Authors

Siobhán Kavanagh, Tom Ryan and Noel Nugent, Teagasc Kildalton

Contributors
Bernard Rice, Oak Park; Fintan Phelan, Athenry

Contents

INTRODUCTION

The expansion of both the dairy and beef enterprises is likely in Ireland, in response to a competitive grass-based system. On dairy farms as quota becomes less of a limiting factor and land becomes more limiting, the requirement for low cost supplementary feeding is likely to increase. Likewise, the source of feed becomes more crucial as unit size increases and the demand for value added products from our customers becomes more important. The cost effectiveness of on-farm storage options for feed becomes increasingly attractive as the scale of operation on farms increase.

It is forecast that the current volatility in worldwide grain markets will continue for the foreseeable future. On-farm storage of grain allows feed security and more accurate forward budgeting.

Labour and convenience are becoming more important from the farmer's viewpoint. High moisture grain storage options present an opportunity to eliminate the requirement for processing of grain at feed-out. While the storage of grain on-farm can complicate an otherwise simple streamlined feeding system, the labour associated with grain storage and feed preparation can blend well with other routine tasks.

Proper feed storage facilities are essential on all livestock farms. The storage of any feed must be in line with best practice in terms of food safety and quality assurance. Under the Feed Hygiene Regulations, a high level of consumer protection with regard to food and feed safety must be ensured.

On livestock farms where grain is grown or can be bought ex-combine there is an opportunity to reduce concentrate feeding costs. Storage and handling facilities are required and any capital investment must be comprehensively analysed before proceeding. Grain can be stored either at low moisture content (dried, ventilated or acid treated) or at high moisture content (crimp, urea treated or caustic treated). The most suitable option will depend on the individual farming system and the storage facilities available. For dried, ventilated, acid treated or caustic treated grain there is a requirement for a sealed storage shed. For crimped or urea treated grain a silo will suffice. However, if additional ingredients are required a storage shed or bin(s) will be needed.

This publication outlines the options available to livestock farmers for the storage and preservation of both low and high moisture grain on-farm. It details the technical requirements for each of the systems and the associated costs, and provides the farmer with the information needed to make an informed decision on the feasibility of on-farm storage of grain on his/her own farm.

CHAPTER 1 - STRUCTURES FOR GRAIN/FEED STORAGE ON-FARM

Detailed descriptions, drawings and costings for four different types of feed store options are outlined in this chapter. Recommendations for the design and construction of these feed stores, together with the options available for bin storage are also discussed as well as detail and costings for the storage of treated grain in storage pits.

Feed Store 1

This storage system consists of a portal frame building, three adjacent grain storage bins and associated aeration, rolling and handling equipment. The general layout of the store and the bins can be seen from the drawings. The store is efficient and well designed. The system for handling the feed is very suitable for the large-scale operation on this farm where upwards of 200 tonnes is fed per annum. A further 200 tonnes are stored in the shed around harvest time, prior to sale.

The portal frame shed has three 6.1m bays. The internal dimensions are 17.6m x 17.6m. The eaves height is 5m and the height at the apex is about 7.35m. There is one roof light in each roof slope of each bay; six roof lights in all. Artificial lighting is via fluorescent lamps. There is a sliding door at the entrance. The size of the door opening is 5.65m wide by 5m high.

There are four storage bays as can be seen from the drawings. There is also room to pile the grain in the bottom left hand corner. The large bay at the back left hand corner is for storing grain and the remaining three bays are used for storing concentrate ingredients.

The store is suitable for tipping a tractor trailer or a rigid bodied truck inside. An articulated truck can tip off some of its load inside and the remainder outside at the door. A loader with a grain bucket is used to move the grain into place. The store has plenty of room inside for easy manoeuvring with the loader.

