ILRI MANUAL

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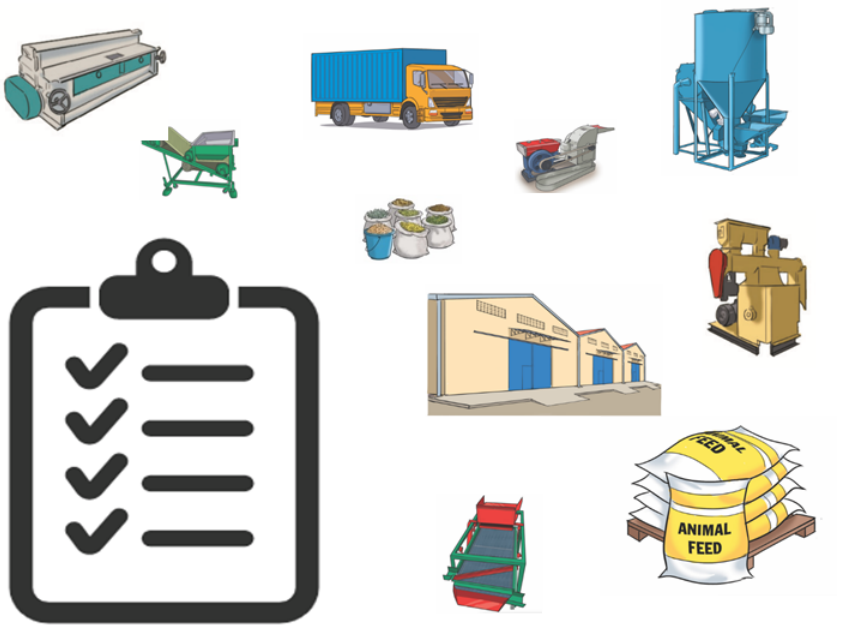

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Good manufacturing practices and quality assurance handbook for small- and medium-sized feed mills in Uganda


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Good manufacturing practices and quality assurance handbook for small- and medium-sized feed mills in Uganda

Joshua Isiko[1], Peter Meijer[1], Pius Lutakome[2] and Ben Lukuyu[2]

[1] Single Spark SMC Ltd, Kampala, Uganda and Single Spark B.V. Netherlands.
[2] International Livestock Research Institute, Kampala, Uganda

March 2022

CGIAR is a global partnership that unites organizations engaged in research for a food-secure future. The CGIAR Research Program on Livestock provides research-based solutions to help smallholder farmers, pastoralists and agro-pastoralists transition to sustainable, resilient livelihoods and to productive enterprises that will help feed future generations. It aims to increase the productivity and profitability of livestock agri-food systems in sustainable ways, making meat, milk and eggs more available and affordable across the developing world. The Program thanks all donors and organizations who globally supported its work through their contributions to the CGIAR Trust Fund.

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Editing, design and layout—ILRI

Cover illustration—Simon Ndonye/ILRI

Manual illustrations— Simon Ndonye/ILRI

ISBN:92–9146–713–8

Citation: Isiko, J., Meijer, P., Lutakome, P. and Lukuyu, B. 2022. *Good manufacturing practices and quality assurance handbook for small- and medium-sized feed mills in Uganda*. ILRI Manual 59 .Kampala, Uganda: ILRI.

Patron: Professor Peter C Doherty AC, FAA, FRS

Animal scientist, Nobel Prize Laureate for Physiology or Medicine–1996

Box 30709, Nairobi 00100 Kenya
Phone +254 20 422 3000
Fax +254 20 422 3001
Email ilri-kenya@cgiar.org

ilri.org
better lives through livestock

ILRI is a CGIAR research centre

Box 5689, Addis Ababa, Ethiopia
Phone +251 11 617 2000
Fax +251 11 667 6923
Email ilri-ethiopia@cgiar.org

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Acknowledgements

The authors would like to thank Simon Ndonye for the illustrations used throughout this handbook.

This handbook was produced by the International Livestock Research Institute (ILRI) as part of the MorePork Project Phase II 'Improving pig productivity, incomes, and pork safety through an environmentally-sustainable and gender-inclusive integrated intervention package'. The project is funded by the CGIAR Research Program on Livestock.

More information: https://www.ilri.org/research/ilri-cgiar-programs/livestock

Key terms

1	Blending	Weighing of raw materials according to the recipe
2	Critical control action(s)	Guidelines to follow to prevent contamination of feeds at any given point, or component in the feed production process
3	Do's and don'ts	List of guidelines on what a feed or ingredient production facility must do and must not do to ensure good-quality and safe animal feeds
4	Extra information	Additional information explaining the do's and don'ts in detail
5	Feed ingredient	Nutrient-containing materials one can mix to produce animal feed
6	Feed producer	A person who deals in animal feeds or feed ingredients/raw materials
7	Good manufacturing practices	Priority activities and considerations a feed or ingredient production facility must do to meet quality thresholds and maintain safety expectations
8	Raw materials	The materials mixed to make animal feed
9	Good quality feeds	These are feeds that contain the minimum nutrient requirements (for a given animal) and are free of any contaminants/hazards

Acronyms

Ca	Calcium
CCP	Critical control point
CF	Crude fibre
CP	Crude protein
DCP	Dicalcium phosphate
EE	Ether extract (crude fat)
EXP	Expiry
FAO	Food and Agriculture Organization of the United Nations
FCR	Feed conversion ratio
FIFO	First-in, first-out
GMP	Good manufacturing practices
HACCP	Hazard Analysis Critical Control Point
IFIF	The International Feed Industry Federation
ILRI	International Livestock Research Institute
Kcal	Kilocalorie
Kg	Kilogram
Lys	Lysine
M+C	Methionine + Cystine
MC	Moisture content
MCP	Monocalcium phosphate
ME	Metabolizable energy

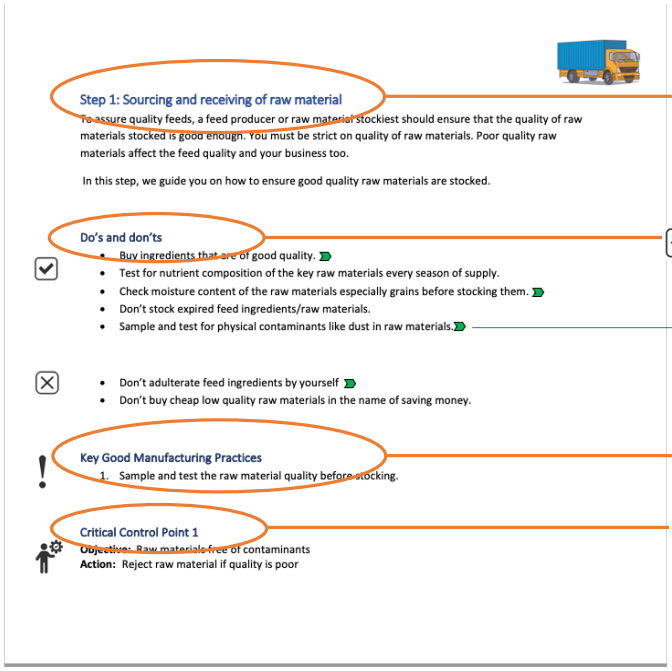
Meth	Methionine
MFG	Manufactured
P	Phosphorus
PPE	Personal protective equipment
RM	Raw material
UNBS	Uganda National Bureau of Standards

How to use this handbook

This handbook aims to assist small- and medium-sized feed mills to improve the quality of their feed production by describing the production process. It gives quality advice for each step in the process. The publication also includes a quality checklist that can be used to assess one's production facility. Based on this checklist, a producer can create a quality improvement plan. This plan includes what needs to be improved, how improvements are going to be made and when the improvements will be completed. A producer can also indicate what they don't want to improve, or what they might improve in the future. The quality improvement plan is a tool that can be used to improve a food facility and is part of the HACCP plan—more about this later.

Good manufacturing practices: Step-by-step

This overview page, illustrates each step in the production process, highlights the main good manufacturing practices, the do's and don'ts, plus the critical control points.



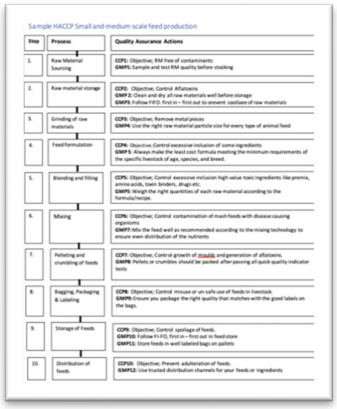
Description of the production step

The do's and don'ts for this step

This green arrow indicates that there is more information about this subject on the following pages

The key good manufacturing practices

The critical control points are guidelines that must be followed to prevent contamination of feeds at given points; they are specific actions that are part of the feed production process.



Sample HACCP Small and medium scale feed production

Step	Process	Quality Assurance Actions
1.	Raw Material Sourcing	**CCP1:** Objective; RM free of contaminants **GMP1:** Sample and test RM quality before stocking
2.	Raw material storage	**CCP2:** Objective; Control Aflatoxins **GMP 2:** Clean and dry all raw materials well before storage **GMP3:** Follow FIFO. first in – first out to prevent spoilage of raw materials
3.	Grinding of raw materials	**CCP3:** Objective; Remove metal pieces **GMP4:** Use the right raw material particle size for every type of animal feed
4.	Feed formulation	**CCP4:** Objective; Control excessive inclusion of some ingredients **GMP 5:** Always make the least cost formula meeting the minimum requirements of the specific livestock of age, species, and breed.
5.	Blending and filling	**CCP5:** Objective; Control excessive inclusion high value toxic ingredients like premix, amino acids, toxin binders, drugs etc **GMP5:** Weigh the right quantities of each raw material according to the formula/recipe.
6.	Mixing	**CCP6:** Objective; Control contamination of mash feeds with disease causing organisms **GMP7:** Mix the feed well as recommended according to the mixing technology to ensure even distribution of the nutrients
7.	Pelleting and crumbling of feeds	**CCP7:** Objective; Control growth of molds and generation of aflatoxins. **GMP8:** Pellets or crumbles should be packed after passing all quick quality indicator tests
8.	Bagging, Packaging & Labeling	**CCP8:** Objective; Control misuse or un-safe use of feeds in livestock. **GMP9:** Ensure you package the right quality that matches with the good labels on the bags.
9.	Storage of Feeds	**CCP9:** Objective; Control spoilage of feeds. **GMP10:** Follow FI-FO, first in – first out in feed store **GMP11:** Store feeds in well labelled bags on pallets
10.	Distribution of feeds	**CCP10:** Objective; Prevent adulteration of feeds. **GMP12:** Use trusted distribution channels for your feeds or ingredients

HACCP plan

This handbook contains an HACCP plan for small- and medium-scale feed production enterprises. HACCP is a plan for hazard analysis, critical control points. This plan ensures that the production facility produces safe feeds that are free from hazards or contaminants.

QUALITY ASSURANCE ACTIONS	FREQUENCY
CLEANING OF EQUIPMENT	Weekly
CHECKING AN AND MAINTENANCE OF EQUIPMENT	Every 2 weeks
FUMIGATING THE STORES	Every 3 months
CLEANING THE WAREHOUSE	Every 3 months
KILLING/BAITE/TRAP RODENTS	Every 3 months
TRAINING STAFF IN GMPS AND CCPS	Every 3 months
CHECKING NUTRIENT COMPOSITION RAW	Every six months
CHECKING NUTRIENT COMPOSITION FEEDS	Every six months
CALIBRATING AND CERTIFYING MEASURING EQUIPMENT	Every year
TRAINING STAFF IN FEED PRODUCTION BASICS	Every two years

Regular checklist

A list of regular checks one can conduct to keep the feed mill clean and free of hazards or contaminants.

