Feed processing technology – an international perspective

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Outline

1. Feed Technology – Historical Perspectives and Recent Developments

2. Feed Safety and Quality – Good Practices

3. Where to from here?
Feed technology in the last five decades

Feed Technology – fueled by increasing demands

Dictated by:
making equipment easier to handle, more efficient, use of novel feed ingredients
Feed technology -- a historical perspective

1960-1980: Modernization Period

- Use of roller mills, hammer mills and pellet pressings
- Storage of pelleted feeds with delivery to farmers on request
- Feed formation in view of legislations
- Limited automation
- Publications on feed technology – process conditions affect quality of pelleted feeds – performance and nutrient digestibility

1980-2000: Consciousness Period

- Mycotoxins and anti-nutritional factors recognized
- Technologies to minimize their effects (toasting and radiation) & pelleting
- Environment & animal welfare
- Use of feed additives [stability and mixing to concerns e.g. antibiotics]
- Development of good quality systems & process optimization
- 1983- First symposium on particle size reduction – Kansas University
  (decrease in cost: energy cost reduction, increase in feed efficiency, optimization of pelleting and conveying; animal species and their physiological stage consideration)
2000-2020: Tailored feed production

Customer-oriented compound feed production
  Feed safety and quality, animal health, hygiene
  Feed additives – benefits and concerns antibiotics)
  Reduction in costs, target nutrient delivery, synthetic amino acids use
  Liquid feed delivery
  Processing integral part of nutrient utilization
    Better control of plants: mixing, grinding, conditioning (proper process and over-processing), pelleting
  On-line NIRS integration
    Analytical methods to test processed animal proteins

Mantra-- Physical quality is important but it should not be at the expense of nutritional quality
Factors controlling pellet quality

Quality – a combination of factors:

- Durability (+++): transport & handling
- Hardness* and appearance including colour
- Surface texture
- Uniformity of size
- Percent fines
- Palatability

* Weight without breaking (hardness & durability not always correlated

- Finer the particles better quality
- State of the equipment: hammer, die, knife, rollers incorrect position of blades, steam valves
Feed technology -- recent developments

Particle size control

A good grinder?

Even-size particles – better control over particle size
Energy efficiency
Flexibility in using different raw materials

Roller and hammer mills together preferred
However height of plant becomes an issue

New hammer mills:
large rotor
low speed
8 screens

120 tons/h (800 kW)
20-40 tons/h (355 kW)
Feed technology -- recent developments

Liquids in feed mill

Earlier
Liquid raw materials were just ‘topping’, applied at 1-2 %
Dosing from storage tank, above mixers (storage of liquid
at temp > Melt. point)
Using volumetric counter flow devices
Large amount of dust sticking to walls and inside ribbon of mixer
Hygiene not a big issue

Now
Continuous mixer below the main mixer
Liquids sprayed in the continuous mixer, as the mixer
passes through
No lump formation though frequent cleaning required
Next step is in the conditioners
Mixing: an important step

Efficient mixing being key to good feed production

- Optimum mixing: ensures uniform distribution of nutrients, vitamins and minerals

A homogeneous nutrient content in each feed pellet.

Ensure optimum growth of the animals.

What is a good mixer

- Provides both fast and efficient mixing
- Easy to clean (no cross contamination, from one formula to another)
- All ingredient in every pellet
Conditioning & Pelleting

Before mesh enters the pelleting stage
Conditioning step – vital
Steam supply system-- critical

Steam generation, control & quality

Dry pelleting
- More starch damage
- Though low energy cost

Steam-conditioned pelleting
- Improved pellet quality
- Higher productivity
- Though higher energy cost

Pellet quality is established in conditioner rather than in pellet die

Online quality Control using NIRS
Conditioning and pelleting

Advantage of pelleting
Reduce pathogens
Increase density of feed, and absorption of nutrients (+)
reduce segregation of ingredients during transport and feeding

Conditioners before pelleting
short term conditioning: steam conditions 20 – 30 sec
long term conditioning: steam for > 60 sec
Conditioning for 5 to 8 min at a temp