Outside the gable end there are three grain storage bins. The overall capacity of the grain bins is 200 tonnes. The bins were bought second hand for approximately €4,000

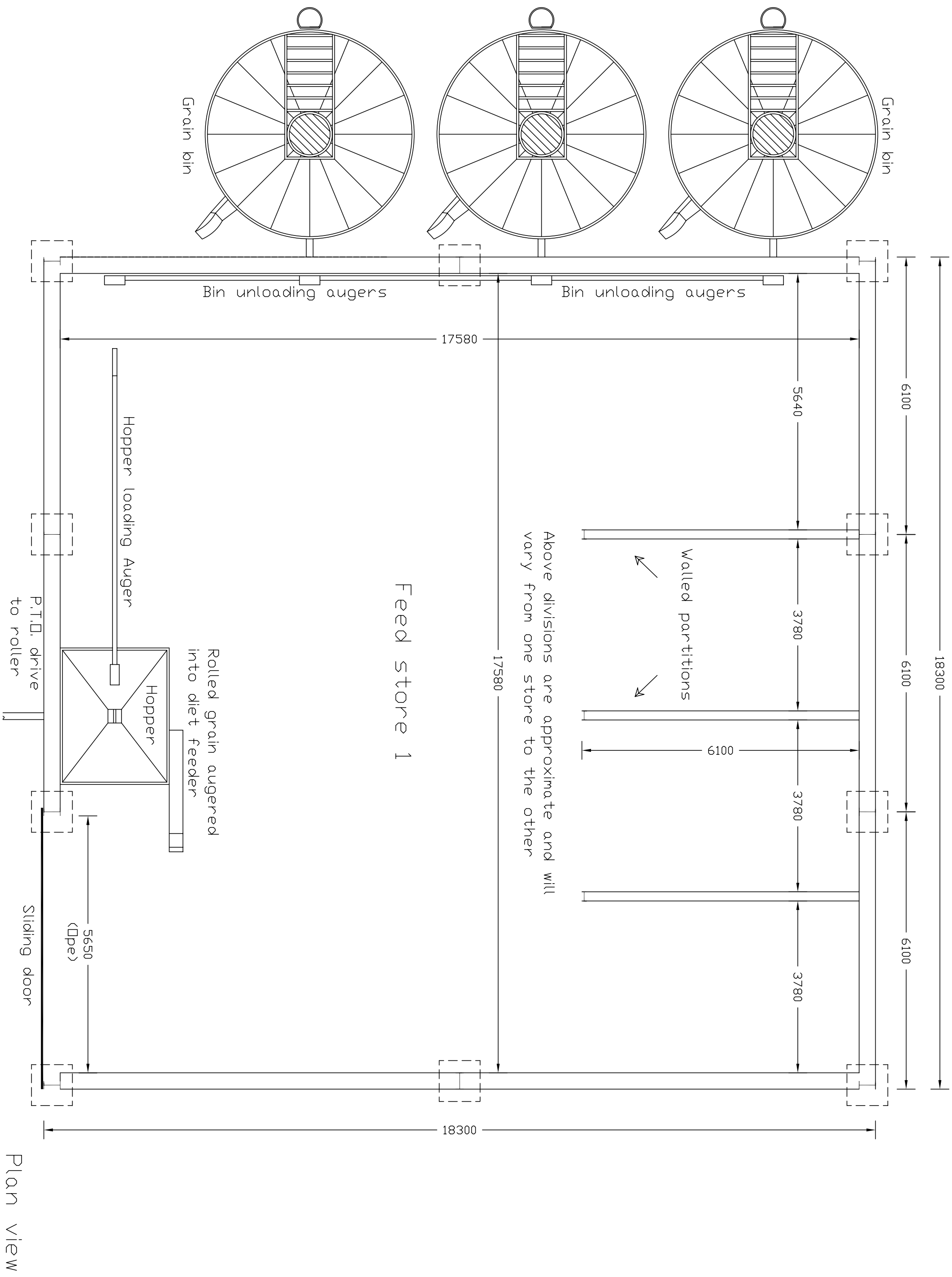
Image 1:
Feed Store 1 - Rolling equipment

