materials. This is crucial when sourcing and procuring materials in India's competitive market.

Before initiating the procurement of raw materials, the organization or feed plant must finalize the desired specifications for each raw material along with the cut-off levels for rejection parameters. This step is pivotal, as the specifications fixed for individual raw materials not only influence their price but also determine the quality of inputs incorporated into the feed formulation. Therefore, the feed plant should formally finalize the specifications for raw materials as well as packing materials well in advance, following the prescribed procedures.

Step 1: Need analysis

The process should begin with identifying the need of quality raw materials. Based on the production demand, the quantity and quality of raw materials should be determined.

The first thing that a feed manufacturer needs to understand is the market. Feed manufacturers need to understand the demand, availability, buying pattern, legal and government compliances, taxes, logistics and transportation used etc. Awareness about the market will help in forecasting demand and planning inventory, building a competitive pricing strategy, recognising trends and opportunities for growth and identifying buyer/seller pain-points and challenges to overcome.

Step 2: Supplier identification

Finding and contacting suppliers is the next step. Care should be taken to ensure that the supplier meets required quality standards and can supply the raw materials in time. Quotes are requested from the identified suppliers and vendors and in specific cases, tenders might also be floated. The process of selecting suppliers depends on the purchase norms followed by the respective feed manufacturing plant or its parent organization.

Step 3: Supplier evaluation

The evaluation stage involves comparing quotes from different suppliers to identify the right one(s). Here, the purchase department might have their specific evaluation criteria – such as price, quality (specifications), certifications, reputation of the business, availability etc. In some cases, samples could be requested to evaluate the quality of raw materials.

Step 4: Supplier contract negotiation

The goal of this step in the raw material procurement process is to find a supplier that offers value-for-money, i.e., best prices, payment terms, delivery schedules, and quality.

Step 5: PO release and fulfilment

Once the supplier(s) has been finalised, releasing the purchase order is the next step. Usually, the purchase department vets with the relevant departments on their final requirements to ensure there is no change in strategy and requirements. As a part of the fulfilment process, the supplier starts delivering the raw materials as per terms and schedules established. The purchase order must adhere to the desired specifications/ standards of the individual raw materials to be supplied by the supplier and rejection norms.

Step 6: Quality inspection

Upon receipt, raw materials are inspected for quality and quantity. This step is crucial, as any deviations can affect product quality and delivery timelines. If the received material does not meet the required standards, a rebate may be applied up to a certain limit (which would be decided by the competent authority and must be mentioned in the PO), or the material may be returned if it fails to meet minimum quality standards.

If the material is accepted, it is sent to the godowns and mapped to inventory and production. The procurement department also initiates payments for the order delivered.

If material is rejected, proper documentation to be maintained stating the reasons for rejection of the lot.

Step 7: Invoicing and release of payment

Payment is processed as per the contract/ PO terms. Once the goods delivered has been accepted, the supplier generates the invoice. If there are disputes or adjustments, it is usually adjusted in this stage. In case of a single order procurement, this marks the end of the raw material procurement process. However, if this is a continuous order, then the part of receiving of goods, inspection, and payments continue.

2.2 Key recommendations for procurement of feed raw materials

CFPs can optimize the procurement of feed raw materials by integrating the following recommendations:

- **Analysis of historical data:** Since price data for commonly used raw materials such as maize, rice bran, DORB, oil cakes etc. are available with the feed plants, it is crucial to analyze these trends to anticipate price fluctuations and make informed purchasing decisions. The seasonal availability of different cattle feed raw materials may also be considered while analysing the historical data.

- **Continuous monitoring of price trends:** The purchase department should continue its practice of daily monitoring of price trends through various portals like CLFMA, NCDFI etc. This will help in understanding market dynamics and making timely decisions.

- **Dynamic supplier list:** Given that the source location of raw materials varies by season (e.g., maize from UP and Bihar during off-season and Rajasthan during the season), it is essential to maintain a dynamic supplier list to ensure availability and optimize transportation costs.

- **Annual targets and procurement planning:** While the current practice is to estimate feed raw material requirements based on the previous year's data, it is recommended to refine these estimates by incorporating growth projections, changes in demand, and any alterations in feed formula due to price changes or seasonal availability.

- **Use of LCF Software:** Regular use of LCF (Least Cost Formulation) software should be continued. This would help in dynamically adjusting feed formulas based on price and availability, thereby optimizing costs, without affecting the quality of the finished product

- **Storage knowledge and management:** Although raw materials are generally not stored for longer periods in most of the cattle feed plants, there should be better documentation and knowledge transfer regarding the storage duration of different materials. Understanding the storage capabilities for materials like DORB, rapeseed extraction, and guar korma (which can be stored for more than three months) could allow for bulk purchases during lower price periods, reducing costs.

- **Supplier identification and engagement:** The CFP should maintain a robust list of registered and vetted suppliers to ensure a competitive procurement process. This will provide flexibility and ensure quality standards are met.

- **Net weight basis of purchase:** It is advisable to follow the practice of purchasing raw materials on net weight basis. CFP should ensure clear communication with suppliers regarding weight considerations (e.g., tare weights of gunny bags and HDPE bags). As this is a very critical issue, the management needs to make a judicious decision based on historical data and a cost–benefit analysis of shifting from the gross weight system to the net weight system. The uniformity in the supply of specific raw materials in standard bags (gunny or HDPE) will determine the effectiveness of procurement on a net-weight basis.

- **E-procurement process:** Feed plant may follow the e-procurement process with reverse auctions, as it ensures competitive pricing. The 30-minute auction window should continue, with a minimum of three suppliers to ensure reliability and cost-efficiency.

- **Dynamic production and procurement system:** Although adoption of least cost formulation system helps in the reduction of formula cost, the overall reduction in the cost of production can be brought about through a dynamic production and procurement system.

1. Dynamic production and procurement system works on the estimation of prices over the succeeding 12 months and therefore, the purchases are scheduled when it is most advantageous. For example, suppose the presence of an ingredient in the formula can reduce the cost of the formula for the current month, but the stock has run out, then the better of the following two alternatives may be recommended – (1) buy now at higher price if it can reduce the overall cost of formula; (2) buy later when the price is likely to reduce, and bear a slightly higher cost of formula for the current month. The major advantages of dynamic procurement process include:

2. It recommends procurement schedule by thoroughly analyzing the stocks available.

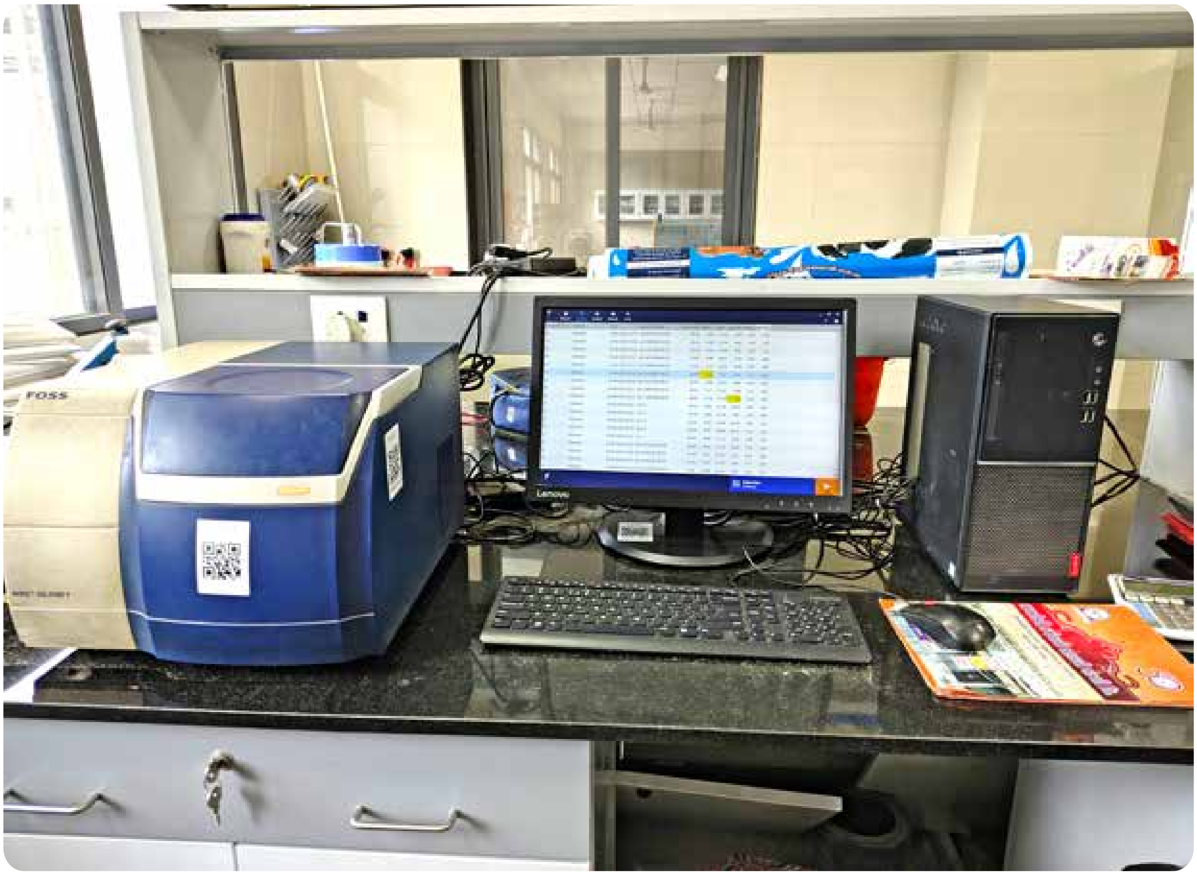
3. It retains the use of a limited stock of any ingredients. The static method requires an arbitrary limit for each month, while the dynamic method needs a limit which is 'just right' the whole year.