Conditioning
Starch gelanisation (optimum 70 C and 25% moisture; time not much effect)
Nutrient utilization (++)
Pathogen mitigation, reduction/elimination in antinutrients
Starch gelanisation is maximum from physical process: pressing through die

Thermal processing: increased daily gain and feed efficiency
Conditioning temperature and moisture requirement

Feed categories (I = high starch; II = heat sensitive high starch; III = high natural protein; IV = high fiber; V = high urea/molasses)

Optimum: 16-16.5% moisture
Steam system, control and quality

Steam system: poorly understood and badly managed

Steam properties:

Saturated steam temperatures for a range of operating pressures typically found in steam systems in feed mills

<table>
<thead>
<tr>
<th>Gauge Pressure</th>
<th>Absolute Pressure</th>
<th>Steam temp °C</th>
</tr>
</thead>
<tbody>
<tr>
<td>psig</td>
<td>psia</td>
<td>°C</td>
</tr>
<tr>
<td>0</td>
<td>14.7</td>
<td>100.0</td>
</tr>
<tr>
<td>20.3</td>
<td>35.0</td>
<td>126.3</td>
</tr>
<tr>
<td>30.3</td>
<td>45.0</td>
<td>134.7</td>
</tr>
<tr>
<td>40.3</td>
<td>55.0</td>
<td>141.7</td>
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<tr>
<td>50.3</td>
<td>65.0</td>
<td>147.8</td>
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<tr>
<td>60.3</td>
<td>75.0</td>
<td>153.1</td>
</tr>
<tr>
<td>70.3</td>
<td>85.0</td>
<td>157.9</td>
</tr>
<tr>
<td>80.3</td>
<td>95.0</td>
<td>162.3</td>
</tr>
</tbody>
</table>

Steam quality

- % of steam in water phase
- Steam passes through pipes, steam cools and turns into a mix of dry and liquid vapour (wet steam) – low energy if enters into conditioner
- More wet stream – lower increase in temp but higher increase in moisture – plugging of machine or low pellet quality

Steam supply

- Steam boiler
- Steam piping
- Steam regulation

Good practices
Steam moisture-temperature optimization

Conditioner

Temp IN 20 degree C  Temp OUT 70 degree C

Real time Moisture - Online humidity technology

For every 14 degree C increase 1% moisture added
Moisture increase = 5% points

New vs old crop Moisture?

Too much moisture (due to excess steam) to feed mesh

Rolls of pellet machine slip on the die surface

Too little moisture

Dry and brittle pellets

Too much heat

Denaturation of nutrients and low feed efficiency

Too little heat

Frictional heating in die, shorten die life, Reduction in pellet mill capacity
### Optimizing press settings

#### Effect of roller-die gap and feeder rate on pellet durability index (PDI)

<table>
<thead>
<tr>
<th>Distance between Roller and die (mm)</th>
<th>Feeder rate (kg)</th>
<th>PDI (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.1</td>
<td>500</td>
<td>85.6</td>
</tr>
<tr>
<td>0.1</td>
<td>1000</td>
<td>82.8</td>
</tr>
<tr>
<td>1</td>
<td>500</td>
<td>87.7</td>
</tr>
<tr>
<td>1</td>
<td>1000</td>
<td>85.8</td>
</tr>
<tr>
<td>2</td>
<td>500</td>
<td>90.6</td>
</tr>
<tr>
<td>2</td>
<td>1000</td>
<td>85.6</td>
</tr>
</tbody>
</table>

- **Higher energy use**
- **Lower production capacity**

Other factors:
- Die hole and die dia
- Die thickness & feeder rate

![Diagram of friction areas](Image)

![Diagram of die, rolls, and layers of mesh](Image)
If you google: "feed mill" and "fire"

Over 100,000 results.

Suggests that a feed mill is a definite fire hazard. In most cases, dust is the accelerating cause for mills to completely burn down or in the worst case to explode. Enough reason to pay attention to explosion prevention.

In the US 281 combustible dust incidents between 1980 and 2005 --
-- killed 119 workers
-- injured 718, and extensively
-- damaged industrial facilities.
-- Injuries or fatalities occurred in 71% of the incidents."
Improper storage – smoking/fire

Reasons: high moisture, compactness, less aeration

Prevention: moisture < 13%, in sacs (not too high) & sufficient space between rows

First in, first out approach

Feed materials with high moisture content undergo physical and biochemical changes when stored at high temperature and high relative humidity.