Self score tool

A list of quality checks for your own production facility to maintain standards. When checking the standards on this list, you could identify and indicate where you might need to improve further to increase quality standards even more. (Find this at https://www.ilri.org or http://feedcalculator.org)

Improvement plan

Based on your Self Score Tool you can create an improvement plan. Here, you can write down what actions you need to take to improve the quality of your feed mill. (Find this at https://www.ilri.org or http://feedcalculator.org)

Chapter one: Quality in feed production

Introduction

Every farmer needs good-quality feed. When a feed mill or raw material stockist/distributor fails to provide farmers with good-quality feeds, both the feed producer and farmer lose money. In this handbook, we will focus on small- and medium-sized feed mills (0.5–5 ton/day).

Good-quality feed production

Good-quality feed production involves the process of producing/making feed that contains the required nutrients to meet the nutrient requirements of a specific animal. It also involves ensuring that the feed is free of contaminants like bacteria, viruses, toxins, drug residues, dust, stones, metal pieces and any other material which could be directly harmful to the animal or indirectly harmful to humans who eat the animal products.

There are five factors that should be considered in the preparation of good-quality animal feeds:

1. **The process of feed production**: an accurate process will help you ensure quality.
2. **The facility**: good conditions at a well-located facility will help you ensure quality.
3. **Equipment**: good functioning equipment will help you ensure quality.
4. **Staff:** skilled and dedicated staff will help you ensure quality.
5. **Record-keeping**: accurate and comprehensive records will help you ensure quality.

HACCP

What is an HACCP?

HACCP is a management plan that refers to 'hazard analysis, critical control point'. An HACCP plan assists production facilities to produce safe feeds free from hazards or contaminants. The plan identifies where attention is needed to prevent contamination or quality spoilage, plus any other steps required.

The contaminants or hazards are categorized as follows:

Physical hazards/contaminants: These include metals, dust, soil, plant material, paper, plastic material, threads, cloth and any other material that is not feed for animals and is visible to the human eye.

Chemical hazards/contaminants: These include drugs, aflatoxins and other toxins or chemicals.

Biological hazards/contaminants: These include disease-causing organisms such as bacteria, viruses, protozoa and fungi.

How to use an HACCP plan

To use an HACCP, follow these steps:

- Identify critical control points (CCPs) and their objectives.
- Design critical control point actions that could help you achieve the stated objectives.
- Print and display the designed critical control actions for each step in the feed production process.
- Train staff to observe and implement the designed critical control point actions at every labelled CCP in the production process.

Figure 1 presents a sample HACCP for small- or medium-sized feed mills. Each production step has a critical control point (CCP) and a good manufacturing practice (GMP). The CCPs and GMPs are elaborated for each production step in Chapter 2.

Figure 1: Sample HACCP small- and medium-scale feed production.

Step	Process	Quality assurance actions
1.	Raw material (RM) sourcing	**CCP1:** Objective: RM is free of contaminants. **GMP1:** Sample and test RM quality before stocking.
2.	Raw material storage	**CCP2:** Objective: Control aflatoxins. **GMP2:** Clean and dry all raw materials well before storage. **GMP3**: Follow FIFO (first-in, first-out) to prevent spoilage of raw materials.
3.	Grinding of raw materials	**CCP3:** Objective: Remove metal pieces. **GMP4**: Use the right raw material particle size for each type of animal feed.
4.	Feed formulation	**CCP4:** Objective: Control the excessive inclusion of some ingredients. **GMP5**: Always make the least cost formula that at least meets the minimum requirements of the specific livestock (consider age, species and breed).
5.	Blending and filling	**CCP5:** Objective: Control the excessive inclusion of high-value toxic ingredients like premix, amino acids, toxin binders, drugs, etc. **GMP5**: Weigh the correct quantities of each raw material according to the formula/recipe.
6.	Mixing	**CCP6:** Objective: Control contamination of mash feeds with disease-causing organisms. **GMP7:** Mix the feed well as recommended depending on the mixing technology to ensure even distribution of nutrients.
7.	Pelleting and crumbling of feeds	**CCP7:** Objective: Control growth of moulds and generation of aflatoxins. **GMP8**: Pellets or crumbles should be packed after passing all quick quality indicator tests.
8.	Bagging, packaging and labeling	**CCP8**: Objective: Control the misuse or unsafe use of feeds in livestock. **GMP9:** When packaging, ensure the right quality matches the labels on the bags.
9.	Storage of feeds	**CCP9:** Objective: Control spoilage of feeds. **GMP10:** Follow FIFO (first-in, first-out) in the feed store. **GMP11:** Store feeds in well labelled bags on pallets.
10.	Distribution of feeds	**CCP10:** Objective: Prevent adulteration of feeds. **GMP12:** Use trusted distribution channels for your feeds or ingredients.

Regular quality checklist

Figure 2 presents a checklist of quality controls for feed mills, and their frequency.

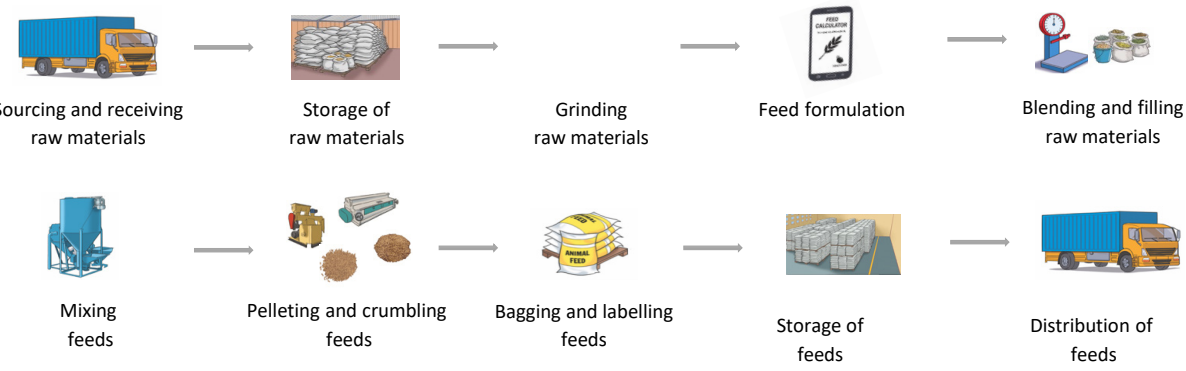
Figure 2: Checklist of quality controls for feed mills.

Quality assurance actions	Frequency
Clean equipment	Weekly
Checking and maintenance of equipment	Every 2 weeks
Fumigate the stores	Every 3 months
Clean the warehouse	Every 3 months
Kill/bate/trap rodents	Every 3 months
Train staff on GMPs and CCPs	Every 3 months
Check nutrient composition of raw materials	Every 6 months
Check nutrient composition of feeds	Every 6 months
Calibrate and certify measuring equipment	Every year
Train staff on feed production basics	Every 2 years

Chapter two: Good manufacturing practices in the feed production process

Good manufacturing practices are key activities and considerations that you need to establish, follow and maintain in feed production to achieve quality standards. In this section, we discuss how you can ensure that you meet quality standards throughout the production process (Figure 3).

Figure 3: The feed production process.



The process of producing good-quality animal feeds includes several steps. These comprise:

1. **Sourcing and receiving raw materials**: This step involves buying the feed ingredients and additives for feed production.
2. **Storage of raw materials**: This step involves keeping feed ingredients and additives clean and dry.
3. **Raw material grinding**: This step involves reducing particle sizes of ingredients for even mixing and feeding.
4. **Feed formulation**: This step involves generating the right recipe to provide the required amounts of nutrients for a given animal.
5. **Blending and filling**: This step involves weighing and heaping or filling the right quantities of all the raw materials in the recipe or formula.
6. **Mixing of feeds**: This step involves turning the different raw materials into one evenly mixed and coloured substance.

7. **Pelleting and crumbling of feeds**: This step involves binding the powders or mash like evenly mixed and coloured substance into a solid form.
8. **Bagging, packaging and labelling of feeds**: This step involves putting the feeds into the right sealed bags with the right labels ready for storage.
9. **Storage of feeds**: This step involves keeping the packaged feeds until they are sold or distributed.
10. **Distribution of feeds**: This step involves getting packaged feeds from the store to a farmer or distribution outlet.

Step 1: Sourcing and receiving raw materials

To ensure quality feeds, a feed producer or raw material stockist/distributor should confirm that the quality of raw materials is good enough. They must be strict on the quality of raw materials. Poor quality raw materials will have a negative effect on the feed quality and your business too.

In this step, we guide you on how to ensure that your stockist/distributor only stocks good-quality raw materials.

Sourcing do's and don'ts

- Buy good-quality ingredients.
- Test for the nutrient composition of the key raw materials every supply season.
- Check the moisture content of the raw materials (especially grains) before stocking them.
- Don't stock expired feed ingredients/raw materials.
- Sample and test raw materials for physical contaminants such as dust.

- Don't adulterate feed ingredients.
- Don't buy cheap low-quality raw materials just to save money.

Key good manufacturing practices

1. Sample and test the quality of the raw material before stocking.

Critical control point 1

Objective: Raw materials are free of contaminants.

Action: Reject raw material if quality is poor.

Sourcing: Extra information

Buy ingredients that are of good quality.

- How can you avoid poor quality raw materials?
  - You can set quality standards for suppliers of the raw materials.
  - You can sample for quality before offloading or paying for the supply.
  - You can sign a contract between the supplier and you mentioning the rejection of poor-quality supplies.
  - If you have enough working capital, buy raw materials at times when they are abundant. Adulteration of

ingredients/raw materials is low during seasons of abundance.

- Commonly adulterated raw materials include:
  - Fish meal or 'mukene' adulterated with sand, stones, etc.
  - Maize bran adulterated with sawdust, husks, cassava, etc.
  - Rice bran adulterated with sawdust, husks, etc.
  - Shells grit adulterated with stones, sand, etc.
  - Limestone adulterated with soil.
  - Brown salt adulterated with red anthill soil.
  - Sunflower adulterated with black soil.

Check moisture content

The moisture content of all raw materials must be no more than 12%. The lower the moisture content during purchase or storage, the longer the storage period. There are several technologies that can be used to estimate moisture content. The oven method is conventionally used but takes longer. New technologies comprise moisture- metre kits from different brands (see Figure 4). Even though most of the kits are calibrated for grains, some of them can be re-calibrated for use on all common ingredients.

To use the moisture metre kits, follow these key steps:

1) Switch on the moisture metre.
2) Start by selecting the raw material you want to measure.
3) Fill the moisture measuring kit with raw materials.
4) Press the 'read' button and wait for the level of moisture to be displayed.

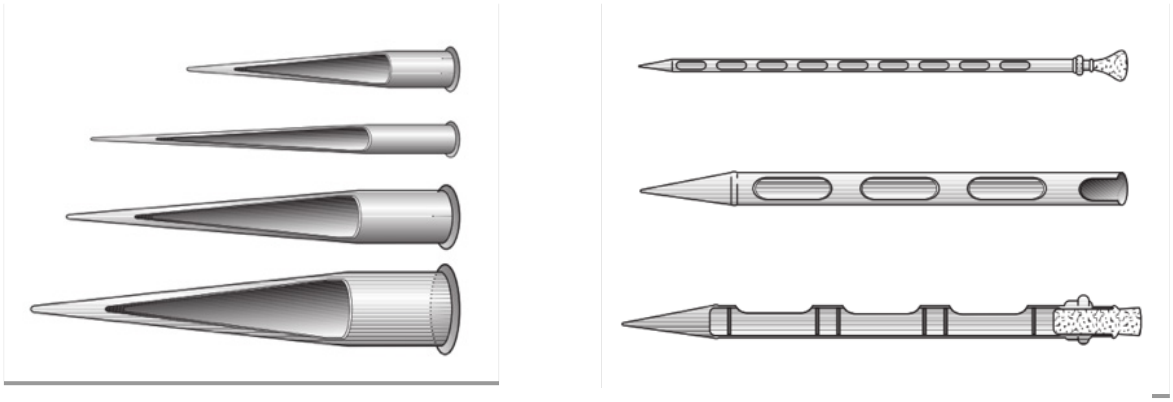
Figure 4: Moisture metre for testing the moisture content of raw materials.