Image 2:
Feed Store 1 - Feed bays

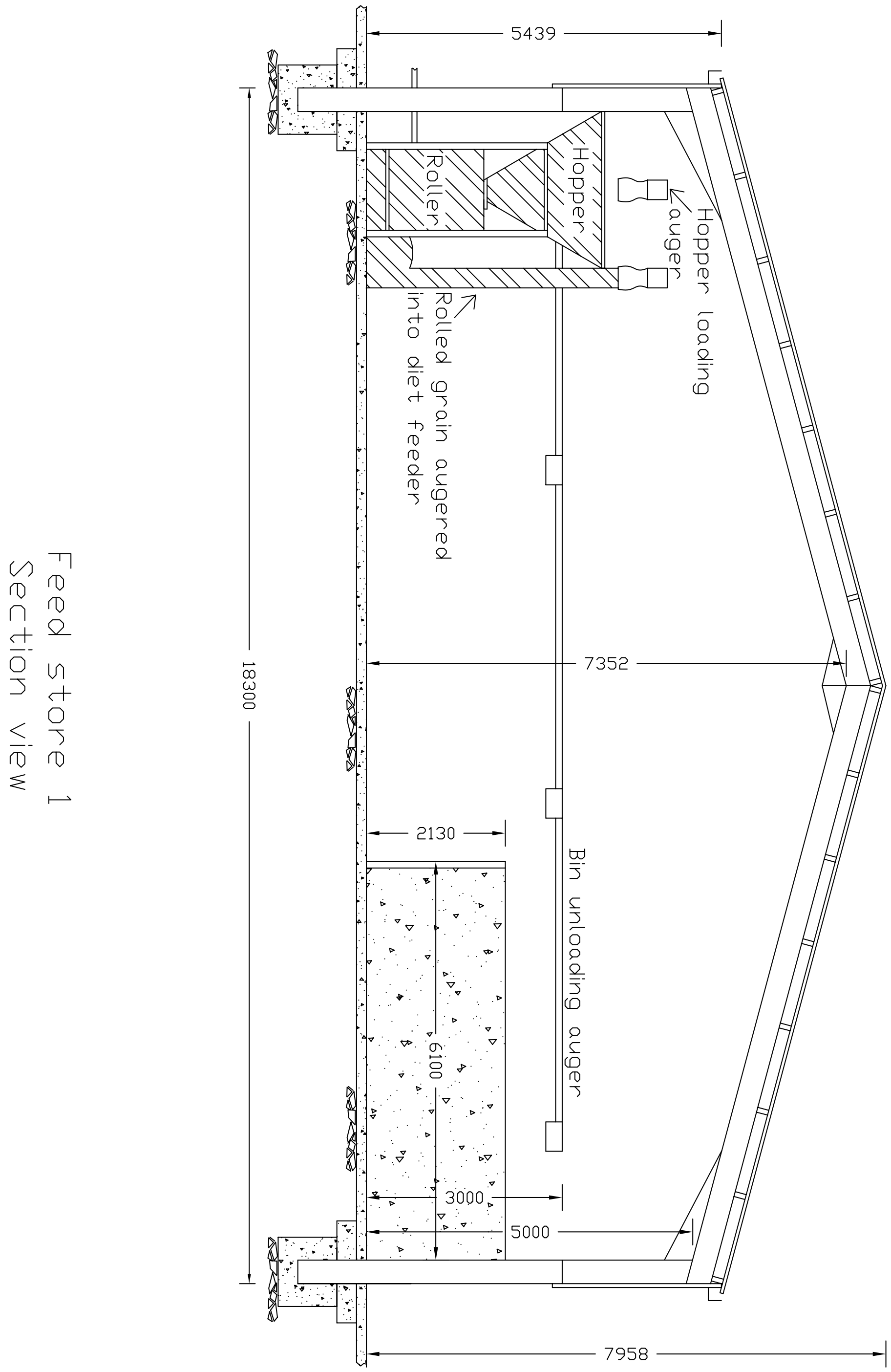
plus the cost of dismantling and re-erection. The bins are filled via a 0.2m diameter PTO/hydraulic driven trailed auger. The cost of the auger is approximately €5,000.

A system of fixed augers conveys the grain from the bins to inside the shed and piles it in the bottom left hand corner. From here it is augured into the hopper above the grain roller and elevator. The roller/elevator combination is PTO driven from the outside through a hole in the wall. The rolled grain is elevated directly into a diet feeder. Alternatively, the elevator can be used to pile up the rolled grain or transfer it into a loader bucket.