4. It can also suggest selling ingredients back to the market whenever found to be the best course of action.

5. Dynamic procurement-production model can compete favourably with other methods of procurement and production planning, as it uses forecasts to plan the subsequent actions more systematically. Moreover, it is based on a rolling year and can view 12 months ahead to make monthly schedules.

- **Procurement interval and advance planning:** Continue procuring raw materials at shorter interval (many large feed plants procure raw materials thrice a month). However, consider extending the lead time beyond one month in case of anticipated price spikes or shortages to secure better rates. A running document or sheet may be maintained to record details of existing stock of each raw material, daily consumption, materials in the pipeline, expected stock exhaustion date, and the lag time between indenting and delivery. These parameters can be tracked more efficiently through an online ERP system. Such an arrangement would ensure that feed plants do not face shortages of essential raw materials required for feed manufacturing.

- **Payment timelines and credit terms:** Maintaining the payment schedule of one month post-delivery is good practice. If feasible, negotiate longer credit terms with suppliers (if not already in place) to improve cash flow without jeopardizing supplier relationships. The payments may be divided into two parts: an initial payment after supply and the balance after completion of quality testing. This decision will be at the discretion of the management.



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3. Raw material storage

Receiving raw material in a feed plant is more complex than it seems and involves several critical steps. Poor-quality raw materials can damage feed processing machinery, increase maintenance costs, and reduce feed production capacity, leading to quality issues with the finished feed. This, in turn, raises the overall processing costs of the feed mill and directly impacts the profitability of the business.

The raw material receiving capacity of the cattle feed factory must meet the needs of the production capacity of the production line. Through using advanced technology and equipment, one can ensure the timely receipt of raw materials, reduce the labour costs, save energy consumption, reduce feed production costs, and also help to protect the environment.

3.1 Inventory and space management of raw materials and finished goods

A feed plant with a capacity of 150 MT per day needs to maintain a raw material inventory for 45 days, requiring approximately 7,000 MT of raw materials. For single-product stacking at a standard height of 15 ft (about16-18 bags), the space required would be around 42,000 sq. ft, based on an estimated requirement of 6 sq. ft per MT of feed material.

Space requirement:

- Sungle product stacking: 15 fit (16-18 bags)
- Space requirement: 7000 MT × 6 sq. ft/ MT = 42000 sq. ft

Dimensions of the storage area:

Building with width - 80,90, or 100 ft,

For example, for 100 ft width:

Length=4200/100 =420 ft

3.2 Storage capacity and stacking guidelines

Maximum stack height: For raw materials, a height of 15 ft (about 16-18 bags) should be maintained, while a height of 10-12 bags is recommended for finished products.

As per IS 607-1971 (Code of Practice for Bagged Food Grain Storage Structures), the required space for a stack is 9.15 x 6.1 x 4.57 m (about 30 ft x 20 ft x 15 ft).

- Ensure 2-3 ft of overhead clearance above the stacks.
- Leave 1.56 m between stacks (parallel to the building width).
- Maintain a 0.76 m passage in the longitudinal direction.
- Keep at least 0.5 m of clearance between the stack and the walls.
- Leave proper alleyways to allow easy and efficient handling operations.
- Use wooden/ plastic crates (6 inches in height) for air circulation and to prevent moisture absorption.
- Install 25 x 51 mm wire mesh on ventilators to protect against birds.

3.3 Pest and insect control

Perform fumigation before and after the monsoon season for effective pest control.

The recommended doses of various compounds are provided below:

Compound	Mode	Dose
Aluminium Phosphite (Celphose Tablet)	Fumigation under the gas proof	If infestation is noticed, use 3 tablets per MT; for fresh stock, use 2 tablets per MT.
Malathion	Sprayed on walls/ alleyways/ bags/ surface	1:100 i.e. 1 part of malathion and 100 parts of water. 3 ltrs./ 100 sq. m or 4 CC per 100 bags
Deltamethrin	Spraying	120 g of deltamethrin + 3 ltrs. of water/ 100 sq. m of surface area once in three months

Feed plants may engage a renowned and well-organized Pest Control Agency to carry out effective pest control inside and outside the plant and godowns.

Similarly, rat/rodant control should also be done by placing physical traps or other methods.

3.4 Factors affecting quality of stored feed raw materials

Material losses occur due to various factors, including fire, damage by rats and birds, rain and condensation, high temperatures, insect infestations, and fungal growth. In addition, changes in feed quality may arise from enzymatic actions and the development of oxidative rancidity.

3.4.1 Moisture of feedstuffs during storage

- Safe moisture level – that develops relative humidity of 75%.
- Actual moisture content will gradually reach an equilibrium dependent on the relative humidity of the air in the store.
- Cereals can be stored well at 10 -12% moisture.
- The ideal moisture content of maize, rice and wheat -13%, 12% and 12.5%, respectively.
- High moisture and heat generated by the growth of fungi and insects - cause 'spontaneous combustion'.

General guidelines on moisture content of grains for safe storage

Duration of storage	Moisture content for safe storage
2 to 3 weeks	14 % or less
8 to 12 months	11% or less
More than 1 year	9 % or less

3.4.2 Chemical changes

- Lipids in feed break down into free fatty acids, which can lead to rancidity.
- Poly-unsaturated fatty acids - prone to oxidative rancidity (expeller vegetable oil cakes, and rice bran are particularly vulnerable).
- Vitamins in feed, especially Vitamin A, E, C and thiamine (vitamin B1), may be lost during storage (when exposed to oxygen, light, and humidity).
- Reduced Amino Acid availability due to high storage temperature.
- Carbohydrates may ferment - produce alcohols and volatile fatty acids.

3.4.3 Fungal and insect damage during storage

- Most fungal growth occurs at temperatures above 25°C and relative humidity above 85%.
- The optimal moisture content for fungal growth is above 15%, although some mycotoxin-producing fungi can thrive at moisture levels as low as 9-10%.
- Fungal growth can lead to local increases in temperature and moisture content. Resistant fungal spores can re-infect materials under favourable environmental conditions. Fungi, such as Aspergillus, can produce mycotoxins (AFB1).
- Moths, weevils, and beetles cause damage through weight loss and expose the feed to further fungal damage.
- At temperatures ranging from 26-37°C, insect populations can reach epidemic levels.
- To assess the extent of infestation about 3 kg samples should be collected from different stacks, sieved and examined. Table given below may serve as a general guideline for insect infestation:

Clean	No insects in stacks or in the sieved sample or the sample incubated for 3 weeks
Light	2 to 3 adult insects in the sample with 1 per cent damaged grains
Medium	5 to 10 adult insects with 3 per cent damaged grains
Heavy	Crawling insects on the stacks, 10 to 20 adult insects in one kg sample, 5 per cent damaged grains
Very heavy	10 to 20 adult insects in 100 g sample. A rustling sound of insects can be heard near bags. Crawling insects on floor and walls

3.5 General recommendations for storing feed and feed raw materials

- ENSURE that ingredients are clearly and indelibly labelled. Hang stack cards on each batch of small materials, noting date of arrival, quantity, production date etc. Differentiate small materials using unique bag colours.
- Mark each material requisition on the respective stack card.
- ARRANGE your store so that new deliveries are not put in front of old stocks. Follow FIFO (First In, First Out) method.
- All finished products should have stack cards indicating Production date, Quantity, Shift (day or night). Follow FIFO method for finished products also.
- ALWAYS keep the store clean and prevent entry of birds, rats etc.
- Regular cleaning of Bins, Silos & other storage facilities to eliminate source of inoculations.

- DO NOT accept deliveries of raw materials which are visibly damp or mouldy or which are obviously infested with insects.
- PLAN your ingredient purchases carefully so that you do not need to keep too great a quantity in stock.
- Make small stacks which are used rapidly - better than large stakes
- RAISE the sacks off the ground by stacking them on wooden/plastic pallets (platforms).
- DON'T allow sacks to rest against the outer walls of the store - leave a space between the stacks and the wall.
- Grain should be stored <13% moisture. If storing >2 weeks, keep aerated & cool.
- Vitamins should not be mixed with minerals before storage. Vitamin and vitamin mixes should be kept in the coolest place. Stocks should be turned over at least every six months.
- Implement temperature control to prevent oxidation and degradation of materials due to excessive heating.

Recommended storage periods for feed and feed ingredients

Feedstuffs	Tropical Zone	Temperate Zone
Ground ingredients	1-2 months	3 months
Whole grain and oilcakes	3-4 months	5-6 months
Compounded dry feeds	1-2 months	1-3 months
Vitamin Mixes	6 months	6 months

4. Manufacturing processes

Process parameters are a crucial aspect of any quality control program. This involves measuring specific components of feed or ingredients at various stages such as batching, grinding, mixing, conditioning, pelleting, cooling, screening, and packing.