Source: VirtualExpo Group (2021).

Sampling and testing for physical contaminants

Some raw materials – especially grains and fish – contain physical contaminants such as soil, husks, plant material, sand and mould. These contaminants also affect the nutrient composition of the raw materials. You can identify them by sampling bags of the raw materials before offloading for stock. To accurately sample the bags, you need specific equipment like bag triers and slotted grain probes (see Figure 5). These are used to pick some material which you can test using the quick and simple organoleptic methods of smell, touch, see and feel.

Figure 5: Bag triers (left) and slotted grain probes (right) for sampling grains to check for husks, dust or soil.



Source: Herrman (2001).

Organoleptic testing to assess the quality of raw materials

There are several organoleptic methods that can be used to test the quality of raw materials:

Non-dry raw material test: To test for moisture content, put a sample of the raw material in a dry transparent polythene bag, tie tightly and put it out in the sun for about an hour. A non-dry raw material will make the polybag look wet with water droplets on the sides.

Sand adulteration test: To test for sand adulteration in raw materials like fish meal, pour water in a bucket to half full. Then put two handfuls of raw materials in the water, stir for about 1–3 minutes, then feel the bottom of the bucket for any sand or stone particles. If the raw material is adulterated with stones, the bottom of the bucket will feel rough and stony.

Husk adulteration in brans: To test if brans, especially rice and maize, are adulterated with husks, put a sample in your palm and blow it out. Brans with high fibrous husks or material will be blown away.

Step 2: Storage of raw materials

After all efforts have been made to stock good-quality raw materials, they need to be stored. If you store them well, you minimize spoilage. Poor storage of raw materials results in moulding, or rodent and pest infestations which in turn affect the quality of raw materials.

In this step, we guide you on proper storage practices for your raw materials.

Storage do's and don'ts

Do's

- Clean and dry raw materials before storage.
- Store raw materials in bags on pallets.
- Organize your stores by expiry dates, or by using the FIFO principle of first-in, first-out.
- Dispose of expired raw materials.
- Weigh ingredients before storing them.
- Always label the bags before storage; include product name, date and weight.
- Fumigate against pests.
- Control rodents.

Don'ts

- Don't put bags of feed ingredients/raw materials on the ground/floor.
- Don't store raw materials past their expiry date.
- Don't pack raw materials in unlabelled bags.
- Don't pack raw materials in incorrectly labelled bags.

Key good manufacturing practices

1. Clean and dry all raw materials well before storage.
2. Follow FIFO (first-in, first-out) to prevent spoilage of raw materials.

Critical control point 2

Objective: Control aflatoxins.

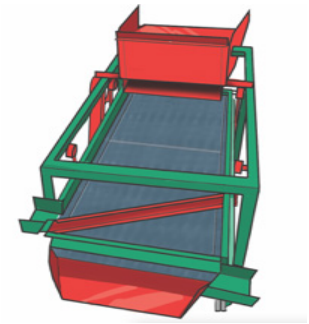
Action: If raw material has mould, reduce inclusion and use toxin binders to detoxify.

Storage: Extra information

Clean and dry raw materials before storage.

Common physical contaminants of raw materials include husks, plant materials, soil, sand in grains, sand and stones in fish. To remove them, manually pick them out when spread or install proper technologies as illustrated in Figure 6.

Figure 6: Sieve stand (left) and winnowing machine (right).

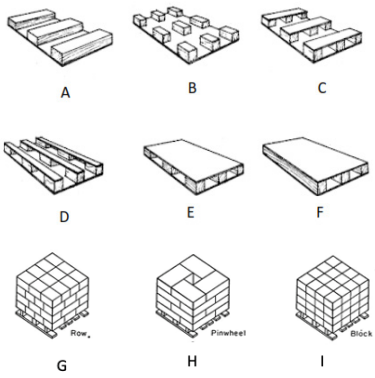


Source: Simon Ndonye (2021).

Store raw materials in bags on pallets

How to stack the feeds on the pallets: follow the designs of pellet used and bulk storage technologies as illustrated in Figure 7.

Figure 7: Stacking of bags on pallets.



There are several pallet designs, as shown in pictures A, B, C, D, E and F.

The choice of pallet depends on the transport technologies you have. The common forked trucks work well for designs C, D, E and F.

Choice of a pallet can also depend on the size of bags. Small bags require designs E and F.

You can stack the bags as demonstrated in pictures G, H and I.

Organize your stores in order of FIFO or expiry date.

Source: Adapted from FAO and IFIF (2020).

- How to implement FIFO
  - FIFO means first-in, first-out.
  - To implement FIFO, the store should be organized in such a way that the raw materials put in first are the ones to be removed first.
  - When using ingredients, start with those you put earlier or those that will expire soonest.

Step 3: Grinding of raw materials

Grinding reduces the particle size of raw materials for easy mixing and feeding. When particle sizes of various raw materials in the formula are greater than 2 mm for over 80% of the material composition, mixing will be uneven. In relation to mash feeds, animals, especially birds, will pick only big particles and leave the fine, highly nutritious particles at the bottom of the feeders. If particles are too small, animals like laying birds may not feed enough due to feeding fatigue.

In this step, we guide you on good grinding practices.

Grinding do's and don'ts

- Grind all large particle raw materials based on the type of feed needed.
- Have different grinder screen sizes ranging from 1mm to 10 mm.
- Grind one particle size for each type of feed.
- Feed production staff must use PPEs.
- All grinder inlets should have a magnet.
- Make the right choice of grinding type.
- Use proper grinding machines.

- Don't grind fines like premix, salt, DCP, MCP, toxin binder, etc.
- Don't use grinder screens with holes.

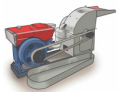
Key good manufacturing practices

1. Use the right raw material particle size for every type of animal feed.

Critical control point 3

Objective: Remove metal pieces.

Action: Use a magnet to remove metal pieces.



Grinding: Extra information

Grind all large particle raw materials according to type of feed needed.

Table 1: Recommended mash feed particle size for different livestock

Livestock	Type of feed	Mash particle size
Commercial layer birds	Layer starter feed	< 1 mm
	Layer grower feed	2–3 mm
	Laver developer feed	3–4 mm
	Layer feed	4–6 mm
Broiler birds	Broiler starter feed	< 1 mm
	Broiler grower feed	2 mm
	Broiler finisher feed	3 mm
Tilapia	Tilapia fry feed	Powder
	Tilapia starter feed	1–2mm
	Tilapia grower feed	3 mm
	Tilapia finisher feed	4 mm
	Tilapia breeder feed	4 mm
Catfish	Catfish fry feed	Powder
	Catfish starter feed	1–3 mm
	Catfish grower feed	4–6 mm
	Catfish finisher feed	7–8 mm
	Catfish breeder feed	7–10 mm
Dual-purpose birds e.g., Kuroiler, Sasso, local chicken	Duo-purpose starter feed	< 1 mm
	Duo-purpose grower feed	2–3 mm
	Duo-purpose finisher feed	4–5 mm
	Duo-purpose layer feed	4–5 mm
Pigs	Pig starter feed	< 2 mm
	Pig grower feed	2–3 mm
	Pig finisher feed	2–3 mm
	Pig standard feed	2–3 mm
	Pig gestation feed	2–3 mm
	Pig lactation feed	2–3 mm
Ruminants	Dairy meal	6–8 mm
	Calf booster	3–6 mm

Sizes of grinding screens

Grinder screens are of different sizes, ranging from 0.8 mm to10 mm (see Figure 8). Choice of sieve size depends on the following:

1) type of feed to be produced

2) form of feed

3) material to be ground

4) type of grinding.

Figure 8: Sizes of grinding screens.

Source: Performance-industries (2021).

Types of grinding

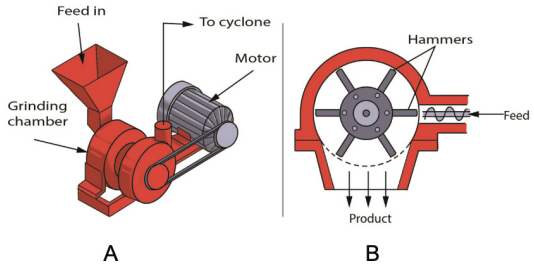
There is single and mixed grinding:

- **Single grinding**: This is when you grind one raw material at a time. For example, you grind maize only. This type of grinding is common in feed mills where farmers buy raw materials for self-mixing.
- **Mixed grinding**: This is when more than one raw material are ground together. For example, you grind fish, cotton seed cake and maize grain together. This type of grinding is only possible if you know the formula and you are going to mix immediately. All that you will need to do is add the fine or already ground raw materials like salt, premix, toxin binder, etc., then mix.

The hammer mill grinding machine

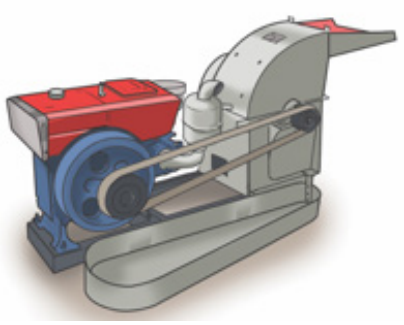
There are many grinding technologies but the commonest one is the hammer mill. Some hammer mills have fans which blow the ground material through the cyclone, while others don't. What is important is that with or without the fan, they all serve the same purpose. Hammer mills without fans are reported to be efficient power consumers and are therefore cheaper to run. These mills are fabricated so that they can run on fuel and are thus, best suited for areas without electricity. The hammer mill technology is illustrated in Figure 9.

Figure 9: Key components of a hammer mill. A: complete hammer mill and motor; B: section showing the hammers and grinding chamber.



Source: (Gachuiri and Lukuyu 2021; Parr 1988).

Figure 10: Diesel-powered hammer mill grinder.



Source: Simon Ndonye (2021).

Step 4: Feed formulation

Feed formulation is a step of feed production where a formula or recipe is generated to produce a given type of feed. If you use the wrong formula, even with good-quality raw materials, you will produce poor quality feeds. A good formula is one that provides minimum nutrient requirements for a given animal at the lowest cost.

In this step, we guide you on good formulation practices.

Feed formulation do's and don'ts

- Follow the minimum nutrient composition for different livestock feeds.
- Use a scientific tool to formulate feeds using the available raw materials.
- Prepare a formula for each feed type.
- Follow directions of inclusion for additives like toxin binder, coccidiostats, enzymes, etc.
- Use balanced feed formulas made by either animal nutritionists or a formulation tool.

- Don't substitute a raw material with another without reformulating.
- Don't assume that related ingredients (like soya bean cake and soya bean full fat) are included in the same way in the formula.
- Don't assume that a formula for another meat animal can work for a different meat animal.

Key good manufacturing practices

1. Always make the least cost formula when providing the minimum requirements of the specific live stock (age, species and breed).

Critical control point 4

Objective: Avoid excessive inclusion of some ingredients.

Action: If at least one of the raw materials in the formula is not available, reformulate to get a new balanced formula.