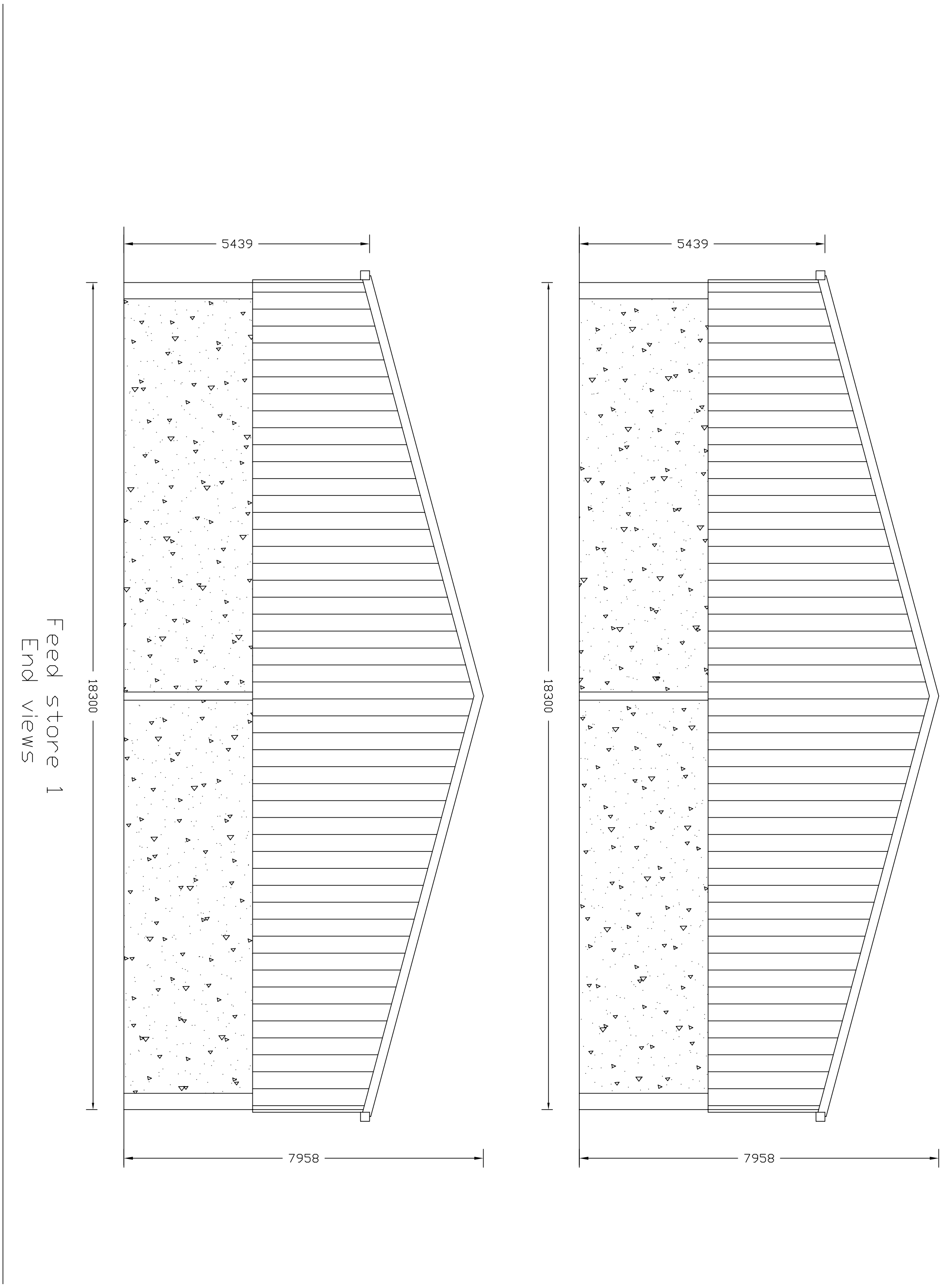
The small bays are used to store concentrate ingredients such as: soya bean meal, citrus pulp, maize distillers grain, etc. These are loaded by front loader into the diet feeder. The cost of the store is approximately €66,000 plus VAT, or about €213 per/m^2. These costs do not include the cost of the equipment and the grain bins. See cost of construction in Table 1.