Especially grains: bursting and gelatinization of starch, increase in feed sugar, production of alcohol and acetic acid, resulting in a sour odour.
Knife setting and pellet quality

Cutter at outside of pellet press

The research showed that the condition of knives (worn or sharp) affect the physical quality of feed pellets.

Worn knife: More dustiness
Reduction in Energy Cost

Increasing the energy efficiency of feed mills

Energy-smart mill makes more feed, cuts carbon output

Tackling energy guzzlers in feed processing

Managing Oxidative Stress From Feed to Food

Feed industry moves a step towards a viable and sustainable energy supply that is also climate-friendly, and environmentally sustainable, and more independent from fossil fuels than ensuring reliable and affordable production of energy. The production of renewable energy is one of the fundamental requirements. As such, different instruments have been implemented like the Renewable Energy Law to fund energy for businesses with high-energy consumption, especially in Germany. The industry, especially the compound feed industry, is one of the biggest consumers of electric energy. In Germany, the overall consumption of the compound feed industry is approx. 1.1 TWh per year. Therefore, energy
Economics of feed drying

-- Energy required to change liquid water into vapour (latent heat of vaporisation) is about 2,350 kJ/kg of water evaporated

-- Typically, dryers will use between 3,000 kJ/kg and 4,500 kJ/kg of water evaporated. A very poorly-operated or poorly-designed dryer might even use much more.

-- Based on a typical value of 3,250 kJ/kg of water evaporated, an extruded feed line producing 75,000 tons per year will typically use about $5 \times 10^{10}$ kJ/year.

Cost will change:
- Natural gas
- Electricity
- Solar power
Economics of feed drying

Drying operation has a significant impact on the bottom line

- You may be sending over 3% of your production out the exhaust stack without even knowing it.

- Downtime for dryer cleaning and maintenance may also be costing you more than you know.

<table>
<thead>
<tr>
<th>Inlet moisture</th>
<th>Outlet moisture</th>
<th>Water removal per ton of product produced</th>
<th>% Increase in water removal</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>24%</td>
<td>10%</td>
<td>184 kg</td>
</tr>
<tr>
<td>2</td>
<td>27%</td>
<td>10%</td>
<td>233 kg</td>
</tr>
<tr>
<td>3</td>
<td>30%</td>
<td>10%</td>
<td>286 kg</td>
</tr>
<tr>
<td>4</td>
<td>30%</td>
<td>7%</td>
<td>329 kg</td>
</tr>
</tbody>
</table>
Economics of feed drying

**Moisture uniformity**
Most extruded feeds are sold by weight. If the product is over-dried, it means sending water at the value of your product.

Suppose that your feed cannot contain over 10% moisture limit.
Product coming out of your dryer has a moisture variation of ± 3% moisture on a wet-weight basis.

This means you must dry your product to 7% moisture on average in order to ensure that no product is over the specified 10% moisture limit.

The result is a 3% loss in production compared to drying the product only to 10% moisture. If dryer could be made to dry more uniformly, you could raise your discharge moisture and get more out of the production line with no additional cost or additional dry ingredients.

Production 75,000 tons per year. A 3% lost in production from this line represents 2,250 tons per year of lost production. At US$400 per ton, it is US$900,000. At US$600 per ton, it is US$1.35 million.

A well-designed, well-adjusted feed dryer should be able to dry feed to within ±0.75% or better. When was the last time you checked the moisture uniformity on your dryer?
Economics of feed drying

Maintenance and sanitation

Many extruded feed producers struggle to keep old, high-maintenance equipment running. The cost of purchasing replacement parts for the dryer may be well documented, but what about the cost of downtime for cleaning and maintaining the equipment?

A dryer producing 10 tons per hour of extruded feed can be producing well over US $100,000 worth of product each day.

If you are spending even three hours a week of unplanned maintenance or cleaning downtime, you have lost 30 tons of final product per week, which equates to US $650,000 per year of lost production. The cost of this downtime must be considered when looking at the economics of your drying operation.