Feed formulation: Extra information

Livestock of different species and ages need different types of feed because they have different nutritional requirements. Table 2 presents the minimum standards of the nutrient composition per type of feed. The logic of naming the feed types is simple. It's the name of the livestock and their growth stage or purpose. For instance, the feed for pigs when they are piglets is known as 'pig starter feed'.

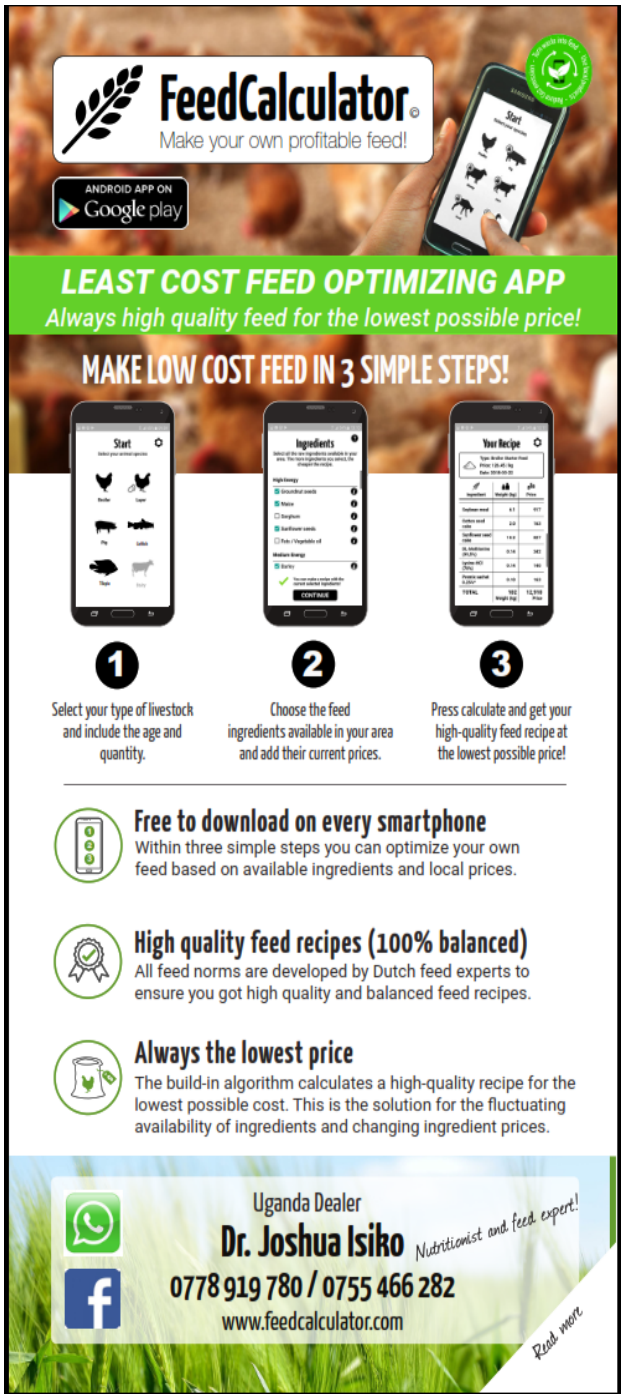
Table 2: Minimum nutrient composition per standard feed types for different livestock species

Livestock	Type of feed	Minimum nutrient composition for standard feeds								
		ME (Kcal/kg)	% CP	% EE	% CF	% Lys	% Meth	% M+C	% Ca	% P
Commercial layer birds	Layer starter feed	3000	20.0	6.0	5.0	1.00	0.45	0.80	1.0	0.70
	Layer grower feed	2800	16.0	6.0	6.0	0.80	0.32	0.70	1.0	0.35
	Laver layer feed	2750	16.5	8.0	8.0	0.70	0.28	0.60	3.7	0.80
Broiler birds	Broiler starter feed	2750	20.0	9.0	5.0	1.20	0.50	0.90	1.0	0.80
	Broiler grower feed	2750	19.5	10.0	5.0	1.00	0.45	0.80	1.0	0.70
	Broiler finisher feed	2750	19.0	10.0	5.0	0.95	0.44	0.76	0.9	0.70
Tilapia	Tilapia fry feed	2500	40.0	10.0	4.0	2.10	0.90	1.40	1.0	0.60
	Tilapia starter feed	2500	35.0	10.0	4.0	2.10	0.90	1.40	1.0	0.60
	Tilapia grower feed	2750	30.0	10.0	6.0	1.70	0.80	1.10	1.0	0.60
	Tilapia finisher feed	2750	25.0	10.0	6.0	1.70	0.80	1.10	1.0	0.60
	Tilapia breeder feed	2750	40.0	10.0	6.0	1.70	0.80	1.10	1.0	0.60
Catfish	Catfish fry feed	3000	50.0	10.0	4.0	2.10	0.90	1.00	1.0	0.60
	Catfish starter feed	3000	45.0	10.0	4.0	2.10	0.90	1.00	1.0	0.60
	Catfish grower feed	3000	35.0	10.0	6.0	1.70	0.80	1.10	1.0	0.60
	Catfish finisher feed	3000	30.0	10.0	6.0	1.70	0.80	1.10	1.0	0.60
	Catfish breeder feed	3000	40.0	10.0	6.0	1.70	0.80	1.10	1.0	0.60
Duo-purpose birds (e.g., Kuroiler, Sasso, local chicken)	Dual-purpose starter feed	2650	19.0	10.0	5.0	1.00	0.45	0.80	1.0	0.70
	Dual-purpose grower feed	2650	18.0	10.0	5.0	0.95	0.44	0.76	0.9	0.70
	Dual-purpose finisher feed	2650	16.0	10.0	8.0	0.95	0.44	0.76	0.9	0.70
Pigs	Pig starter feed	3300	19.0	10.0	2.5	1.40	0.35	0.80	0.9	0.75
	Pig grower feed	3300	18.0	6.0	5.0	0.95	0.27	0.55	0.7	0.60
	Pig finisher feed	3300	17.0	7.0	6.0	0.75	0.18	0.45	0.6	0.50
	Pig standard feed	2900	16.0	7.0	8.0	0.80	0.20	0.45	0.9	0.60
	Pig gestation feed	2800	15.0	7.0	8.0	0.80	0.20	0.45	0.9	0.60
	Pig lactation feed	2900	17.0	7.0	15	0.60	0.20	0.40	0.6	0.55
Ruminants	Basic dairy meal	11800	15.5						0.5	0.4
	Calf booster feed	13500	17.5						0.7	0.5

NOTE: These nutrient compositions may vary based on the regulations and standards of a given country or region. When checking for quality, the objective is to get a nutrient composition for a given type of feed which is either equal to those provided in the table or above (except for CF and EE which must be equal to those provided in the table or below). Sources of data include (Gachuiri C., 2021); (Ptc+, n.d) and Feed Calculator App.

Scientific tool to formulate: The FeedCalculator app

Figure 11: The FeedCalculator app.



Source: FeedCalculator app.

In this section, you will be introduced to the smartphone formulation software: the FeedCalculator app.

The FeedCalculator app is a free-to-download app available on Google Play Store. It enables you to make feed recipes for layers, broilers, pigs, Catfish, and Tilapia. Feed recipes for dairy and dual-purpose chicken are being developed.

It has different nutrient levels of feeds: smallholder, standard and high-quality feed.

In addition to the feed recipes, it gives feed intake tables based on actual numbers of livestock per week or per day. These tables can give buyers of animal feeds good extra information about directions for use.

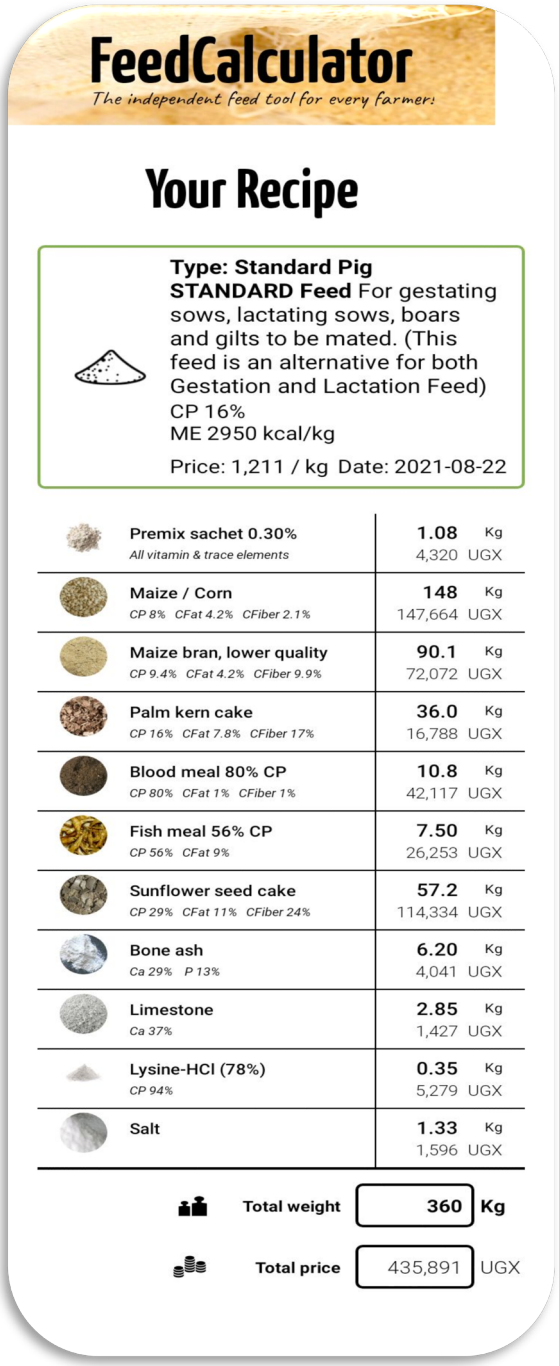
This app is also an educational tool which includes useful information on available feed ingredients, feed types, nutrient requirements, plus spade mixing procedures.

It contains an interactive map which one can use to search for the nearest supplier of feed ingredients, consultancy, drugs, chicks, piglets, fingerlings, etc. This interactive map also allows feed millers to market themselves.

The FeedCalculator app is a growing innovation worldwide and projects aimed at adding modules for dual-purpose and ruminant feeds are currently being implemented.

Watch tutorials at www.feedcalculator.org

The FeedCalculator app can be used to generate recipes as shown in Figure 12.



FeedCalculator

The independent feed tool for every farmer.

Your Recipe

Type: Standard Pig
STANDARD Feed For gestating sows, lactating sows, boars and gilts to be mated. (This feed is an alternative for both Gestation and Lactation Feed)
CP 16%
ME 2950 kcal/kg

Price: 1,211 / kg Date: 2021-08-22

Premix sachet 0.30% *All vitamin & trace elements*	1.08 Kg 4,320 UGX
Maize / Corn *CP 8% CFat 4.2% CFiber 2.1%*	148 Kg 147,664 UGX
Maize bran, lower quality *CP 9.4% CFat 4.2% CFiber 9.9%*	90.1 Kg 72,072 UGX
Palm kern cake *CP 16% CFat 7.8% CFiber 17%*	36.0 Kg 16,788 UGX
Blood meal 80% CP *CP 80% CFat 1% CFiber 1%*	10.8 Kg 42,117 UGX
Fish meal 56% CP *CP 56% CFat 9%*	7.50 Kg 26,253 UGX
Sunflower seed cake *CP 29% CFat 11% CFiber 24%*	57.2 Kg 114,334 UGX
Bone ash *Ca 29% P 13%*	6.20 Kg 4,041 UGX
Limestone *Ca 37%*	2.85 Kg 1,427 UGX
Lysine-HCl (78%) *CP 94%*	0.35 Kg 5,279 UGX
Salt	1.33 Kg 1,596 UGX

Total weight 360 Kg

Total price 435,891 UGX

Source: FeedCalculator app.