4.1 Batching

- In modern plants, automatic weighing of different materials as per formulation to make one batch is called batching or proportioning. In this any no. of silos of suitable capacity as per total capacity of plant, are incorporated and are having gravity or screw feeders for controlled discharging of material into weigh bin underneath it. Generally, two set of bin or silos are installed - one for major ingredients, second for minor ingredients. The discharge of both weighing bins comes into common surge for further processing. Bin vibrator or shaking devices are installed on some or all of bins to make the material flow in case of jamming of bin.
- The weighing is done through an electronic controller working on PLC or microprocessor based, which can be operated through a computer. The computer control and record all the detail of a batch- over or under weighing of ingredients from set point, reporting on each batch, shift, day, weak, month basis.
- The generally desired features of a batching system include: accurate weighing within specified time to meet output of plant and it should be highly reliable and work automatically, it should have manual control also in case of auto failure.
- Calibration of weighing scales within specification limits is key to get precise measurement as per the formulations. Time, screw conveyor diameters, and the use of Variable Frequency Drives (VFD) at multiple speeds determine the accuracy of ingredient addition. Deviations from specification should not exceed 1% for major ingredients and 2% for minor ingredients.
- Under no circumstance should the overage or shortage of one ingredient be corrected when adding the next ingredient. Smaller ingredient inclusions like vitamins and minerals require greater scale resolution, finer control of equipment, and a higher degree of accuracy during weighing.
- Additionally, ingredient free fall can occur where ingredients fall into the scale after conveying turns off, yet ingredients are still being added. Therefore, routine scale checks are critical to ensure accurate weighing.
- Operators should review each batching report for ingredient discrepancy before shipment of complete feed to compare formulated and actual ingredient addition. Each report should include time and date, formula name and number, ingredient names, ingredient lot numbers (if applicable), ingredient quantities, theoretical and actual weight of ingredients added, where feed was stored, and operator identification. Additionally, batching equipment should

be sized appropriately to meet a system's needs.

- Collecting system data over time can be a management tool used to create change and maintain processes and equipment. The automation system can provide increased production rate, tracing and tracking of lots, data collection, process monitoring, inventory tracking, regulatory compliance, and product integrity. These benefits can be seen through system reports of equipment motor loads, operator efficiency, bearing temperatures, inventory variance, processing rates and alarms.
- The order of ingredient addition from bins into the mixer is important for establishing a uniform mix. For example, smaller ingredients might fall between the tub and ribbons or paddles, resulting in incomplete mixing. For this reason, ingredients should be added to the mixer in order from largest to smallest: major, minor, and then micro. Major ingredients include those with the highest inclusion in the batch (for example, corn, oil meals). Minor ingredients, such as limestone and dicalcium phosphate, should be added next. Micro ingredients, such as vitamins, trace minerals, amino acids, and other feed additives, should be added last.
- The location of discharge of micro-ingredients should also be considered to prevent discharge into dead zones, or areas of the mixer where mixer paddles or ribbons do not reach. The size of the batch of feed should never exceed the volume which the mixer is designed. However, the ingredient density must be considered since it can influence the uniformity of the mix. Generally, high by-product feed will decrease the density of the feet and therefore the batch size should decrease. As a general guideline, ribbons should always be visible. Material build up on the shaft, paddles or ribbons is a key indication that ribbons, and paddles are not functioning properly.
- Initial moisture content of the combined raw material batch should not exceed 11%.

4.2 Grinding

Grinding is a key step in the feed manufacturing process that involves reducing the size of ingredients to improve the feed and animal performance. Grinding can be done in a feed mill using a variety of machines, including hammer mills and roller mills. The quality of the grinding operation is determined by the particle size and throughput.

4.2.1 Factors affecting the performance of a hammer mill

- **Peripheral speed of hammers:** Impact velocity is one of the most important factors in pulverizing hard and large pieces. For any hammer mill, there is an important relationship between the speed of rotation and capacity. Slower speeds produce coarser products. The ideal tip speed for a hammer mill should be between 19,000 and 22,000 feet per minute. Energy consumption is intensified by increase in tip speed and hammer thickness.
- **Hammer Thickness:** Hammer design is a crucial factor in the design of a hammer mill. Wear typically occurs at the tip of the hammer, so some hammers are designed to be turned edge-for-edge and end-for-end. This arrangement provides four wear surfaces, making the design more economical. Reducing hammer width can improve production and efficiency. Additionally, by decreasing hammer thickness, both capacity and efficiency can be increased.
- **Diameter of screen opening:** Efficiency increases as the screen openings are enlarged, because the mill does less work per unit of material being processed. The fineness of the grind can be controlled by the size of the screen. Studies indicated that the smallest screen hole diameter (1.5 mm), largest hammer thickness (6 mm) and smallest tip speed (68.12 m s-1) were responsible for higher energy consumptions.
- **Kind of grain:** Since grain composition varies in terms of starch and fiber content, the power required to reduce different grains also varies. In general, cereal grains with higher starch content and less fiber are easier to grind. Oats are harder to grind than barley, while corn is the easiest.
- Factors like the flowability, grain size, moisture content, fat content and temperature sensitivity of the raw ingredients should be considered. For example, material with high moisture or fat content tends to be viscous and more challenging to grind. Higher moisture or fat content also reduces the material's flowability, reducing production efficiency and speed and leading to lower throughputs. For most animal feed mill equipment, the moisture content of the mixed raw material should be below 15%. Fat content will vary based on product and fineness but should generally be less than 8%.
- Herman and Loughin (2003) demonstrated the effects of screen size and moisture content on size reduction. Elevated moisture content increased the cost (kWh/ton) of grinding 34% for the 2.0 mm screen and 44% for the 2.7 mm screen. Increasing screen size saved 36% for lower moisture content and 27% for higher moisture content. Elevated moisture content increased the time to grind 3.5% for the 2.0 mm screen and 22.5% for the 2.7mm screen. Increasing screen size reduced time to grind 52% for the lower moisture content and 28.4% for the higher moisture content. Setting limits of acceptable ingredient moisture content and target particle sizes would improve machine efficiency, reduce the cost of grinding, and provide savings.

- The energy required by feed mill equipment like hammer mills varies greatly depending on the material. For example, the power needed to grind sorghum is half that of corn, whereas the need for power to grind both meals from cotton and soybeans is very similar. Power requirements for hammer mills also depend upon the mesh size of the hammer mill's sieve.
- **Air flow through the mill:** The amount of air flowing through the mill can affect how particles strike the impact surface. A value of 4,000 cubic meters per hour per square meter of screen surface is considered optimal.

4.2.2 Other considerations for improving grinding efficiency

- Ensure that more than 80% of the average particle size is below 1 mm. Studies have shown that the digestibility of grain with diameter of 0.85 ~ 0.95 mm is increased by 3% to 5% compared with diameter of 1.7 to 1.8 mm. The size of the general particle from 0.5 to 2.0 mm is suitable, which varies according to different varieties of livestock and poultry, the feeding stage and raw materials. Because too fine feed will increase the power consumption of feed processing, reduce the output, increase the wear of grinder and its parts like hammer, screen and so on, and reduce the service life.
- Adjust the gap between the hammer tip and screen based on the desired grinding texture: a smaller gap for fine grinding and a larger gap for coarse grinding. The hammer mill should have a gap adjustment feature to accommodate different grinding textures.
- The ideal tip speed for a hammer mill should be between 19,000 and 22,000 feet per minute.
- The average ideal power consumption of the grinding unit should not exceed 9 units per ton.
- A 1% increase in moisture content can reduce yield by 6%. High moisture can also clog screens and cause rust.
- Screen area to horsepower ratio: For most applications, a ratio of 14 in²:1 hp is preferred.
- The maximum temperature difference between the material entering and exiting the grinding process should not exceed 5 degrees.

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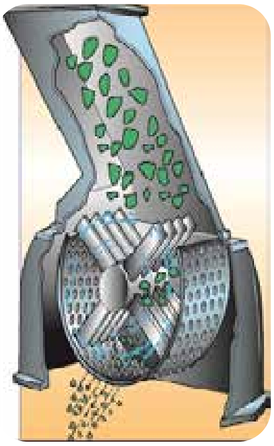

4.3 Mixing

- The overall goal of mixing is to create a uniform mix in the minimum amount of time. Evaluating and monitoring mixer performance is critical to ensure distribution of ingredients.
- The term "mixed" can mean either blended, implying uniformity, or made up of dissimilar parts, implying scattering. As applied to formula feeds, the objective of mixing combines each of these definitions; i.e., the scattering of dissimilar parts into a blend.
- Physical properties of ingredients, such as particle size, play an important role in the homogeneous mixing process. In general, the smaller and more uniformly sized the ingredients are, the closer they will approach random distribution during mixing.
- In most of the feed plants, continuous ribbon mixture is used. The continuous or "twin-spiral" mixer consists of a horizontal, stationary, half-cylinder with revolving helical ribbons placed on a central shaft so as to move materials from one end to the other as the shaft and ribbon rotate inside. Capacity can be from a few litres to several cubic metres. The speed of shaft rotation will vary inversely as the circumference of the outer ribbon; usually optimum between 75-100 metres per minute. Since material travel is from one end to the other, either end may be used for discharge. These mixers may be inverted for cleaning.
- Many of the problems in feed mixing are due to differences among feed ingredients in particle shape, size, and density. Feed ingredients with similar sizes and densities tend to blend easily and quickly. For example, ground or