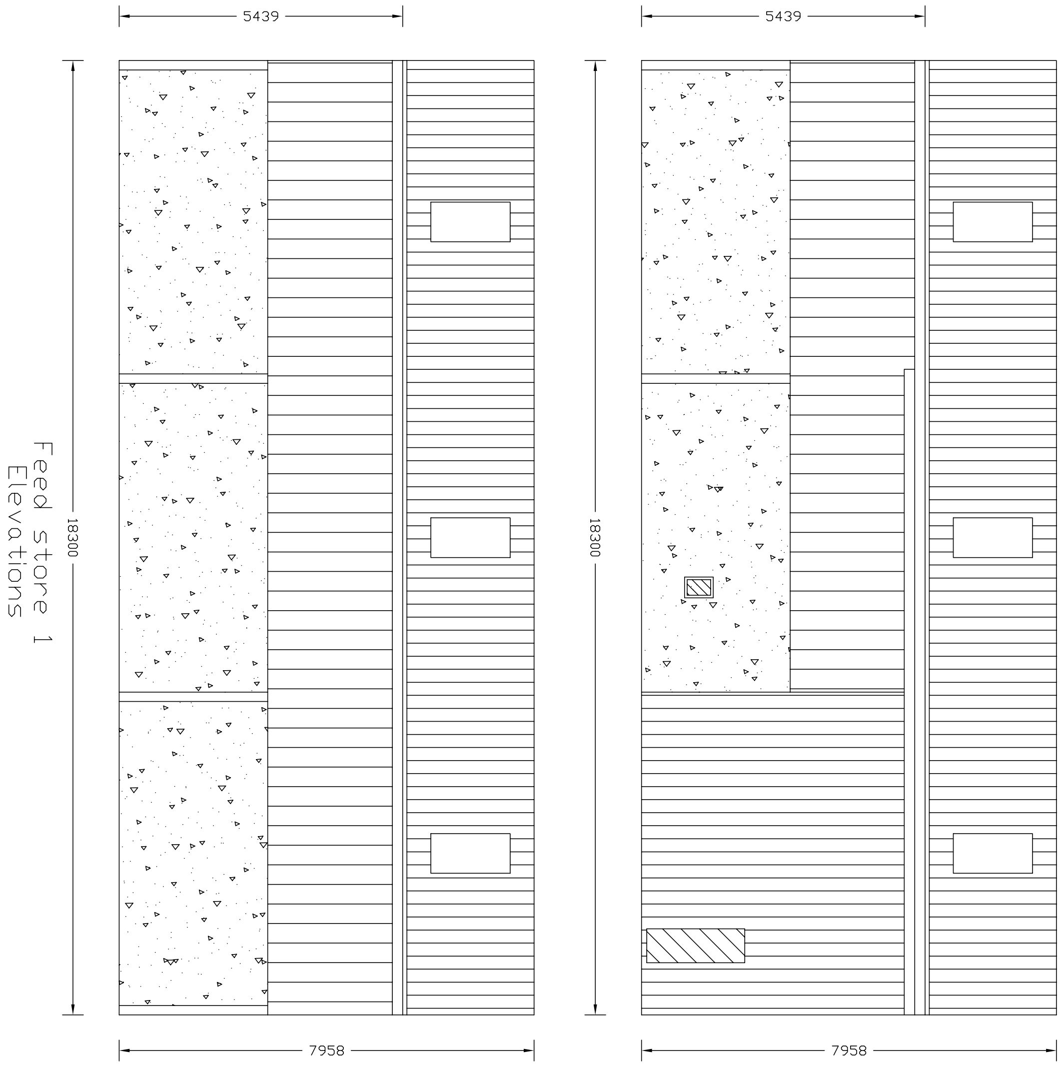
Drawing of Feed Store 1 (a)



Drawing of Feed Store 1 (b)



Drawing of Feed Store 1 (c)



Drawing of Feed Store 1 (d)

Feed Store 2

The general layout of this store can be seen from the following drawings. It is a four-bay portal frame shed with 4.8m standard bays. The internal dimensions are 18.7m long and 12.2m wide. The eaves height is 5m and the height at the apex is about 6.6m. There is transparent sheeting in the side cladding – one sheet per bay at each side. There are no roof lights. Fluorescent lamps provide artificial lighting.

There is a sliding door for machine access with a seperate people access door incorporated into it. The sliding door is 6m wide by 5m high.

Grain is stored at the back of the store. This area can easily hold about 150 tonnes. The grain heap used to make the ration on this farm normally occupies the back two bays. There are no issues with tipping a 10 or 11 tonne trailer load of grain within the shed at the back wall. If using bigger trailer loads, the load would need to be tipped partially inside the store at the back and the remainder unloaded at the door and then moved in by a front loader.

The middle part of the floor area is kept clear of grain and is used solely for access to unload grain and for room to manoeuvre the tractor and front loader. At 12.2m wide there is adequate space for manoeuvring. The store has ample room for manoeuvring machinery inside, even if it is only 10m wide.

In addition to areas for storing grain and manoeuvring, there are four small bays for the roller and managing the concentrate ingredients (see Image 4). Each bay is 3m deep, 2.4m wide and has timber partitions of about 1.2m high.