This recipe is for a specific type of feed: Standard Pig Standard Feed. It provides guidelines on the list of ingredients/raw materials and the correct quantities you need to mix to make quality feed for gestating sows, lactating sows, boars and gilts. This recipe is 100% balanced and is the least cost option based on the selection of ingredients/raw materials and their prices per kilo.

NOTE: The list and quantities of these ingredients/raw materials may change when you change your selection and prices of ingredients in the app.

This recipe gives you exact proportions based on money (Total price) or amount of feed you need (Total weight). You can enter any amount in the app before saving the recipe.

Step 5: Blending and filling

After generating a balanced least-cost formula, extra care must be taken while using it to make animal feeds. An error made during the weighing of raw materials or filling raw materials on either a heap or in a mixer will lead to poor quality feeds. Therefore, you must ensure accuracy during this step of the feed production process.

In this step, we guide you on good blending and filling practices.

Blending and filling do's and don'ts

- Make sure the weighing scales are calibrated and certified by the authorities, e.g., Uganda National Bureau of Standards (UNBS).
- Use micro weighing scales to measure quantities of less than 2 kg.
- Have a tick board or book for every time you blend and fill. Tick off the raw material weighed and filled.
- Clear the blending area of any other bags that might cause confusion.
- Weigh small quantity raw materials in a bag or bucket to avoid loss.
- In case of spade mixing, mix small quantity raw materials by hand before pouring on the heap.
- Fill small quantities to the mixer or mixing heap last.

- Don't weigh less or more quantities with variations of more than 0.1 kg.
- Don't weigh quantities below the minimum weight of a given weighing scale.
- Don't use large weighing scales to measure small quantities of ingredients less than 2 kg.
- Don't use non-calibrated or non-certified weighing scales.

Key good manufacturing practices

1. Weigh the correct quantities of each raw material according to the formula/recipe.

Critical control point 5

Objective: Control excessive inclusion of high-value toxic ingredients like premix, amino acids, toxin binders, drugs, etc.

Action: If a mistake is made and you add more than the required amount of raw material to the mixer or mixing heap, complete mixing, pick a sample to determine the nutrient composition, then reformulate to correct the error.

Blending and filling: Extra information

How to use weighing scales

- Common errors or mistakes made when using weighing scales:
  - Weighing small quantities using weighing scales designed for large quantities.

- Forgetting to tear off macro-weighing scales before placing bags.
- Weighing heavy quantities on small range weighing scales.
- Assuming that bags must be catered for in weights by adding 0.1 kg.
- Placing weighing scales on uneven ground, floors or surfaces.

- How to prevent errors or mistakes during blending and filling:
  - Tear off or reset weighing scales to start from a zero reading.
  - Clear blending and mixing area of any bags or material on the ground.
  - Make sure the weighing scales are properly stationed on a level surface.
  - Have appropriate technologies such as micro-weighing or macro-weighing scales.
- Examples of macro- and micro-weighing scales:

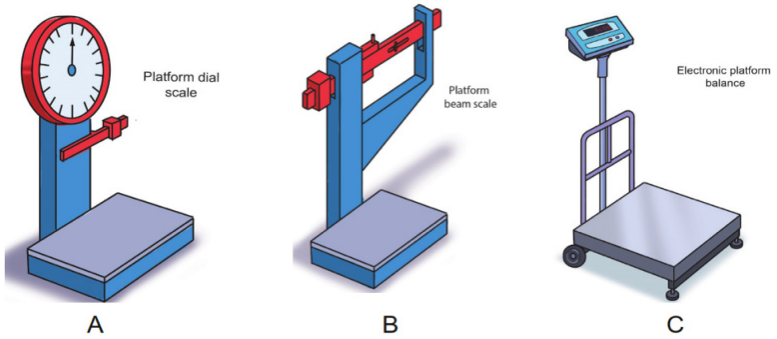
There are many models and brands of micro- and macro-weighing scales. Some of these include the electronic digital, the spring dial pointed, and the beam balance pointed. The easiest to use is the electronic digital one because they weigh in grams. See Figures 13 and 14 for illustrations of the micro-weighing scale and macro-weighing scales, respectively.

This kind of micro-weighing scale (Figure 13) requires a small bucket where one can put raw materials. To use it correctly, first put the empty small bucket on the platform of the scale and tear off or re-set the reading to zero. After that, pour the material you want to weigh into the bucket.

Figure 13: Micro-weighing scale.

Source: AliExpress (2021)

Figure 14: Macro-weighing scale.



All the three models in Figure 14, A, B, C can be used to weigh large quantities.

Model C is the best for accuracy in feed production because it is easy to read the weight from the digital screen.

Source: (Gachuiri and Lukuyu 2021; Parr 1988)

How to use a tick book/board/receipt

- Common errors or mistakes made when tick book/board/receipt is not used:
  - Forgetting small quantity raw materials like premix, toxin binders, coccidiostats.
  - Leaving out an ingredient.
  - Filling wrong ingredients in the mixer or mixing heap.
  - Using improperly stationed weighing scales.
- How to prevent errors or mistakes during blending and filling:
  - Use a blending tick board each time you are blending.
  - Even if you are using receipts, tick every raw material on the receipt.

In the example in Figure 15, the ingredients that have been weighed and poured on the mixing heap or in the mixer are ticked. In this case, even if one is interrupted, they are able to tell which ingredients have not yet been added to the mixer. This is a good practice that should be used during blending.

Figure 15: Example of blending good practice.

TICK BOOK/BOARD/RECEIPT

Date: 1/8/2021 **Client:** Matsiko

Ingredient	*Quantity*	
Premix	0.25 kg	
Maize	41 kg	√
Maize bran	25 kg	√
Palm Kernel ca	10 kg	
Blood meal	3 kg	
Fish meal	2 kg	
Sunflower seed	15.8 kg	√
Bone ash	2 kg	
Limestone	0.5 kg	
Lysine	0.1 kg	
Salt	0.4 kg	
Total	100 kg	

Source: FeedCalculator App

Step 6: Mixing of feeds

As guided in the previous step, the feed ingredients or raw materials must be mixed to get an even nutrient and colour substance. The result is called mash feed. This step is critical because in case of any undermixing, the quality of feed will be poor. With meat animals, uneven mixing will cause uneven growth sizes in flocks or herds of the same age. In egg production, uneven mixing will cause egg drops and variations in the number of eggs per laying nest unit. Therefore, a feed producer must ensure that thorough mixing of feeds is done.

In this step, we guide you on good mixing practices for good-quality feed production.

Mixing do's and don'ts

- Use proper mixing equipment.
- Clean the mixer or mixing area to remove any material and dirt before using it to prepare a new type of feed.
- Mix for the recommended time or times according to the method you choose:
  - In case of vertical mixer, mix for minimum of 15 minutes after filling the last ingredient.
  - In case of horizontal mixer, mix for minimum of 5 minutes after filling the last ingredient.
  - In case of spade mixing, move feed from one place to another at least 7 times.
- In case of spade mixing, pre-mix small quantities in a bag or container before pouring on top of the heap.
- Mix not less than the minimum batch size/weight for a given mixer.
- In case of spade mixing, do not step on the feed with dirty shoes. Use special clean shoes or bare feet.
- Always weigh the mixed feed after packaging to make sure quantity matches with batch size.

- Don't fill small quantity raw materials first in mixers or heaps.
- Don't mix raw material particles that are large together with those that are too small.
- Don't use eyes to judge whether it has mixed well.

Key good manufacturing practices

1. Mix the feed well as recommended depending on the mixing technology to ensure an even distribution of the nutrients.

Critical control point 6

Objective: Avoid contamination of mash feeds with disease-causing organisms.

Action: Install a mixer to reduce contamination from the floor.

Use special clean shoes for spade mixing.

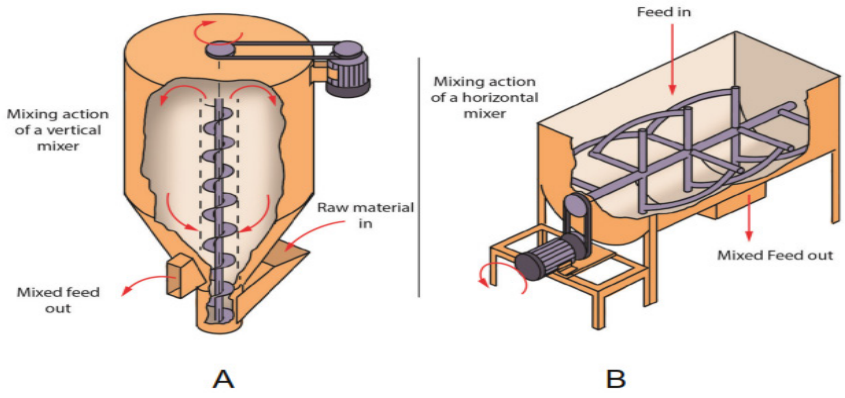
Restrict access to the mixing area for animals and non-staff.

Extra information

Types of mixing equipment

There are many technologies for mixing. These are categorized into vertical mixing equipment, horizontal mixing equipment and circular mixing equipment. The vertical and horizontal mixing equipment (Figure 16) are the most common in developing countries.

Figure 16: A= Vertical mixer, B= Horizontal mixer.

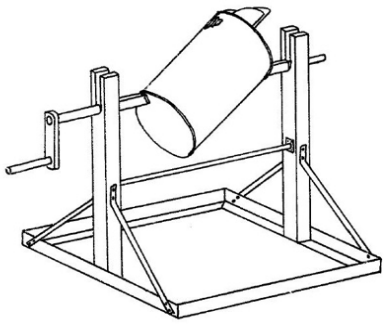


Adapted from Parr (1988) and modified by Simon Ndonye (2021).

- To use the mixer properly, keep it running even while emptying.
- It is safe to turn on the mixer when it is empty.
- In case power goes off, keep the batch of feed in the mixer until power returns.
- Once power is back, start timing from zero.

The hand mixer in Figure 17 is used to mix small quantities of feed. It works best for quantities below a batch size of 100 kg, and is recommended for use in farm feed mixing.

Figure 17: Hand Mixer..



Source: BackYard Chickens

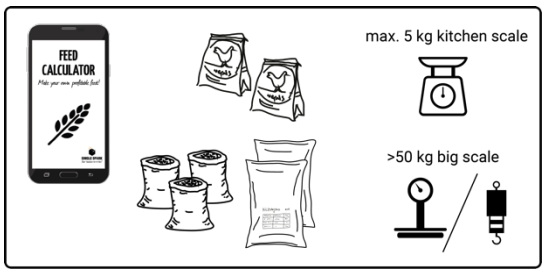
Steps for proper spade mixing

Though spade mixing seems simple, many people do not use the spade well. Figure 18 illustrates the key steps to follow when mixing feeds well using the spade.

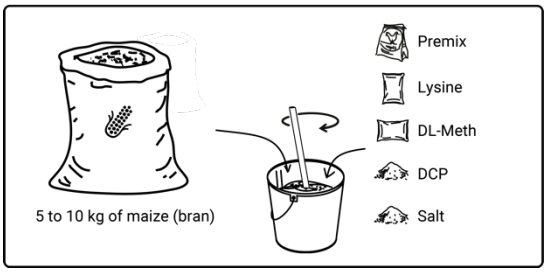
Figure 18: How to mix feed.