• Please look at your drying operation
• Infact look at energy cost at every step, identify hotspots and put in place interventions
Feed Safety and Quality – Good Practices
Animal feed, animal health and human wellbeing nexus

- Unsafe feed leads to poor animal health and welfare, which impacts adversely human health and wellbeing.

- Quality of animal feed affects the quality of animal-sourced food, which in turn affects human health.

Outbreaks of BSE and diseases due to *Salmonella*, *E. coli O157*, *Listeria* etc. forced feed industry and Governments to develop stringent quality & safety control systems.

*Melamine in feeds from Vietnam*  
--- Thai authorities, Nov 2016

*Mycotoxin prevalence increasing in Asia*  
--- Biomine survey, 2016

*Aflatoxins are of concern in distiller grains*  
--- Makkar (2013)
Health Hazards associated with animal feed

Sources of contamination in animal feed:
- Pesticides
- Natural toxins
- Veterinary drug residues
- Chemical fertilizers
- Dioxins
- Radionuclides
- Radio pollutants
- Mycotoxins
- Heavy metals
- Microbial hazards
- Medicated feed

Animals
- Duration of exposure
- Type & concentration of contaminants
- Colonization
- Bioaccumulation
- Bio magnification
- Bio transfer

Unsafe food consumption

Safe animal feed - Safe food - Safeguard human health
Role of business operators/primary producers

Major responsibility in producing safe feed lies with the manufactures of animal feed including manufactures of feed additives, medicated feed.

The role of primary producers and other allied operators such as suppliers, distributors, storage providers etc are equally important in ensuring feed safety.
Many countries have made

- Good Manufacturing Practices (GMP) and
- Hazard Analysis and Critical Control Point (HACCP)

based feed safety system mandatory for:
- Preparation
- Storage and
- Transportation of animal feed (starting from the primary production)

Good Hygiene Practices (GHP)  
Good Agricultural Practices (GAP)  
Integration
 Implement Good Hygiene Practices (GHP) to avoid the microbial and other contaminations of the product.

 Implement Good Agricultural Practices (GAP) to ensure that the product is not contaminated from environmental contaminants such as heavy metals, pesticides etc.

 GAP include selection of suitable farm lands, selection of good quality seeds and propagation materials, crop rotation and soil management, feed management, pest management, water quality management, waste management, animal health management, harvesting, storage & transportation, input and output management, record keeping etc.

 Conduct regular monitoring of agricultural fields/animal farms to ensure the health and welfare of cultivated plants/ reared animals involved in the production of animal feed. Have an effective animal/ plant health programme in place.
Adopt temperature controls and moisture controls to avoid contamination of products from microbes and also from bio toxins.

Proper pest control system shall be adopted to avoid product contamination. Prevent introduction and spread of contagious diseases and report such disease outbreaks to the Competent Authority at the earliest.

Establish traceability system to trace back the inputs and outputs.

Care shall be taken for the use of pesticides, veterinary drugs and other toxic chemicals to avoid residual contamination. Proper storage and use of chemicals shall done with record keeping.

Primary producers and allied operators shall take necessary registration/permission from the Competent Authority, as applicable, after complying all the legal requirements specified by Competent Authority.
A. LAYOUT AND CONSTRUCTION

B. FEED SAFETY CONTROL SYSTEM

I. HACCP: The principles of Hazard Analysis and Critical Control Point (HACCP) developed by ‘Codex Committee on Food Hygiene’ provide the systematic basis for the identification and control of hazards so as to ensure the safety of feed.

II. Hygiene & Sanitation: Good Hygienic Practices (GHP) at all stages of production, processing, transportation, storage and distribution are one of the most important component of Feed Safety Management System which will help to avoid contamination of the product from environment, food contact surfaces, water, employees and other possible sources.

III. Personal Hygiene: Since employees are the major source of contamination, business operators are to develop proper control measures to ensure employee’s personal hygiene, appropriate movements and behaviour.
Good Manufacturing Practice (GMP): GMPs are practices and procedures adopted to ensure the safety and suitability of feed and food that can be applied throughout the feed/food chain.