In the front right hand corner of the first small bay there is a hopper and grain roller (see Image 3); the hopper is filled by a front loader. The roller is driven by a tractor PTO shaft through a hole in the wall. The hole in the wall can be sealed off to keep out vermin when not in use. The hopper discharges grain directly into a smaller hopper mounted on the roller. The shape of the big hopper is designed so that it discharges its grain off-centre towards the gable end wall of the shed. This allows the roller to be placed nearer the gable end keeping the PTO shaft as short as possible. It also suits the angles and general setup of the auger for the rolled grain.

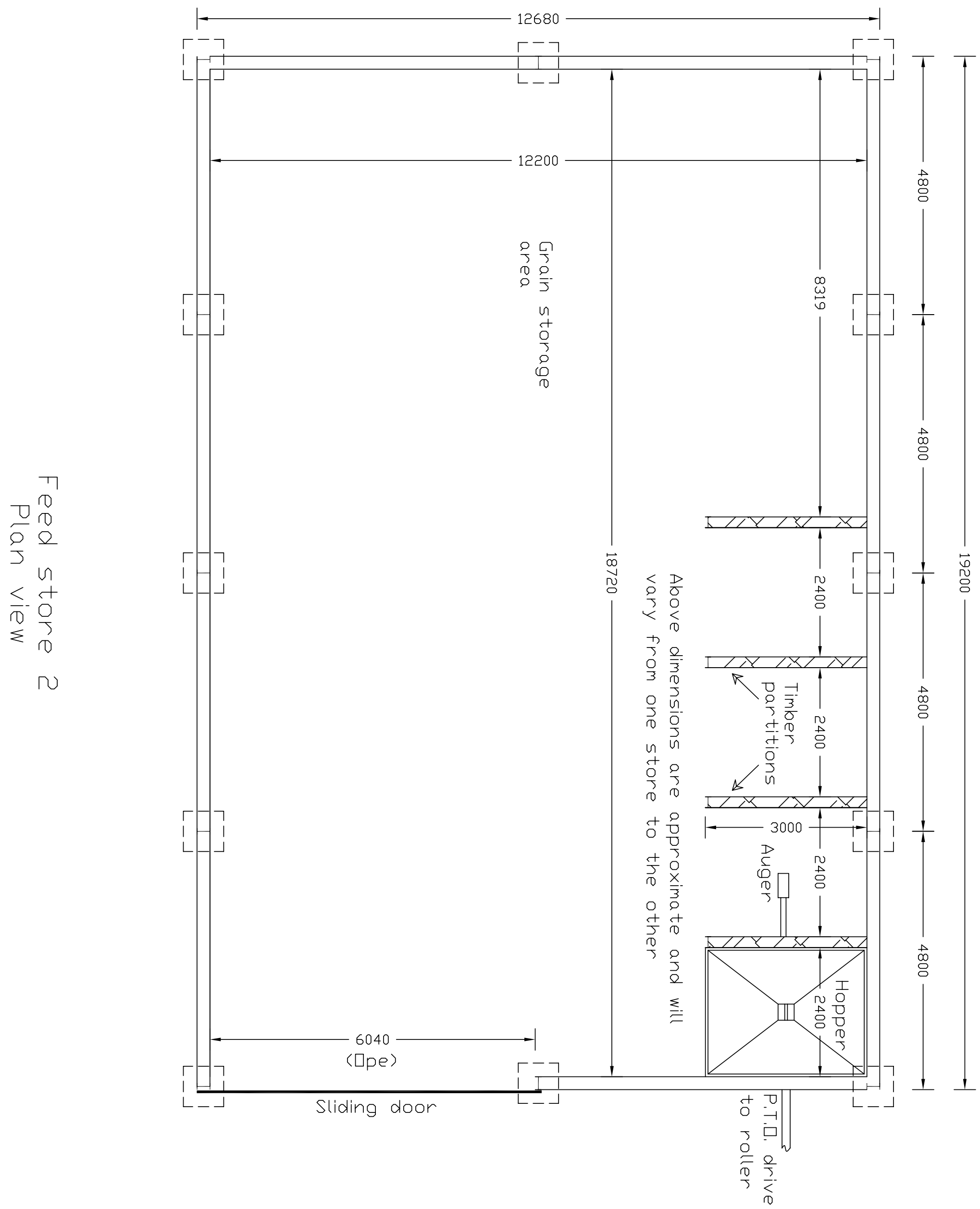
Image 3:
Feed Store 2 - Rolling equipment