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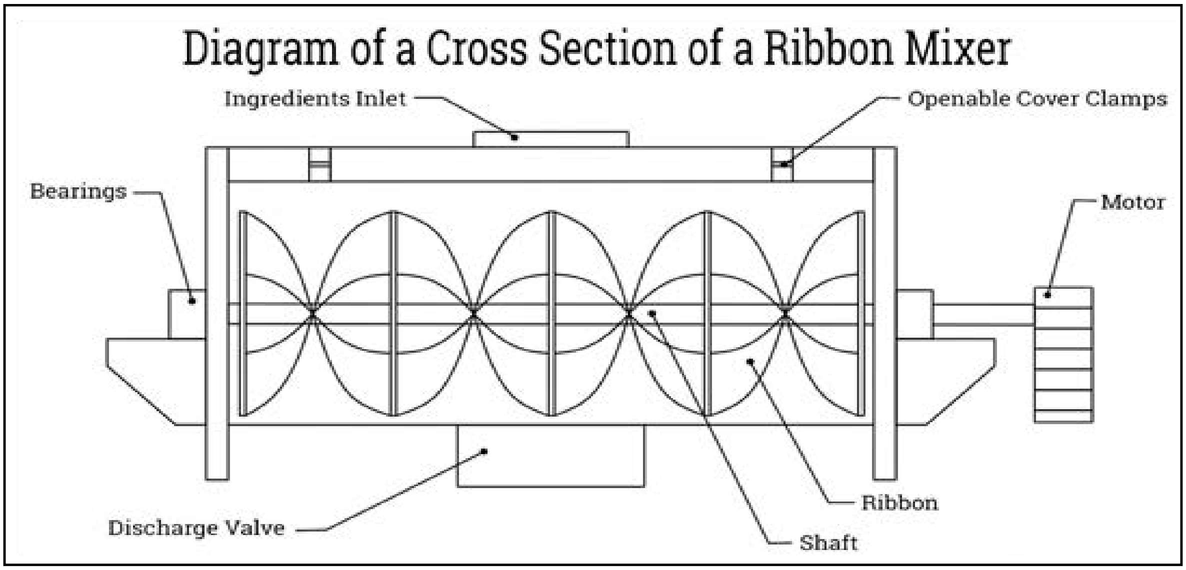
cracked grains have densities similar to that of the oilseed meals. Consequently, there is usually very little difficulty in obtaining a uniform blend of these feed ingredients. Minerals on the other hand have densities which are vastly greater than that of grains and oilseed meals. Forages have low densities, and highly varied particle shapes and sizes. This diversity of physical form and density of individual feed ingredients complicates the preparation of uniform feed mixes.



- The type of mixer used to mix ingredients greatly influences the time needed to create a uniform mix. The common mixing times for dry mix for different types of mixer are given below (Froetsschner, 2005):

Mixer Type	Mixing time (Min.)
Paddle mixer	3.0
Ribbon mixer	2.0
Double ribbon mixer	1.0 -2.0

4.3.1 Mixing uniformity test

- The principal objective in feed mixing is to assure that an animal receives all of its formulated nutrient allowances every day. For precision formulation to be successful, a uniform mix must be determined by the coefficient of variation (CV).

- A mixer uniformity test is often done by using a single source tracer (i.e. salt, trace minerals, etc.) as the indicator. Ten samples should be pulled in order from mixer discharge or sack off with a probe and the tracer analyzed to be tested for uniformity. Mixer uniformity CVs should be done annually, if not biannually, for validation or when there are major changes in ingredient characteristics.

- Most feed manufacturers use the coefficient of variation or CV to measure mixer performance and mixture uniformity. The CV is defined as 100 * standard deviation/mean. A 5% CV is the industry standard for most ingredients. An ingredient mix CV of 5% permits that an animal receive at least 90% of its formulated dietary allowances 95% of the time.

- With respect to ingredient ratio, the lower the ingredient concentration in the mix, the higher the CV. Thus, the CV is usually higher for trace mineral, vitamins and other additives because their ingredient ratios are low (less than 1:10,000).

- The feed industry standard is a CV of less than 10% (Herrman and Behnke 1994). Efficiency of mixing is rated based on CV as per the following:

Percent CV	Rating	Corrective action
<10%	Excellent	• None
10-15%	Good	• Increase mixing time by 25 to 30%
15-20%	Fair	• Increase mixing time by 50%, Inspect for worn equipment. • Check ingredient addition. • Overfilling.
>20%	Poor	• Possible combination of all the above. • Consult extension personnel or feed equipment manufacturer.

4.3.2 Premixing

- Premix micro ingredients such as vitamins, trace minerals etc. with a suitable diluent prior to their inclusion in a feed batch. Diluents serve to dilute the micro ingredient and thereby facilitate the rate of mixing. Examples of suitable diluents include the macro minerals typically incorporated in a feed mix (i.e. salt, limestone, dicalcium phosphate). Diluents should be dry in order to permit a more uniform dispersion of individual micro ingredient particles. Moisture must be avoided as it may cause entrainment and clumping (hygroscopic compounds such as urea are not suitable diluents). Premixing may be done by using a small portable cylinder mixer (cement mixer) or through premix plant. Protective clothing, gloves and dust mask should be worn when handling micro ingredients.

4.3.3 Other considerations for improving mixing efficiency

- Ribbon and auger mixers operate most efficiently if they are filled to 70 to 90% of capacity. With paddle mixers, satisfactory mixing may be obtained at much lower levels of loading (25% of capacity).
- The mixer should not be overloaded. Overloading the mixer will cause some of the feed to float above the mix and not blend properly. With paddle and ribbon mixers the mixer bars should rise at least 12 cm above the level of the mix.
- Improper mixing can also occur if the tolerances between the mixer bars and the sides of the mixer are not set properly. Mixers are factory-set with an agitator clearance of 0.3 to 0.9 cm. If that clearance increases to 1.3 cm, mixer efficiency will be impaired.
- Mixers should be visually inspected periodically. Establish a set schedule for inspecting the mixer. Worn paddles and ribbons should be replaced.
- Do not deviate from proper mixing times. If possible have mixing time controlled by a timer.

4.4 Conditioning and mixing of molasses

- Conditioning the feed is an important part of feed processing. When mash feed passes through the conditioner, it is exposed to high pressure steam. This steam provides the heat and moisture required for starch gelatinisation, particles adhesion and removal of pathogens in the mash. The steam temperature and retention time in the conditioner are two important factors that can influence pellet quality, defined with the so-called pellet durability index (PDI) and the hardness level of the pellet.

- Studies showed that the optimum temperature for producing high quality pellets is 75-80°C, and the minimum retention time in the conditioner is 60 seconds. A higher retention time in the conditioner causes more moisture penetration into the feed particles, and can be obtained through reducing peddle movement for example. Increasing the retention time of the mash feed in the conditioner (with a constant temperature) increases the PDI and hardness. But while increasing temperature in the conditioner can enhance pellet quality, it can also lead to biochemical reactions which in turn can decrease nutrients availability and negatively affect the beneficial effects of pelleting.

- Depending upon formulation, optimum conditioned mash moisture is in the range of 14.0 to 15%, with 4 to 5% coming from conditioning. As a rule, we can expect to add 1% moisture to the pellet mash for each 12.5 °C increase in mash temperature from steam. If the mash is already at 11-12%, the final mash moisture will be at or above the upper level of the range of optimum moisture. Conversely, if the mash temperature is at 30 °C, and we target 80 °C, we'll only be adding about 4% moisture.

- There are times when we simply can't reach target temperatures before the upper moisture level is met. Other times, when the grain is dry and warm, we simply can't get enough steam into the mash without exceeding target temperatures.

- Steam pressure at the boiler should be between 8.5 and 9.5 kg/cm². Steam pressure after the pressure reducing valve (PRV) should be between 2.0 and 2.5 kg/cm². Ensure the steam is dry and saturated.

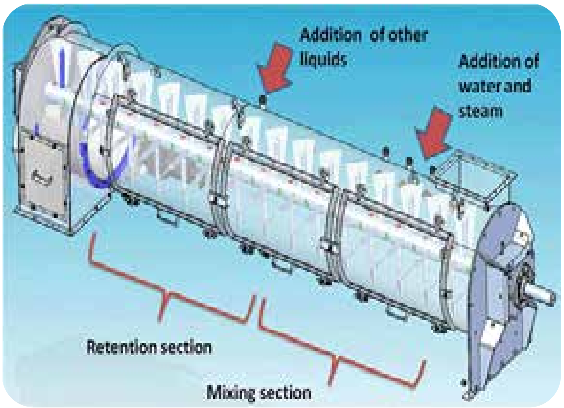
- For a boiler in a feed mill, the water quality should be "soft" with minimal dissolved minerals, meaning it should be treated to remove hardness (calcium and magnesium) and have low levels of total dissolved solids (TDS), ideally through a softening process like ion exchange, to prevent scaling and corrosion within the boiler.

- Ideally, hardness should be less than 5 ppm as calcium and magnesium can form scale deposits. Total dissolved solids should be monitored and kept within acceptable limits, typically below 3500 ppm for low-pressure boilers. pH should be slightly alkaline (around 8-10) to minimize corrosion.

- When adding molasses to cattle feed, careful attention should be given to mixing it thoroughly and evenly to avoid uneven distribution. A proper mixing system should be used to ensure uniform blending of molasses throughout the feed. To ensure the correct amount of molasses is added according to the formulation, its flow should be monitored regularly using a molasses flow meter.