HOW TO MIX FEED

Instruction sheet how to mix your separate ingredients into a quality feed mix.

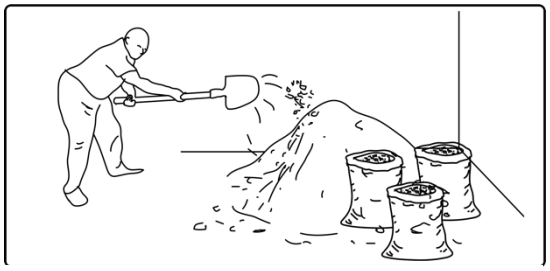


1) Take your recipe from the FeedCalculator app.
Collect all the ingredients. Take all the needed tools: 1 kitchen scale (max 5 kg), 1 large scale (spring balance) that can measure 50 kg, bucket, shovel, clean floor or thick plastic sheet.

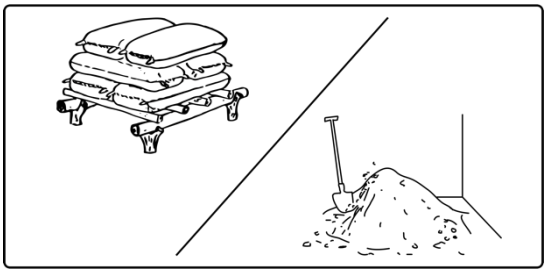


2) Mix all the ‘‘small amount ingredients’ (according to your recipe) with 5 to 10kg maize (bran) thoroughly in a bucket or on the floor. You can use your hands or a small shovel. Note: Make sure the maize (bran) is completely dry (no moisture) so the ingredients do not clump together. Ensure precision when weighing the small ingredients

3) Add the mixture with the ‘small amount ingredients’ on top of a larger amount of maize(bran) like 50kg or 100kg. Use a shovel to mix it thoroughly. Take your time to do this till you have a uniform mixture.



4) Now you can add all the other large amount ingredients (according to your recipe) on the floor and mix everything thoroughly with a shovel till a uniform mix is achieved. Take your time to do this properly. Now your feed is ready to use!



5) You can store the feed in 50kg bags in a dry place, lifted from the floor. Or you can keep it on a pile. Make sure you stir the whole pile every day to maintain the quality of the feed.

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Step 7: Pelleting and crumbling of feeds

Many producers in developing countries produce mash feeds. However, the performance of mash feeds is lower compared to pellets and crumbles. As feed producers upgrade to pellets and crumbles, quality must be assured. Even though a pellet has good physical properties, the nutrient quality remains most crucial for the farmer. There are two types of pellets: sinking and floating pellets.

To make crumbles, feed producers must first make mash, form this into pellets and then crush it into crumbles. Therefore, good-quality mash will lead to good-quality pellets, resulting in good-quality crumble. Key aspects of physical pellet and crumble quality include: 1) Very hard pellets lower digestibility of feed; 2) Very rough pellets cause injuries to animals; 3) In case of fish feed, poorly floating pellets increase the feed conversion ratio (FCR) of fish feed; 4) Pellets with moisture content above 10% have a short shelf life.

In this step, you will be guided on good pelleting and crumbling practices for good-quality feed production.

Pelleting and crumbling do's and don'ts

- Grind raw materials for pelleting into very fine particles, less than 0.8 mm in size.
- When using a binder, make sure it is part of the formula.
- When using coaters or mixed flavours, they must be part of the formula.
- Use the right pelleting equipment.
- Dry and cool pellets well.
- Test for moisture content before packaging and sealing pellets in bags.
- Test for pellet physical qualities before packaging and sealing the bags.
- In the case of floating pellets, ensure that they float 100% for at least one minute.
- Pellets for crumbles must be of good quality.
- Use a rolling machine to crumble feeds.

- Don't package pellets with moisture content above 11%.
- Don't package pellets when hotter than 40°C.
- Don't use a hammer technology grinder to crumble feeds.

Key good manufacturing practices

1. Pellets or crumbles should be packed after passing all quick quality indicator tests.

Critical control point 7

Objective: Control growth of moulds and generation of aflatoxins.

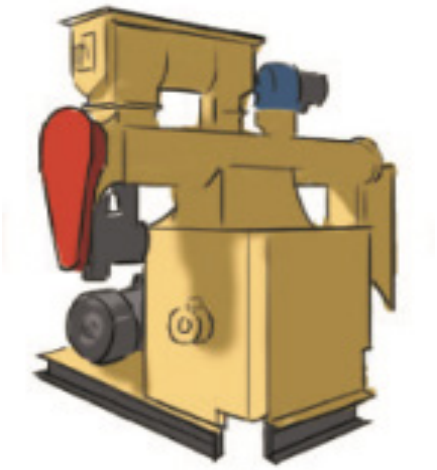
Action: If pellets are hotter than 40°C, allow them to cool before weighing and sealing. If pellets are not dry to moisture content below 11%, re-dry them.

Pelleting and crumbling: Extra information

Pelleting equipment design

The pelleting machines are designed based on the type of pellets to be produced. The machine used to produce sinking pellets is known as a press line. The press line is based on the principle of pressing the mash feed through the die. The machine used in production of floating pellets is called an extruder, which is based on the principle of heating to melt and expansion through the die. A producer must choose the right pelleting equipment based on the type of pellets they need to produce. All animals (except fish) just need sinking pellets. A producer only needs an extruder if one would like to produce floating fish feeds. A simple small-scale pelleting machine for sinking pellets is illustrated in Figure 19.

Figure 19: Non-portable pelletizing machine.



Source: Simon Ndonye, 2021.

Portable pelleting machines (see Figure 20) powered by hydroelectricity or generators are also available.

It is important to understand that not every formula can produce good pellets. If you install a pellet line or machine, contact a formulation expert to guide you on the right feed ingredients to use for better pellet quality.

Good quality pellets should have the following properties:

- Easily absorbs moisture content
- Easily disintegrate with moisture
- Smooth
- Must not have cracks

Figure 20: Portable pelleting machine for sinking pellets.

Source: Proveg (2021).

Pellet particle sizes for different feed types

Pellets have several advantages:

1. The pelleting process binds the nutrients in the feed, thus enabling animals to take in balanced quality portions of feed.
2. Potential disease-causing organisms are killed during pelleting and therefore this is safer.
3. Pellets improve production, especially if the best particle size is used to feed animals.

Crumbling is important for very young animals which need very small particle sizes. Therefore, big pellets are made and crumbled into smaller particles. Figure 21 illustrates the major differences between pellets, crumbles and mash feeds – their level of fineness. Mash feeds are very fine followed by crumbles, then pellets.

Figure 21: Mash verses crumbles and pellets.

Source: Feed-pelletmachines.com (2021).

Determining pellet particle sizes

This simple particle testing kit in Figure 22 can help a producer to determine the average particle size of the feed. To use it, fill the top chamber A to level 100 as labelled on the kit. Close it with a slide on top. Shake it with chamber A on top until no more particles are going through any screen. To determine the average particle size, turn the kit with side B on the bottom and C on the top. Check for the chamber with the highest level to give indicator of average particle size. For average particle size intended, the chamber should show at least level 80.

Figure 22: The particle size grading kit.

Source: Leentfaar (2021).

The recommended pellet sizes for each feed type and livestock are presented in Table 3.

Table 3: Recommended pellet sizes for different livestock feeds

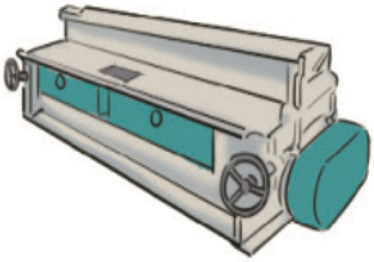
Livestock	Type of feed	Pellet size
Commercial layer birds	Layer starter feed	≥2 mm
	Layer grower feed	3–4 mm
	Laver developer feed	4–5 mm
	Layer feed	5–8 mm
Broiler birds	Broiler starter feed	≥1 mm
	Broiler grower feed	2 mm
	Broiler finisher feed	3 mm
Tilapia	Tilapia fry feed	
	Tilapia starter feed	1–2 mm
	Tilapia grower feed	3 mm
	Tilapia finisher feed	4– 6 mm
	Tilapia breeder feed	4–6 mm
Catfish	Catfish fry feed	
	Catfish starter feed	1–3 mm
	Catfish grower feed	4–6 mm
	Catfish finisher feed	7– 8 mm
	Catfish breeder feed	7–10 mm

Table 3: Recommended pellet sizes for different livestock feeds

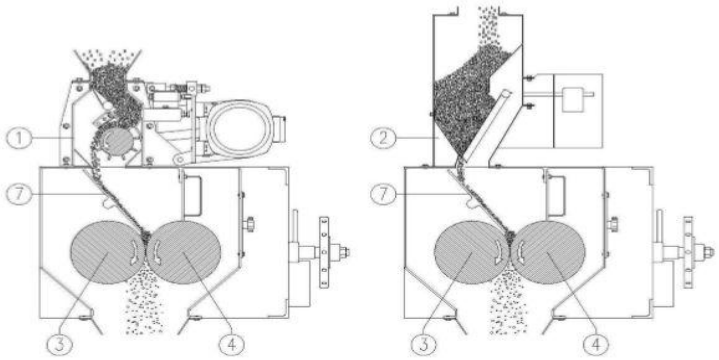
Livestock	Type of feed	Pellet size
Dual-purpose birds, Kuroiler, Sasso, local chicken	Duo-purpose starter feed	1 mm
	Duo-purpose grower feed	2 – 3 mm
	Duo-purpose finisher feed	4–6 mm
	Duo-purpose layer feed	4–6 mm
Pigs	Pig starter feed	2 mm
	Pig grower feed	3 mm
	Pig finisher feed	3 mm
	Pig standard feed	3–4 mm
	Pig gestation feed	3–4 mm
	Pig lactation feed	3–4 mm
Ruminants	Dairy meal	8–10 mm
	Calf booster	6–8 mm

The roller crumbler

Crumbling is a process of breaking big pellets into smaller multi-shaped particles. This process needs equipment that uses appropriate force to crush the pellets into small pieces. A roller crumbler is appropriate for this process. The principle and designs of the roller crumbler are illustrated in Figure 23. The size of the crumbles is determined by the space between the two rollers 3 and 4.



Source: Simon Ndonye (2021)



Source: Le Meccanic (2021)

Step 8: Bagging, packaging and labelling of feeds

After making the mash, pellet or crumble feeds, they must be packaged well for storage or distribution. This step in the feed production process is also critical in ensuring the quality of feeds. Errors in packaging can result in wrong and unsafe use of feeds. For instance, imagine producing finisher broiler mash feeds but mistakenly using packaging for broiler grower mash feed bags. This automatically makes the feed poor quality. Remember, the labels on the bags or packaging material are a description of the unseen quality characteristics of the feed in the bag as well as user directions. In addition, if the feed is poorly packaged, it could develop moulds. Therefore, extra care should be taken to package and label feeds correctly.

In this step, we guide you on good packaging and labelling practices for good-quality feed production.

Bagging, packaging and labelling do's and don'ts

- Ensure that all packaging materials are well labelled before putting in bags.
- Only use bag weights and feeds that match the labels on the packaging material.
- Test for particle size, moisture content and other quick quality indicators before sealing the bags.
- Seal the bags well using a good sealing technology.

- Don't leave feed unsealed for a long time; it will lose its attractive smell.
- Don't bag in non-labelled packaging material.
- Don't bag in packaging material for different feed types.
- Don't bag in packaging material with unmatching quantity labels.