- Incoming materials
- End product specification
- Process control
- Incorporation of feed additives and pre-mixtures:
  - Control of carry-over
  - Control of undesirable substances
- Quality Control
- Storage management
- Control on cross contamination
- Waste Management

✓ Traceability and recall procedures
✓ Packing
✓ Labelling
Dealing with non-conforming products:

• Business operator must evaluate the cause of the non-compliance and conduct risk assessment for the procedure proposed to be used for dealing with the affected product.

• The affected batch must be segregated immediately by a responsible person to avoid cross contamination.

• Non-conforming products shall be reworked, downgraded or disposed by the business operator, after obtaining clearance from the Competent Authority.
Dealing with non-conforming products:

- Depending upon the type of contamination/defect, following methods of disposal may be adopted.
  - Burying the product without polluting the environment.
  - Sterilising the product under pressure and then bury in a suitable place.
  - Incinerating or co-incinerating the product with or without sterilising.
  - Making the product into organic fertilisers/soil improvers after processing.
  - Composting or anaerobic digestion after processing/pressure sterilisation.
  - Using the product as fuel for combustion.

- The procedure will be executed under the supervision of the Competent Authority. The Authority may charge a fee for its services.
Labelling of feeds

General Requirements for Labeling

i. Name, address & contact number of the producer/manufacturer of the feed, including approval number, as applicable.

ii. Country of origin (in case of international trade).

iii. Type of feed (e.g.: feed materials, complimentary feed or, complete feed etc).

iv. Lot identification number.

v. Net quantity (in units of mass or volume).

vi. Moisture content of the feed
Special Labeling Requirements for compound feed

a. Information about the species or category of animals for which the feed is intended.
b. Manufacturing and expiry dates.
c. Instructions for the proper use of feed, highlighting the purpose for which the feed is intended for.
d. Analytical constituents of compound feed such as crude protein, crude fat, crude fiber, lysine, calcium etc with percentage of composition shall be labeled.
e. List of Feed materials contained in the feed in descending order by weight.
f. Feed additives having maximum permissible limit and ‘Zootechnical additives, coccidiostats and histomonostats’, etc shall be mentioned in the label.
Implementation of Good Hygiene Practices (GHP), Good Agricultural Practices (GAP), Good Manufacturing Practices (GMP) and HACCP, starting from primary production, is of utmost importance in establishing feed safety.

Feed safety can be established only through the collective efforts of all the stakeholders of the food chain and the governmental agencies.

Both the business operator and Competent Authority shall play a pivotal role in ensuring the high level protection of human health and animal welfare through feed safety.

Competent Authority shall establish regular monitoring, sampling and testing to ensure that the feed safety system is in place and the feed produced is safe for the targeted animal.
Strict norms and control systems for quality & safety

• Proper authorisation of the animal feeds and also the premises of its manufacture shall be given by the Competent Authority, after conducting satisfactory audits.

• Only authorised/certified feeds, feed additives and medicated feeds shall be allowed for national or international trade.

• The establishments meant for manufacturing animal feed, feed additives, medicated feeds shall be approved and monitored by the officials of Competent Authority.

• Well equipped laboratories shall be established by the Competent Authority for testing all the quality and safety parameters of the feed as per the international requirements.
Need for a strong feed regulatory authority

Regulatory authority (quality and safety aspects):

- Test commercial feed ingredients for the industry to establish a baseline
- Conducting risk assessment and guide the feed industry
Where to from here?
Will take time

Why not have

NDDB

NDDB Feed Control Service

Analytical Service

Outreach & Education
What intervention/changes?

“If we do not know what we have or where we are, it becomes impossible to put in place interventions to make improvements”

Stage 1
- Situation analysis
- Base line determination

For example:
- Energy cost determination at each important stage
- Feed or feed ingredient wastage determination at each state
- State and functioning of grinding, conditioning, pelleting, drying stages?
- GMP/GHP/GAP: what these are? Are we following them?
- An analysis of HCCAP

Stage 2
- Identification of interventions to improve the situation (for each of the modules).

Stage 3
- Development of tools and mechanisms to monitor the situation at regular intervals
Change has never happened this fast before, and will never be this slow again
Thanks for your attention