Imprortant points to note:

- Ensure a minimum retention time of 60 seconds, with the ability to adjust for increasing or decreasing the retention time.
- Add a minimum of 1.5% to 2.0% moisture through the conditioners.
- Use a double-shaft design for better steam mixing.
- Employ multi-point steam injections for even distribution.



4.5 Pelleting

- Most modern pellet mills used a ring type die turning about two fixed rollers, with the die and rollers mounted in a vertical plane. A few mills are built with the dies and rollers in a horizontal plane with the rollers turning within the stationary die.
- In the pelleting unit, the conditioned mash is forced through holes in the die by roller pressure. Die thickness is a factor in the production of high-quality pellets and must be accurately balanced with the formulation and conditioning. Die thickness and hole size varies with the type of product to be pelleted. Pellet die specifications of FAO are given below:

Feed Categories	Die hole diameter (mm)	Die thickness, (mm)
High grain, complete feeds containing not more than 25% protein	4	40-50
	5	45-55
	6	50-60
Feed containing 5-25% sugars and/or dry milk powder or whey	4	20-35
	5	25-40
	6	30-45
Protein supplements containing 5-30% molasses	4	30-45
	5	40-50
	6	45-55
Feeds containing high levels of urea with or without molasses	4	20-35
	5	25-40
	6	30-45

- All pellet mills incorporate some type of speed reduction device, since die speeds are always less than the conventional motor speeds. In some cases, variation in die speed is desirable to produce optimum results on individual groups of feeds. Currently, mills are being built with speed change mechanisms.
- L/D Ratio in pellet mill dies: The L/D ratio is the effective length (L) divided by the hole diameter (D). High L/D ratios provide high pellet die resistance as feed moves through the hole. Low L/D ratios provide low resistance as the feed moves through the hole. For example, die of 3 mm hole size with L/D ratio 1: 12 means, 12 (working ratio) multiply by hole size i.e. 3 mm = 12 x 3 = 36 mm (working length)
- The effective length refers to the die thickness that directly impacts the feed. The greater the effective length, the higher the compactness of the pellet. Conversely, a shorter effective length results in lower pellet compactness and PDI. However, one must be cautious when selecting the working length of a pellet mill die. Increasing the effective

length beyond a certain limit, without considering other process parameters like grinding texture, oil, and fiber content in the formulation, can lead to poor die performance and potential clogging of the pellet mill die.

- Gap adjustment between pellet mill die and roller: The working gap between the ring die and roller must be set correctly, as it significantly impacts the proper use of the ring die. Generally, the gap between the ring die and the pressure roller should be around 0.1-0.3 mm. In practice, it is ideal to adjust the roller so that it is in a state of "barely turning" while rotating the ring die by hand.
- The pellet mill die accounts for more than 70% of the total cost of consumables in a feed mill. Factors that affect die life include the type of metal used (with a minimum chromium content of 12.5%), feed formulations (formulations high in fiber content are harder, making pelleting more difficult and reducing die life), particle size, conditioning, moisture addition, maintaining the proper gap between the die and roller, etc. Generally, a ring die can be used to produce about 20000 tons of pellets.
- For a pellet mill with a 220 hp capacity (output of 21 tons per hour), the power consumption should be approximately 9-11 kW/MT. The pellet mill's amperage load should be at 95%.
- The type of raw material being used and the size of the pellet machine can affect the RPM and production capacity. For example, hard raw materials require a more powerful pellet machine to produce pellets. RPM of a ring die pellet mill is usually between 1450–1500 RPM.
- Feed formulation has the greatest impact on pellet quality, accounting for 40%, followed by grinding and conditioning, each contributing 20%. The die contributes 15%, with the remaining 5% influenced by other factors.
- A higher tonnage per run enhances mill efficiency by reducing the frequency of operator shifts between feed types during mixing or pelleting. Therefore, efforts should focus on minimizing pellet mill changeovers to optimize efficiency.

4.5.1 Pellet Durability Index (PDI)

- Pellet quality is usually expressed as the Pellet Durability Index (PDI) and measured by using a tumbling device, in which the pellet sample to be tested is first sieved to remove fines, then tumbled in the tumbling can devise for a defined period of time. Then after tumbling we compare the fines produced during tumbling with actual weight.
- PDI = weigh of the pellet after tumbling / weight of Pellet before tumbling x 100
- At PDI lower than 85 pellets tend to break during crumbling; producing more fines which result in more recycling of feed and low final output.
- Among the various factors affecting PDI, feed formulation has the greatest influence, accounting for approximately 40% of pellet quality. A higher oil content in the formulation decreases PDI, while a higher proportion of de-oiled cakes increases it. Other important factors include particle size, conditioning, and die configuration. Conditioning contributes about 20% to both pellet quality and PDI.
- The Pellet Durability Index (PDI) should be more than 85%.

4.6 Cooling

* The pellets are cooled as water evaporates from their surface and is removed by the air. The air also absorbs heat from the pellets, which improves the air’s water holding capacity.
* In modern feed plants, counterflow coolers are commonly used, where the airflow moves in the opposite direction to the pellets. This ensures that the pellets are cooled evenly and gradually. Counterflow coolers are highly efficient in cooling feed pellets.
* Before cooling, a feed pellet coming out of a pellet mill is typically around 75-85°C, while after cooling, the temperature should be close to ambient temperature, usually only a few degrees higher, around 3-5°C above ambient. The maximum variation in temperature after the pellet cooler should not exceed ±5 0C from the ambient temperature.
* The moisture content of the pellets after cooling should be maintained between 11.0% and 11.5%.
* The heat and moisture in pellet feed are removed by the air, and sufficient air volume is required to ensure optimal output from the counterflow cooler. Below is a guide on the cooling time and air volume for the pellet cooler:

Pellet size (mm)	Cooling time (min)	Reference air volume (m3/min)
4-5	5~6	22.6
6-8	6~8	25.5
10	7~8	28.3
12	8~10	31.1

**The picture is indicative and is not intended to promote any particular brand*

4.7 Bagging storage and dispatch

Packing materials:

For packing of finished feed High Density Polyethylene (HDPE) / Polypropylene (PP) Woven Sacks should be used (as per IS 14887:2014).

The high-density polyethylene (HDPE) or polypropylene (PP/BOPP) used for manufacture of tape shall confirm to the requirements specified in IS 10146 or IS 10910 respectively. The fabric used in the manufacture of HDPE/PP woven sacks shall be woven as a tube on circular looms from HDPE/PP tapes having width of 2.5 mm (tolerance of ± 10 percent) conforming to IS 6192 and IS 11197 respectively, and linear density of 111 tex (1000 denier).

Labelling of bagged finished product

In the case of bagged product, correct packaging and labels must be applied at the time of bagging. Labels must meet state/ central government regulatory requirements, if any.

4.8 Loading, transport and delivery

Loading, transport and delivery of packaged feed products must maintain the identity and integrity of each feed variant post production, thereby minimising any post-production unintended mixing or contamination risks.

Loading: A formal system must be in place to ensure loading of all vehicles used for transport of packaged feed products with the correct product name/code, without risk of damage, unintended mixing or contamination. Damaged or leaking bags and other packaging should not be loaded for delivery.

Transport: Transport vehicles must be kept in clean, well maintained and roadworthy condition, and designed such that feeds can be kept dry and protected from damage or contamination during transport and delivery.

Delivery: The recipient of a given consignment of packaged feed products has responsibility for the provision of adequate, safe and unobstructed facilities for unloading, and the clear and visible identification of all their storage facilities (Dairy Cooperative Society/ feed godown at village level, etc.).

If any significant spillage occurs during unloading, this must be reported to the appropriate person at the CFP and to a representative of the customer and the spilt feed disposed of responsibly.

Where a customer has in place particular quarantine/biosecurity measures which impact on movements of vehicles/ drivers/ products to or on the farm/DCS level, or decontamination of delivery vehicles/drivers/ products, prior to their arrival at the farm/ DCS, these must be adhered to by the feed mill and transport drivers, and the CFP must ensure that truck drivers are made aware of these requirements.