Key good manufacturing practices

1. Ensure that you package the right quality that matches the labels on the bags.

Critical control point 8

Objective: Control the misuse or unsafe use of feeds in livestock.

Action: Label feeds well by declaring all required information about quality, composition and directions for use.

Packaging: Extra information

Proper labelling of feeds

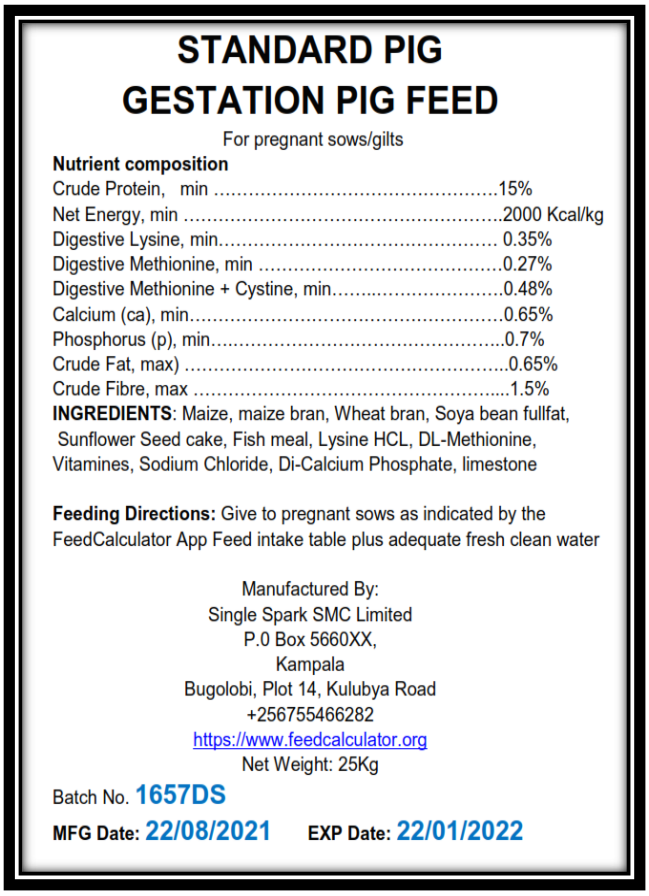
- Common errors or mistakes made during bagging, packaging and labelling feed:
  - Bagging feeds in mismatched packaging materials.
  - Forgetting to write the manufacturing date and expiry date.
  - Forgetting to add the batch numbers.

- Proper labelling must include: 1) type of feed, 2) the animals to be fed, 3) nutrient composition, 4) raw materials used, 5) directions of feeding, 6) batch number, 7) date of manufacture, 8) expiry date and manufacturing details. A sample of proper labelling of feeds is illustrated in Figure 24.

This sample label can be modified depending on your feed brand. All information should be included on the label. Labels can be made on a sticker or printed directly on a bag. The numbers in blue in the sample label can be written with either a permanent mark or a stamp.

It is important to make sure that the labelling information meets the regulations for your targeted market.

Figure 24: Sample feed label.



Step 9: Storage of feeds

After packaging the feed, it must be well stored to prevent spoilage or to keep it from expiring. Spoilage at this step is difficult to detect in non-transparent packages. Therefore, extra care must be taken to remember all good packaging and storage practices.

In this step, we guide you on good feed storage practices for good-quality feed production.

Storage do's and don'ts

- Store in bags
- Store bags on pallets.
- Follow the FIFO principle (first-in, first-out). Distribute or sell the first feeds in the store first.
- Organize your stores in order of expiry date.
- Dispose of expired feeds.
- Only store feeds in bags with proper labels.
- Weigh feeds before sealing for storage.
- Store raw materials and packaged feeds in different areas of the facility.
- Fumigate against pests.
- Control rodents.
- Keep records of feeds in and feeds out.

- Don't store feeds in a bag that has labelling for a different feed.
- Don't store feeds in unlabelled bags.
- Don't heap feeds in the open.

Key good manufacturing practices

1. Follow FIFO (first-in, first-out) in feed stores.
2. Store feeds in well labelled bags on pallets.

Critical control point 9

Objective: Control spoilage of feeds.

Action: If feed expires or gets spoilt in store, dispose of it.

Storage: Extra information

The first-in, first-out (FIFO) principle

FIFO is a key storage strategy where feeds that were put in store or produced first are the first ones to be sold or distributed. To implement FIFO well, all feed packaging and stacks must be labelled with manufacturing dates. Feeds should be well organized so that it is easy to remove the ones that were stored first. Feeds must be stored in stacks of bags on pallets with at least one metre between the pallet rows. Figure 25 illustrates how to organize your store for easy implementation of the FIFO strategy.

Figure 25: A well-organized store.

Source: Simon Ndonye, 2021.

Shelf life/expiry dates of feeds

Shelf life/expiry dates of feeds vary depending on the moisture content, form of feed, equipment used, quality of packaging material, and sometimes feed ingredients used. For feeds to have a longer shelf life, the following should be ensured:

- Package and store feed with moisture content below 11%.
- Package feeds in bags that are waterproof to prevent oxidation.
- Use antioxidants as additives in your feeds.
- Control pests and rodents.
- Keep feed store dry and at room temperature.

The following durations are recommended as shelf-life periods for different feed forms and packaging conditions:

- Mash feeds packaged in non-waterproof bags expire within 3 months (90 days) after the manufacturing date.
- Well-dried pellet feeds and crumbles packaged in non-waterproof bags expire within 4 months (120 days) after the manufacturing date.
- Well-dried mash or crumble or pellet feeds packaged in waterproof bags expire within 6 months (180 days) after the date of manufacture.

Step 10: Distribution of feeds or raw materials

Distribution of feeds depends on the business model of the feed production facility. One may sell directly to farmers, retailers or both. Distribution channels must be well planned and monitored to ensure quality. There are many ways in which the value of feeds can be reduced during distribution. These include adulteration by unauthentic retailers, damages during transportation, and spoilage during storage in retailers' outlets. Therefore, a strategy to ensure quality during distribution should be put in place.

In this step, we guide you through the good distribution practices for good-quality feed production.

Distribution do's and don'ts

- Distribute only well labelled and packaged feeds or raw materials.
- Include a unique quality feature on packaging to differentiate your feeds from fake products.
- Use trusted distribution methods.
- Retool key distribution channel actors on assured quality distribution.
- Follow up on the performance of your feeds.
- Recall and investigate fake or poor quality feeds.

- Don't distribute unlabelled feeds or raw materials.
- Don't deny responsibility for fake feeds that carry your brand labels.

Key good manufacturing practices

1. Use trusted distribution channels for your feeds or ingredients.

Critical control point 10

Objective: Prevent adulteration of feeds.

Action: In case of any poor performance due to quality, recall the feeds or feed ingredients and investigate the cause.

Distribution: Extra information

How to recall feeds and feed-related products

Recalling a product means asking your clients to return that product to the factory, feed mill or store. It is important to realize that at that time, some of the products might already have been used. To initiate a recall, follow these steps:

- Understand the complaint made by the users.
- Get details of the batch number ranges associated with the complaint.

- Draft a recall advert including the following information:
  - An apology statement
  - Name of product (feed type and brand description)
  - Associated batch numbers
  - Place of delivery by users
  - Duration of receiving the returned feed
  - Contact information of receiver or inquiries.
- After receiving the feeds or any product, you must investigate the cause of the quality complaints. To investigate the error or mistake, follow these steps:
  - Stop selling or distributing batches of feeds associated with the complaint.
  - Sample returned feeds and test for whole nutrient composition and specific suspected toxins related to the complaint.
  - Sample feed still in store and test for whole nutrient composition and specific suspected toxins related to the complaint.
  - If nutrient composition and other tests are related to the complaint, then investigate the production process, facility, records, persons, equipment for the possible source of the quality error.
  - If the cause is identified as correctable, recycle all feeds with associated batch numbers.
  - If the cause is identified as non-correctable, dispose of all associated batch numbers of feeds returned and that are still in the store.
  - If nutrient composition and other tests are not related to the complaint, investigate further for other causes at the users' facilities.
  - Publish a report of your investigation and actions.

Chapter three: Good manufacturing practices for the feed mill facility

The whole feed production process steps are carried out within a facility. That facility may be a temporary or permanent warehouse located in any given area. The location and design of the facility are very important in quality assurance. The facility must protect the raw materials, equipment and people from contamination and harm.

Here, we guide you through good facility practices.

The facility do's and don'ts

- Locate the feed mill in a place far from livestock farms.
- Locate the feed mill in a non-waterlogged area.
- Establish a toilet, changing and showering section at the entrance of the facility.
- Floors of the facility must be made of rough concrete.
- Ensure there is a stable, clean water supply.
- Protect lights from direct breakage which could result in contamination of feed with broken pieces.
- Build a good facility with all the sections for quality feed production.
- Use rodent-proof designs for your housing or facility.

- Don't paint the walls of the facility with lead-based paint.
- Don't establish your feed mill facility in a wetland.

Key good manufacturing practices

1. The feed mill facility should be as safe as possible to prevent contamination.

Feed mill facility: Extra information

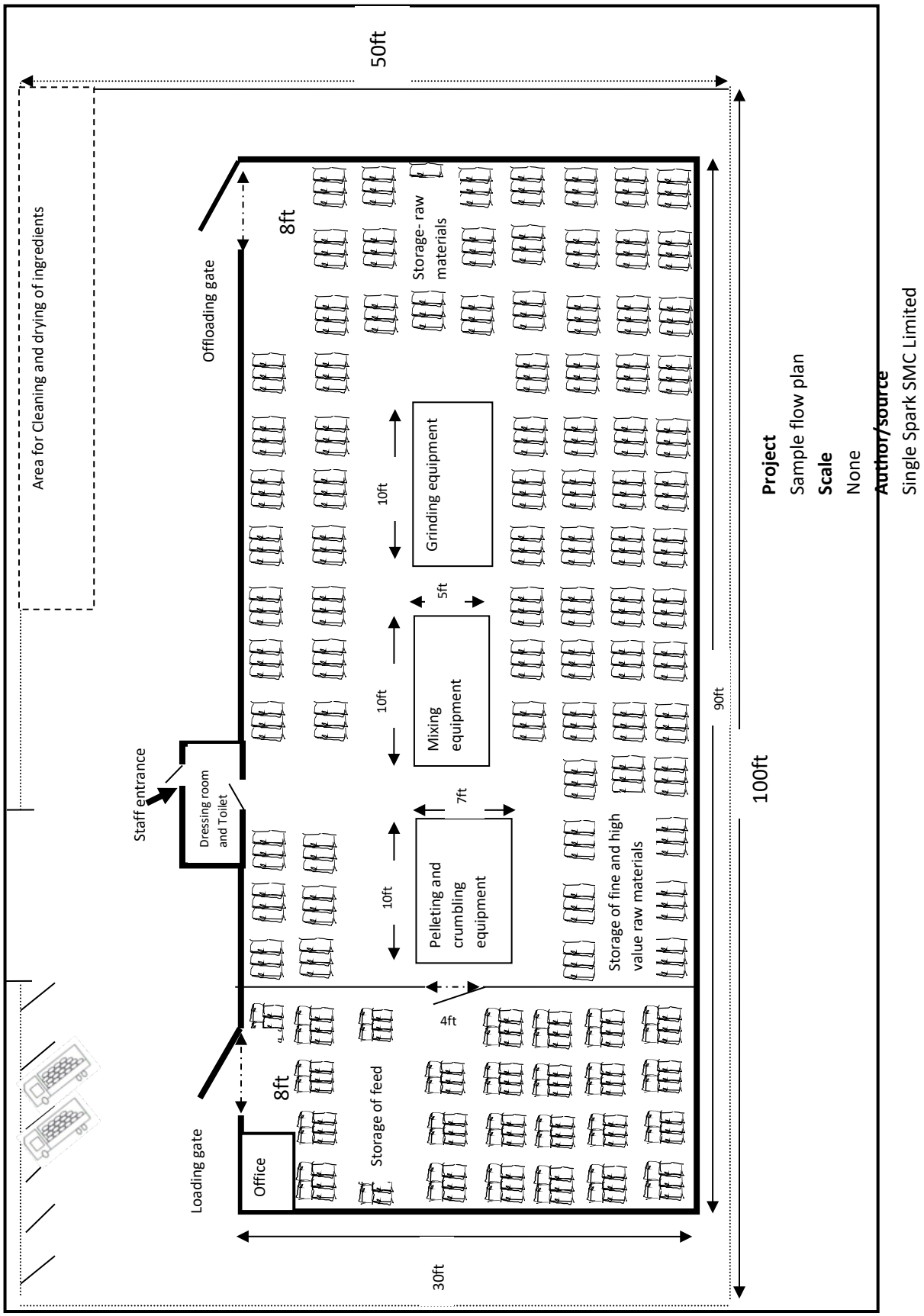
Sections of a good feed production facility