**The picture is indicative and is not intended to promote any particular brand*

4.9 Key recommendations for feed manufacturing process

- Maintain weighing accuracy in such a way that deviations do not exceed 1% for major ingredients and 2% for minor ingredients during batching.
- Do not compensate for over- or under-weighing of one ingredient by adjusting the quantity of the next ingredient while batch making.
- Ensure routine calibration of weighing scales and conduct periodic checks to prevent errors.
- Follow the prescribed order for adding ingredients. The order is - major ingredients, followed by minor ingredients, then micro-ingredients.
- Maintain hammer mill tip speed between 19,000 and 22,000 ft/min to ensure optimal performance.
- Select screen size and hammer thickness judiciously to achieve a balance between energy consumption, throughput, and particle fineness.
- Ensure that more than 80% of particles are below 1 mm following grinding, with an optimal range of 0.5–2.0 mm depending on type of animal and its physiological stage.
- Keep raw material moisture below 15% and fat content below 8% to avoid clogging and reduced efficiency during grinding.
- Maintain mixer loading capacity at 70–90% for ribbon or auger mixers.
- Conduct mixer uniformity (CV) tests annually or after major formulation or equipment changes, maintaining CV below 10% (industry standard) and preferably ≤5% for most ingredients.
- Always mix micro-ingredients with dry, suitable diluents such as salt, limestone, or DCP to formulate premix.
- Maintain conditioner temperature at 75–80°C with a minimum retention time of 60 seconds.
- Target mash moisture of 14–15%, incorporating 1.5–2.0% moisture addition through conditioning.
- Use dry, saturated steam; maintain boiler pressure at 8.5–9.5 kg/cm² and PRV outlet pressure at 2.0–2.5 kg/cm².
- Ensure that boiler water quality adheres to standards (hardness <5 ppm, TDS <3500 ppm, and pH 8–10).
- Use molasses flow meters and keep verify the quantity of molasses.
- Maintain die–roller gap at 0.1–0.3 mm in the pellet mill.
- Optimize formulation, grinding, and conditioning, as these processes account for approximately 80% of pellet quality.
- Minimize frequent changeovers; larger batch runs enhance mill efficiency.
- Target a Pellet Durability Index (PDI) more than 85%.
- Reduce pellet temperature to 3–5°C above ambient temperature following cooling, with variation not exceeding ±5°C.
- Use HDPE/PP woven sacks conforming to IS 14887:2014 and related BIS standards.
- Ensure correct labelling in accordance with regulatory requirements at the bagging stage.
- Reject damaged or leaking bags during packing and dispatch. Implement a formal loading verification system to prevent product mix-ups.

5. Quality Control of raw materials and finished feeds

A large number of raw materials are considered for the production of cattle feed, based on their chemical composition and current price structure. The quality of the final product is determined by both the quality of the raw materials and the processing methods used. Additionally, adulteration of raw materials is a common issue. Therefore, implementing strict quality control measures during the procurement process is crucial.

5.1 Sampling

- Samples should be collected from both the center and the edges of the bags. While it's ideal to take samples from every bag, this may not be feasible for very large consignments. In such cases, a standard sampling procedure based on reliable statistical methods should be applied. This procedure ensures that the quantity of each sample, the number of samples, and the percentage of bags sampled are proportional to the size of the consignment.
- Every consignment should be given a separate code number so that it can be recorded for analysis, reporting and issuing.
- The number of bags to be selected from the lot shall depend on the size of the lot and shall be in accordance with the below table:

Lot size	Bags to be selected for sampling
Up to 50	30% of the bags
51 – 100	20% of the bags
101 – 300	15% of the bags
301 – 500	10% of the bags
501 and above	5% of the bags

- Individual sample preparation: The total quantity of material drawn shall be not less than 1.5 kg. Mix all the portions of the material drawn from the same bag thoroughly. Take about 0.75 kg of the material and divide it into three equal parts. One of the sets shall be for the purchaser, another for the vendor and the third for the referee.
- Composite sample preparation: From the mixed material from each selected bag remaining after the individual samples have been taken, equal quantities of the material from each bag shall be taken and mixed up together so as to form a composite sample weighing not less than 0.75 kg. This composite sample shall be divided into three equal parts and transferred to clean and dry containers, labelled and sealed airtight. One of these samples shall be for the purchaser, another for the vendor and the third for the referee.
- Referee samples: Referee samples shall consist of a set of test samples and a

composite sample and shall bear the seal of the purchaser and the vendor and shall be kept at a place agreed to between the two.

5.2 Evaluation of feeds and feed ingredients for quality

5.2.1 Physical evaluation

Physical evaluation is a relatively simple yet somewhat imprecise process. During the physical inspection of feed raw materials, factors such as colour, size, uniformity, smell, taste etc. are assessed.

- Colour - Orange to red colour of sorghum indicates high tannin content. Browning or blackening due to heat on improper storage reduces nutritive value.
- Homogeneity - Presence of fibrous material, especially in de-oiled groundnut cake. Rice polish is contaminated with husk. Clumps in mineral ingredients are not suitable for premixing.
- Smell - Musty odour indicates the beginning of fungal contamination or boring insects. Odour of petroleum products is suggestive of excessive pesticide or fungicides.
- Teste -To detect rancidity in oil rich feed ingredients this is the best method.Teste - The level of salt can be detected by tasting the ingredient and the feed. Bitter taste of rice polish indicates rancidity of fatty acids.
- Presence of foreign materials - Presence of foreign materials and grain weevils can be easily detectable during physical evaluation. Sometimes in De-oiled mustard cake foreign materials are available like wood particles, iron particles etc. Maize grains can be received with visible weevil infestations.

A list of common adulterants is listed below

Feed ingredients	Common adulterants
Groundnut cake	Groundnut husk, urea, non-edible oil cakes
Mustard cake	Argemone mexicana seeds, fibrous feed ingredients, urea
Soybean meal	Urea, raw soybean, hulls
De-oiled rice bran, wheat bran	Ground rice husk, saw dust
Mineral mixture	Common salt, marble powder, sand, lime stone
Molasses	Water
Maize	Cobs, cob dust, sand
Rice kani	Marble, grit

- Spot tests can be conducted to identify various types of adulterants, such as mahua cake, argemone seed, castor cake, neem seed cake, urea etc.

5.2.2 Chemical evaluation

- The quality control laboratory should be equipped with at least the basic facilities to analyze key nutrient parameters. Since purchasing decisions and feed formulations rely on the analysis of raw materials, it is crucial to ensure the highest level of accuracy in these analyses.

- During routine quality checks of raw materials and finished feed, apart from testing basic nutrient composition, special care should be taken to check for aflatoxin B1 in both raw materials and finished feed, as per BIS specifications. For quick checking of raw materials such as maize, oilcakes, and DORB, rapid test kits can be used. However, regular testing of raw materials and finished feed for Aflatoxin B1 should also be done using standard laboratory methods recommended by AOAC.

- All samples should be analyzed in duplicate to minimize experimental errors, and the variation between duplicate samples should be kept to a minimum. If significant variation occurs, the samples must be re-analyzed.

- The personnel conducting the analysis should be qualified, experienced, and efficient, ensuring the process is completed swiftly to facilitate timely payment to suppliers, prompt use of the consignment, and effective marketing of the finished feed.

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5.2.3 Quality check points during production

- Ensure that samples are systematically collected by the sampler during the receipt of raw materials.
- Review the accuracy reports from the computerized batch preparation system to confirm that the weighing of each raw material aligns with the feed formula. If there is an error of more than 10 kg in the batching process, notify production management for correction.
- Regularly monitor and maintain the dust extraction system at each dumping point to ensure it is functioning properly and efficiently.
- Clean magnetic grills at the dumping hoppers daily. Additionally, maintain jute twine removers regularly.
- Verify that the hammer mill sieve has the correct hole size and is not damaged.
- Check the moisture content in the feed mix before conditioning. After the ingredients are thoroughly mixed in the steam injection chamber, collect a sample to measure moisture content and the temperature at which the material is fed into the pellet mill.
- Confirm that the pellets exiting the pellet cooler are adequately cooled and do not contain excess moisture.
- Ensure the pellets are sufficiently cooled and their physical quality is acceptable before they are bagged and sealed.
- The QC officer should ensure that finished feed samples are collected from each bag and a composite sample from every 100 bags is prepared.

**The picture is indicative and is not intended to promote any particular brand*

5.3.4 Laboratory equipment

The minimum laboratory equipment with their estimated cost required for a 300 MTPD feed mill includes the following:

Sl. No.	Name of the equipment	Qty.	Indicative Cost (Rs Lakh)
1	Near Infra-Red (NIR) Analyzer with computer with winisi calibration software.	1 set	55
2	Cyclotec Sample Mill	2 nos.	10
3	Remi make lab mixer	2 nos.	10
4	Electronic analytical balance - 200 g weighing capacity	2 nos.	6
5	Kjeltec for crude protein estimation (with digestion and distillation unit)	1 no.	45
6	Fibretec for crude fibre estimation	1 no.	20
7	Soxtec for crude fat estimation	1 no.	20
8	Microwave Muffle furnace	1 no.	5
9	Digital vacuum oven, thermostatically controlled	1 no.	6
10	Vacuum pump, double stage	1 no.	
11	Digital Hot Air Oven, thermostatically controlled	2 nos.	6
12	Digital Muffle Furnace, thermostatically controlled	3 no.	9
13	Metal Distilled Water Plant - 20 ltr/hour	1 no.	3
14	Top pan balance (electronic)- 2kg capacity	1no.	1
15	Digital pH meter with electrode	1no.	1
16	Centrifuge, digital speed control (capacity 6 tubes min.)	1no.	2
17	Orbital mixer cum incubator.	1no.	3
18	Hot Plate	2 no.	1
19	Fume chamber with exhaust system	2 nos.	10
20	Computer with printer	1no.	1
21	Top pan balance (electronic)	2 nos.	1
22	Moisture Analyser	1no.	1
23	Sample Grinding mill	1 no.	1
24	UPS	1 no.	25
25	In vitro lab equipment	1 set	45
26	Spectrophotometer	1 no.	5
27	HPLC (for analysis of Aflatoxin and Vitamins)	1 no.	45
28	PDI testing equipment	1 no.	4
29	Aflatoxin B1 test kit & reader	1 no.	5

5.3.5 Least Cost Feed Formulation (LCF)

- In a cattle feed plant, one of the most significant aspect of production is to derive an appropriate formula to produce nutritionally balanced feed at the lowest possible cost. This formulation can be worked out by using LCF software.
- Cattle feed plants should run least-cost formulation (LCF) software on regular basis or as needed, especially when fluctuations occur in the price or composition of feed raw materials.
- In computing the least cost formula, the marginal value of each of the nutritional element in the total requirement of raw materials is found by linear programming technique.
- The Animal Nutrition officer must keep in mind the type of animal and the type of physiological function for which finished feed is desired while making specifications for minimum-maximum levels of nutrients and other constraints.
- Constraints are generally resorted to restrict the use of individual or a group of ingredients to a maximum or minimum limit. Individual restrictions should be generally based on toxic principle including anti-metabolites, palatability etc.
- It is advisable to set a maximum limit on the use of certain ingredients, including unconventional feed items. For example, the inclusion of urea should be restricted to 1%. Similarly, a minimum limit should be maintained for essential ingredients, such as mineral mixtures.
- The minimum and maximum limits of individual feed ingredients should also vary according to the type of feed formula. For example, early lactation feed should be rich in energy; therefore, a minimum of 15% grain should be included when preparing LCF.
- Interested cattle feed plants may write to NDDB for ID creation and technical help in this regards.

5.4 Feed and raw material specifications

High-quality ingredients are essential for the production of superior finished feed. Therefore, adherence to defined ingredient specifications during the procurement of raw materials is critical. These specifications form the foundation for raw material purchasing, feed formulation, and quality inspection of both incoming materials and finished feed. For ingredient descriptions and general nutritional specifications of various feed ingredients used in feed manufacturing, the relevant Bureau of Indian Standards (BIS) specifications available on the BIS website (www.bis.gov.in) may be referred.

Similarly, for finished feed, manufacturers must strictly adhere to the specifications prescribed by BIS. As per the Food Safety and Standards Authority of India (FSSAI) directives, all cattle feed plants in India must conform to the BIS specifications for compounded cattle feed and carry the BIS mark on their products. A list of relevant BIS specifications for compound feed is provided at **Annexure I** for ready reference.

5.5 Key Recommendations for quality control of raw materials and finished feeds

- Establish and maintain a basic, well-equipped quality control laboratory.
- Procure raw materials and manufacture finished feeds in strict conformity with BIS specifications.
- Adopt a statistically sound sampling protocol and draw samples from the centre and edges of bags; assign a unique code to each consignment to enable traceability.
- Perform mandatory physical examinations of raw materials for colour, odour, homogeneity, foreign matter, and infestation.
- Exercise vigilance against common adulterants, utilizing spot tests as per requirement.
- Ensure aflatoxin B1 testing for high-risk raw materials and finished feeds, employing rapid test kits supplemented by confirmatory laboratory methods.
- Monitor moisture and temperature regularly before conditioning and after cooling of feed pellets.
- Collect finished feed samples at regular intervals via composite sampling.
- Execute all lab analyses in duplicate, duly performed by trained and qualified personnel.
- Use LCF software on a regular basis for feed formulation, particularly at the time of price or quality fluctuations of raw materials. Maintain ingredient and nutrient constraints aligned with animal type, safety, and palatability.
- Restrict inclusion of risky ingredients (e.g., urea ≤1%) while mandating minimum inclusions of essentials ingredients such as mineral mixture.
- Obtain mandatory BIS certification and apply requisite markings on compounded cattle feeds as per FSSAI directives.

6. Losses in feed weight

Losses in feed weight during feed manufacturing can result from several factors including moisture loss, storage loss, handling loss, etc.

6.1 Handling loss: These are the losses due to loading, unloading and transportation from godown to intake hopper or railway siding to godown. Hicks (1992) describes handling losses as being "due to loss of volatile compounds such as oils, mechanical losses from broken kernels and foreign material, and possibly also due to respiration of the seed itself. The 3-year on-farm average (of handling losses) was 0.82% compared to 0.88% for the commercial facilities" according to research published by Iowa State University.

6.2 Storage loss: This is due to moisture evaporation, insect infestation, damage caused by rodent and birds, putrefaction and formation of lumps due to bad storage conditions or rancidity. Within the feed industry, shrink of up to 1 % of the feed mill output is regarded as being in the standard or expected range (Fahrenholz, 2017).

Respiration during the storage period may cause dry matter loss up to 1 % or more. Depending on ambient temperatures and relative humidity, i.e. depending on climatic conditions, grain will adapt and stabilize its moisture content to an equilibrium (Sadaka, FSA1074). At any given storage temperature, the equilibrium moisture of the grain will drop with the relative humidity of the ambient air and vice versa.

6.3 Production loss: This dust loss is due to various processes, such as conveying, cleaning, mixing and grinding. Leakage of dust through various conveyers and machines can be kept to minimum by using effective packing at all bolted joints and by maintaining effective aspiration system. In grinding, loss occurs due to removal of moisture. Powdered material going out as losses can be minimized by properly maintaining the suction fans and bag filters of the dust extraction systems. However, de-oiled cakes (light material such as rice bran) suffer maximum loss due to grinding.

During the cooling process, a blower creates an airstream. A cyclone is then used to separate the dust from the airstream, then recycles the air. Most of the fine dust particles are so tiny, that although they will be separated from the air stream initially, they will later be recycled back into the airstream via the cyclone. According to Fahrenholz (2017) even in high efficiency cyclones, 0.075 lb of dust emissions may be expected per ton of feed (34 g/ton). With an annual production of 100000 MT this would add up to 3 to 4 MT shrink by dust emissions.

6.4 Moisture loss: Moisture loss is calculated by subtracting the average moisture content of the finished goods from the average moisture content of the raw material batch. Ideally, the moisture content of the finished pellets in the bag should be between 10% and 11%, depending on the atmospheric temperature and humidity. Since cooling is an evaporative process, moisture loss of about 2-2.5% happens during this process. However, there are instances when overcooling occurs, leading to excessive drying. When the average moisture loss or shrinkage exceeds the expected level, it can result in financial losses. Given that net profit margins in some feed companies are as low as 1% to 2%, this factor can significantly impact whether the company makes a profit or incurs a loss, making it a critical aspect of feed mill management.

6.5 General recommendations:

- Conduct a moisture check on raw materials during manufacturing of feed, with sampling at various stages - after batching, grinding, conditioning, pelleting, cooling, and in the final product - as needed.

- Take corrective actions based on reports, such as adjusting the grinding temperature, adding moisture in the mixer, managing steam quality and quantity, optimizing retention time in the conditioner, setting the cooler bed level and sensor, adjusting the blower valve according to temperature, and cleaning the cyclone and ducts. Also, consider moisture and weather conditions.

- Utilize automation modules for inventory management by receiving feedback from weigh scales (for raw materials), tracking material stock in the warehouse, and monitoring the daily weight of finished goods leaving the feed mill. This should be done every 10 days, three times a month.

- Despite all corrective measures, some shrinkage may still occur due to factors like seasonal raw material availability, grain prices, risk of mould or fungus in finished feed during the rainy season and machinery limitations with different formulations. It is prudent to account for a 0.5% to 0.6% process loss in cost estimations. Each plant should identify where shrinkage or gains may occur and make every effort to control and minimize these losses.

7. Maintenance of feed mill

Ideally, a preventive maintenance schedule should be followed. Variations of preventive maintenance should be planned and performed on all equipment to prevent unplanned failures. For instance, a time-based approach schedules preventive maintenance tasks at fixed intervals, such as every 10 days. Alternatively, a condition-based maintenance strategy monitors the actual condition of an asset to determine the necessary maintenance tasks.

For this, a segment wise checklist comprising the following points may be developed:

Particulars	Daily	Weekly	Monthly
Scale	Test the standard weight to ensure scale accuracy. If possible, get the scale certified by a reliable third party.		
Hammer Mill		Clean motor cooling fins to ensure good operation and efficiency.	Check hammers for wear and replace or reverse direction of worn hammers. Check if the shaft has been wearing the hole in the hammers and replace if there is much wear.
			Check the inside of the screen for wear. The edge of the holes should be "sharp", not worn down. If the holes are worn down, the direction of the hammers can be reversed to extend the life of the screen.

Particulars	Daily	Weekly	Monthly
Mixer	Clean the dust of motors. Too much dust can cause overheating, lower efficiency, and reduce the life of the motor.	Check if the belts are cracking or getting worn out. If they are, replace them.	Check to make sure there is not very much room between the tube and the edge of the screw. The distance between the screw and the tube should be less than approximately 5 mm. The screw will wear down over time, reducing the efficiency of the mixer and increasing mixing time.
Conditioner		Clean the conditioner to remove any sticky materials on walls/corners.	
Others	Clean the dust of motors. Too much dust can cause overheating, lower efficiency, and reduce the life of the motor.	Inspect spouting and hoppers for any holes. Repair, patch, or replace any damaged spouts or conveying equipment. Make sure bags are stacked neatly on pallets, at least 0.5 m away from the wall.	
Sanitation	Sweep the production area, clean up bags, string and other trash. Clean debris and vegetation away from the outside of the building, at least 1 m. This discourages rodents.		