The key sections of a good feed production facility include the following:

- **Washrooms/changing room**: This is where staff clean or shower and change clothes/use PPEs required for safe feed production.
- **Office:** This is where the management team of the feed mill or processing facility sits to receive clients. Non-staff must not go beyond the office to prevent contamination
- **Raw material offloading and cleaning area**: This is where the trucks park and raw materials are sampled for quality, cleaned, properly packaged and labelled for storage.
- **Raw material store**: This is where all raw materials are kept. It must be large enough to hold raw materials for at least two weeks of production.
- **Processing equipment section**: This is where the grinders, mixers and other equipment are installed. It must be spacious enough.
- **Feed bagging and packaging section**: To avoid errors during bagging, a designated place is needed where feed is well sampled for quality, weighed to the right quantities, labelled and sealed for storage or distribution. This section is always at the end of the processing equipment line, just after the mixer if one is producing mash feeds, or in a drier and cooler section if one is producing pellets or crumble.
- **Feed store**: This is a different storage space for finished products. Don't mix raw materials with feeds in the same store. Mistakes could occur; staff might distribute ingredients instead of feed or use feed as an ingredient.
- **Feed loading are**a: A good feed production facility should have a separate loading area. It is important for a facility to have two gates: loading and offloading gates.

The sections must be well planned with the feed mill having a well-thought-out floor plan. A sample floor plan of a small- or medium-scale feed mill is illustrated in Figure 26.

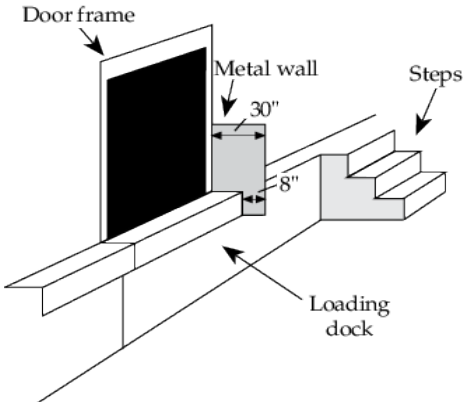
Figure 26: Sample floor plan of a small feed production facility.



Illustrations of rodent-proof construction and installations

Rodents can enter the warehouse through doors or gates. It is important to prevent entry of rodents right from the gate or door. See Figure 27 for tips on how to build a rodent-proof door.

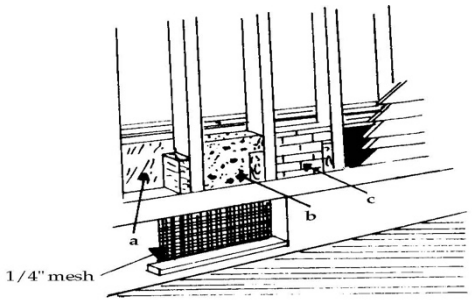
Figure 27: Rodent-proof feed mill facility gate construction.



Source: Wildlife Damage Management (2021).

Rodents can also make and access the warehouse through holes in the walls. Your construction should therefore prevent rodents from digging holes to enter the warehouse. See Figure 28 on how to build a rodent-proof warehouse. Use: a) iron sheet in between the wood, b) concrete stones c) brick stones d) mesh wire ¼' for the wall.

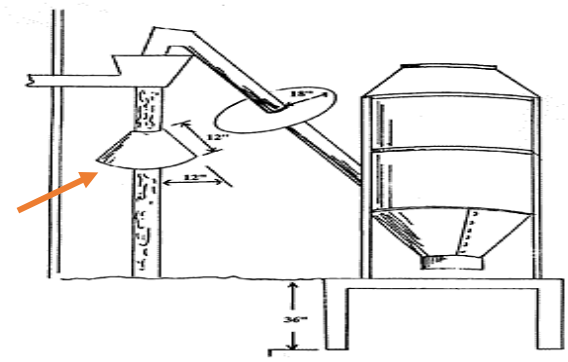
Figure 28: Illustration of rodent proofing.



Source: Wildlife Damage Management (2021).

In case the rodents managed to enter the warehouse, you can prevent them from entering equipment by fixing guards as illustrated in Figure 29.

Figure 29: Guards used to prevent rodents from climbing equipment.



Source: Wildlife Damage Management (2021)

Chapter four: Good manufacturing practices for feed mill staff

The third component for assurance of quality feed production is the people or staff who work in the feed production facility. Even in cases where the production process and facility meet all the quality standards, if staff do not adhere to good manufacturing practices, feed quality will be compromised. People may be the source of contamination or errors, and these lead to poor quality feeds. Therefore, people must be equipped to adhere to good manufacturing practices.

Below, we guide you through good personnel practices for good-quality feed production.

Personnel do's and don'ts

- Ensure all staff follow the guidelines of the GMPs and the critical control actions.
- Ensure all staff wear protective gear/clothes (PPEs).
- Ensure all staff are well skilled in production of animal feeds and identification of feed ingredients.
- Non-staff should be restricted from accessing production areas unless wearing protective gear/clothes (PPEs).

- Don't ignore feed production guidelines with an 'I know it all' attitude.

Key good manufacturing practices

1. Staff must be skilled in feed production and other necessary operations in the feed mill.
2. Staff must be clean and put on the required PPE.

Feed mill staff: Extra information

Ensuring that staff adhere to the good manufacturing practices and critical control actions.

Staff can be a big challenge when producing good-quality feeds. Remember that it is human nature to forget and to opt for easier options/shortcuts. This weakness must not be allowed to compromise the quality of feeds. It can be resolved by building the capabilities and discipline of staff in the following ways:

- Conduct refresher training for all staff periodically, at one-month intervals (if staff are new) or every three months.
- New staff must be oriented in the good manufacturing practices and critical control actions before starting operations.

- Introduce penalties for staff who violate the good manufacturing practices and critical control actions.
- Display the good manufacturing practices and critical control actions in different places within the feed mill.

Key components of the personal protective equipment kit

Staff are the only component of production that move in and out of the facility daily. In the process, they carry many contaminants on their clothing, especially disease-causing organisms. The easiest way to prevent such contaminants from mixing with the feed is by staff using personal protective equipment (PPEs). After entering the facility, staff should put on the PPEs before entering any of the processing sections of the facility. Typical components of the PPE kit are presented in Figure 30.

Figure 30: Pictorial representation of typical PPE kit components.

Overall
Source: Hawaii real media (2021)

Gumboots
Source: Farm House (2021).

Nose, eye, mouth mask
Source: RPF (2022).

Helmet
Source:Majestic Overseas(2021)

Gloves
Source: Colbrook (2021)

Source: Colbrook (2021)

Chapter five: Good manufacturing practices for feed mill equipment

The fourth component of quality assurance for feed production is equipment. Equipment is critical for accuracy in quality standards. In feed production process steps like grinding, blending, pelleting, crumbling, packaging and storage, accurate equipment is required to ensure the good quality of feed products. Calibration, maintenance and repairs are key practices needed for accurate and safe equipment.

Below, we guide you through good equipment practices for good-quality feed production.

Equipment do's and don'ts

- Develop a maintenance and repair scheduled for your equipment.
- Calibrate or certify equipment, like weighing scales.
- Clean equipment after every session of use.
- Make sure equipment operators are skilled in the use of the equipment.
- Replace old poor performing equipment immediately.
- Have at least two large weight weighing scales: one for the blending section and another for the finished feed bagging and packaging section.
- Have the minimum equipment for good-quality feed production.

- Don't delay the repairs and maintenance of equipment.

Key good manufacturing practices

1. Always install or provide enough properly operating equipment.

Equipment: Extra information

Minimum equipment and tool requirements for good-quality feed production

A good feed mill should have the minimum equipment to produce good-quality feeds. Below are the production process steps with the required minimum equipment for good-quality feed production.

- Raw material receiving, cleaning and storage:
  - Moisture metre for moisture testing
  - Sieve stand for cleaning raw materials
  - Pallets for stacking bags
  - Stitching machine for sealing bags
  - Sampling bag triers
- Processing of raw materials:
  - Grinding machine, for reducing particle sizes
- Formulation, blending and mixing:
  - Micro-weighing scale for weights of 2 kg or less
  - Macro-weighing scale for weights above 2 kg
  - Timer for tracking mixing times
  - Mixer, for even mixing
- Bagging, packaging, labelling and storage:
  - Appropriate weighing scale
  - Moisture metre
  - Stitching machine
  - Pallets
- Maintenance
  - Grease gun
  - Toolbox

Chapter six: Good manufacturing practices for feed mill record-keeping

Record-keeping is the fifth component for quality assurance. Record-keeping is important in the process, people, facility, and equipment components of quality assurance in feed production. Therefore, good record-keeping must be maintained in the production of feed.

Here, we guide you through good record-keeping practices for good-quality feed production.

Record-keeping do's and don'ts

- Have record books at all critical production process steps to record activities daily.
- Record feed types produced daily.
- Record incidences of unusual operations daily.
- Record the quantity of raw material used daily.
- Record batches produced daily with their matching quality indicators.
- Record packaged feed quantities stores daily.
- Record recyclable feeds daily.
- Record sales or deliveries daily, including details of feed type, batch number and client details.

- Don't record things in your head.

Key good manufacturing practices

1. Maintain proper records in your feed mill.

Record-keeping: Extra information

Samples of feed mill record books

There are many books used in feed mills. These include: the raw material inventory, the feed store inventory book, delivery book, quality control record book, staff attendance book, and finance books. Among these, the following are important for good-quality feed production.

The raw material inventory (Figure 31) – this book should be used to collect the following information:

Figure 31: Sample raw material inventory book.

Raw Material Inventory Book				
Date	Raw material	Quantity of RM in	Quantity of RM out/used	Balance in store

Quality control record book (Figure 32) – this book should be used to collect the following information:

Figure 32: Sample quality control record book.

Sample quality control record book				
Date	Batch no.	Quality indicators tested	Results	Recommended action

Feed store inventory book (Figure 33) – this book should be used to collect the following information:

Figure 33: Sample feed store inventory book.

Sample feed store inventory book					
Date	Type of feed	Batch no.	Quantity of feeds in	Quantity of feeds out	Balance in store

Delivery record book (Figure 34) – this book should be used to collect the following information:

Figure 34: Sample delivery book.

Sample delivery book							
Date of delivery	Client	Client Address	Client Telephone	Type of feed/ingredient	Batch no.	Quantity	Client's Signature

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ISBN: :92–9146–713–8

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