8. Important KPIs of Cattle Feed Plant

Description	KPIs	Industry standard
Raw material storage	Max. stack height for raw materials	15 ft
	Space between stacks and distance from walls	1.56 m & 0.5 m
	Moisture of stored raw materials	12% or less
	Max. storage duration (cereal and cakes) in tropical regions	3-4 months
Batching	Batching mixing time	120 sec.
	Order of raw materials during batching	Ingredients should be added to the mixer in order from largest to smallest: major, minor, and then micro.
	Calibration frequency and deviation allowed	Deviations from specification should not exceed 1% for major ingredients and 2% for minor ingredients
Grinding	Tip speed of hammer mill	19000-22000 ft per min.
	Grinding time	3.5-4.0 min.
	Moisture content of the mixed raw material before grinding	Should be below 15%
	Air flow through the mill	A value of 4,000 cubic meters per hour per square meter of screen surface is considered optimal.
	Hammer mill power consumption	Should not exceed 6 units per ton.
	Particle size after grinding	80% of the average particle size is below 1 mm.
	Temperature difference between the material entering and exiting the grinding process	Should not exceed 5^0C

Description	KPIs	Industry standard
Mixing	Mixing time as per the mixer type (ribbon mixture)	120 to 180 sec.
	Coefficient of Variation (CV%)	CV should be less than 10%
	Loading of mixture	Ribbon mixers operate most efficiently if they are filled to 70 to 90% of capacity
Conditioning	Steam pressure	Steam pressure at the boiler should be between 8.5 and 9.5 kg/cm². Steam pressure after the pressure reducing valve (PRV) should be between 2.0 and 2.5 kg/cm².
	Steam temperature	75-85^{0}C
	Minimum retention time of feed mix in the conditioner	About 60 seconds
	Hardness of water	Should be less than 5 ppm
	Min. moisture addition through conditioner	1.5-2%
Pelleting	Pellet mill power consumption	Should be approximately 9/11 KW/MT
	Pelleting temperature	70-75^{0}C
	Gap between the ring die and the pressure roller	Should be around 0.1-0.3 mm
	RPM of a ring die pellet mill	Usually between 1450–1500 RPM
	Die hole diameter and die thickness	6 mm & 50-60 mm 8mm & 62-80 mm
	Die change (at what production level?)	A ring die can be used to produce about 20000 tons of pellets
	Pellet durability index (PDI)	Should be more than 85% (90%)
Cooling	Cooling time	6-8 min.
	Pellet temperature after cooling	The maximum variation in temperature after the pellet cooler should not exceed ±5^{0}C from the ambient temperature.
	Final moisture (%) after cooling	Should be maintained below 11%.

Description	KPIs	Industry standard
Other parameters	Energy consumption for feed production	22-23 KW/ MT feed production
	Power factor	Should be more than 0.98
	Overall loss	Should not be more than 1.5%.
	Storage loss	Should not be more than 1%
	Process loss	0.5-0.6%

9. Way forward

The efficiency of a feed plant is influenced by multiple factors, including the receipt and quality assessment of raw materials, process optimization at various production stages, and minimizing losses at different points. To enhance overall efficiency, plant managers must address these aspects systematically, adopting a structured approach to evaluate performance across all sections of the plant.

Insights gained from visits to various cattle feed plants have enhanced the understanding of operational challenges and best practices. Interested plants may be extended the necessary support to improve operational efficiency and achieve long-term sustainability in an increasingly competitive market.

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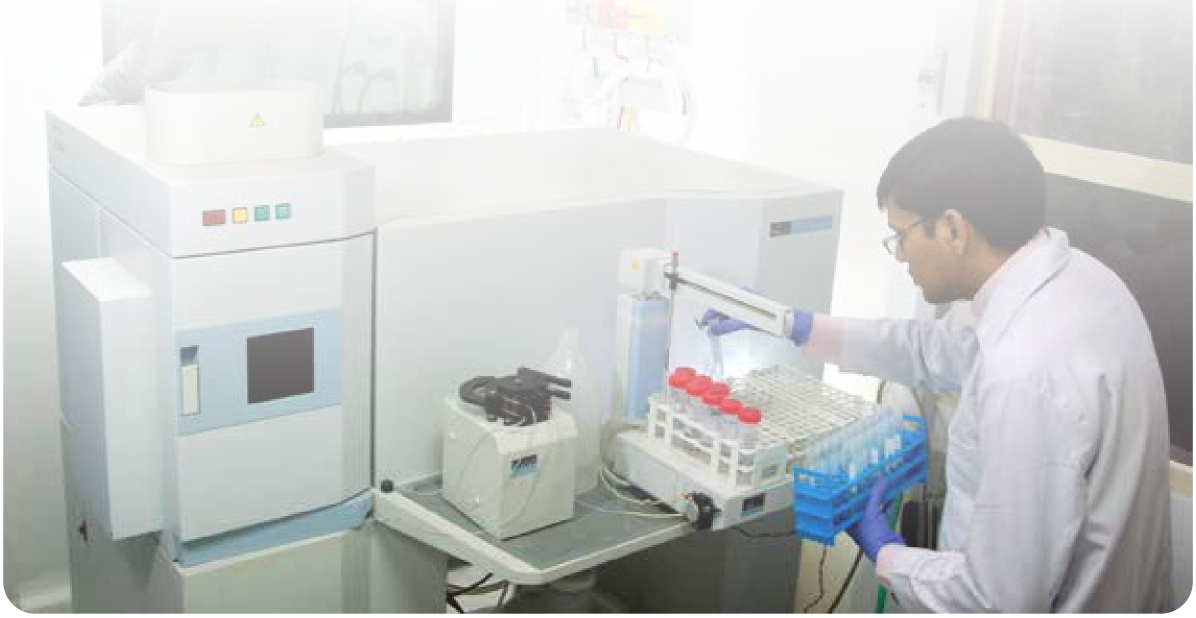

**The picture is indicative and is not intended to promote any particular brand*

Annexure I

A. Requirements for Compounded Feeds for Cattle (IS 2052: 2009)

Sl. No.	Characteristic	Requirements	
		Type I	Type II
i)	Moisture, percent by mass, Max	11	11
ii)	Crude protein (N × 6.25), percent by mass, Min	22	20
iii)	Crude fat, percent by mass, Min	4.0	3.0
iv)	Crude fibre, percent by mass, Max	10	12
v)	Acid insoluble ash, percent by mass, Max	2.5	3.0
vi)	Salt (as NaCl), percent by mass, Max	1.0	1.0
vii)	Calcium (as Ca), percent by mass, Min	0.8	0.8
viii)	Total phosphorus, percent by mass, Min	0.5	0.5
ix)	Available phosphorus, percent by mass, Min	0.25	0.25
x)	Urea, percent by mass, Max	1.0	1.0
xi)	Vitamin A, I.U./kg, Min	7 000	7 000
xii)	Vitamin D3, I.U./kg, Min	1 200	1 200
xiii)	Vitamin E, I.U./kg, Min	30	30
xiv)	Aflatoxin B1 (ppb), Max	20	20
xv)	Cadmium, mg/kg, Max	0.5	0.5

Notes: The values for requirements at Sl. No. (ii) and (xv) are on moisture free basis

B. Requirements for Compounded Feed for Buffalo (IS 18792: 2024)

Sl. No.	Characteristic	Requirements
i)	Moisture, percent by mass, Max	**11**
ii)	Crude protein (N × 6.25), percent by mass, Min	22
iii)	Crude fat, percent by mass, Min	5.0
iv)	Crude fibre, percent by mass, Max	10
v)	Acid insoluble ash, percent by mass, Max	2.5
vi)	Salt (as NaCl), percent by mass, Max	1.0
vii)	Calcium (as Ca), percent by mass, Min	1.0
viii)	Total phosphorus, percent by mass, Min	0.7
ix)	Available phosphorus, percent by mass, Min	0.3
x)	Urea, percent by mass, Max	1.0
xi)	Vitamin A, I.U./kg, Min	10,000
xii)	Vitamin D3, I.U./kg, Min	13,000
xiii)	Vitamin E, I.U./kg, Min	40
xiv)	Aflatoxin B1 (ppb), Max	20
xv)	Cadmium, mg/kg, Max	0.5
xv)	Cadmium, mg/kg, Max	0.5

Notes: The values for requirements at Sl. No. (ii) and (xv) are on moisture free basis

C. Requirements for Calf Starter Meal and Calf Growth Meal (IS 5560: 2024)

Sl. No.	Characteristic	Requirements	
		Calf Starter	Calf Growth Meal
i)	Moisture, percent by mass, Max	10	10
ii)	Crude protein (N × 6.25), percent by mass, Min	23	22
iii)	Crude fat, percent by mass, Min	4.5	4.0
iv)	Crude fibre, percent by mass, Max	9.0	10
v)	Acid insoluble ash, percent by mass, Max	1.5	1.5
vi)	Common salt (as NaCl), percent by mass, Max	1.0	1.0
vii)	Calcium (as Ca), percent by mass, Min	0.8	0.8
viii)	Phosphorus (as P), percent by mass, Min	0.5	0.5
ix)	Available Phosphorus, percent by mass, Min	0.3	0.3
x)	Urea, percent by mass, Max	-	0.5
xi)	Vitamin A, I.U./kg, Min	10000	10000
xii)	Vitamin D3, I.U./kg, Min	2000	2000
xiii)	Vitamin E, I.U./kg, Min	75	75
xiv)	Aflatoxin B1 (ppb), Max	20	20
xv)	Cadmium, mg/kg, Max	0.5	0.5

Notes:

1. The values for requirements at Sl. No. (ii) and (xv) are on moisture free basis.
2. While analyzing for crude protein, it should be ensured that the nitrogen has not been derived from urea or other ammonium salts.

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