Image 4:
Feed Store 2 - Bays for feed ingredients

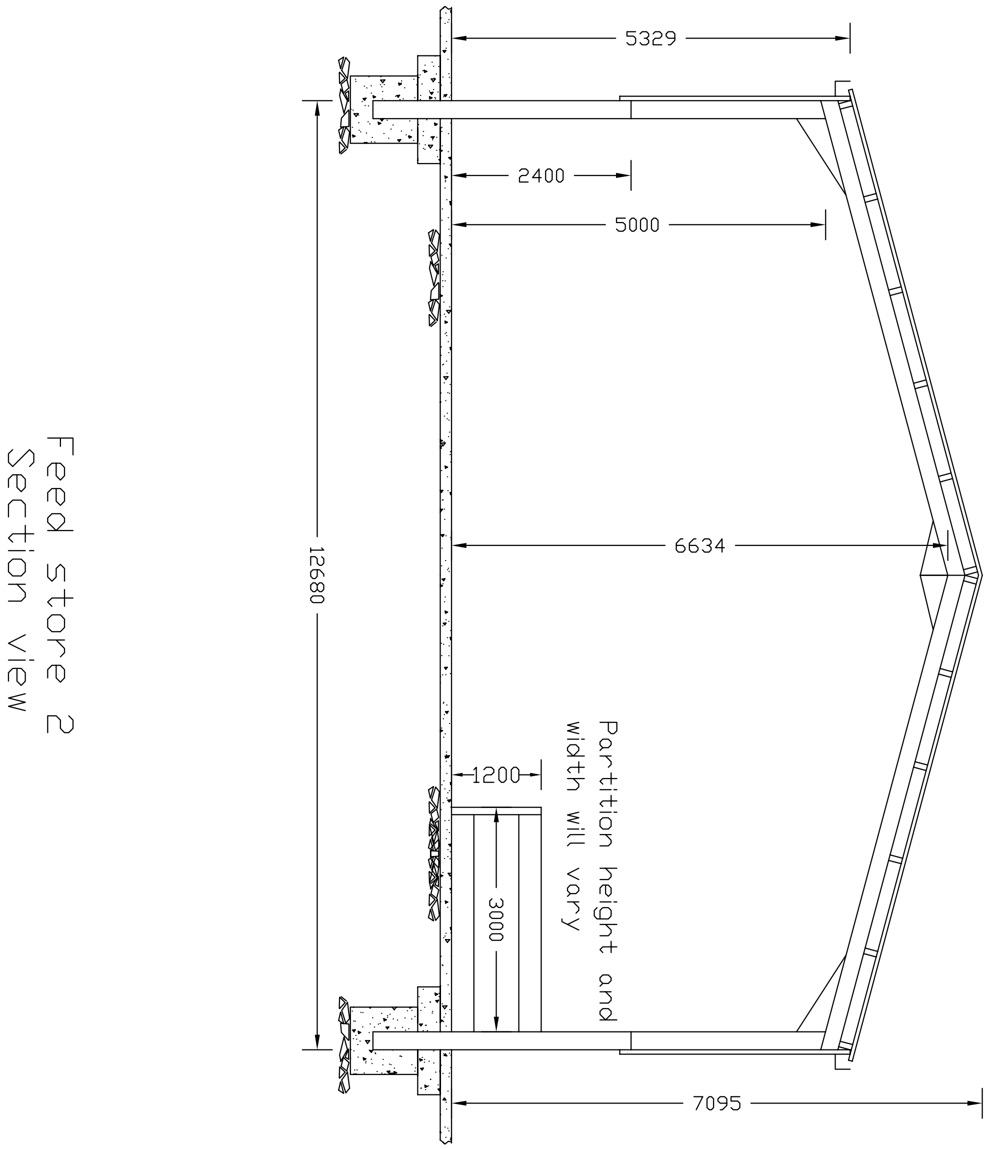
The rolled grain falls into a cowling under the roller from where it is augured into the adjacent small bay. It can be taken from there for use. The fourth (innermost) small bay is used to store a three-way premix of soya, distillers and gluten. The third small bay is used to mix the rolled barley with the premix.

It may seem that these small bays are too small and narrow; however, they work very well in practice and pose no problems using a front loader for mixing and taking out feed. The mixed ration is loaded into a diet feeder and weighed before adding the forage.

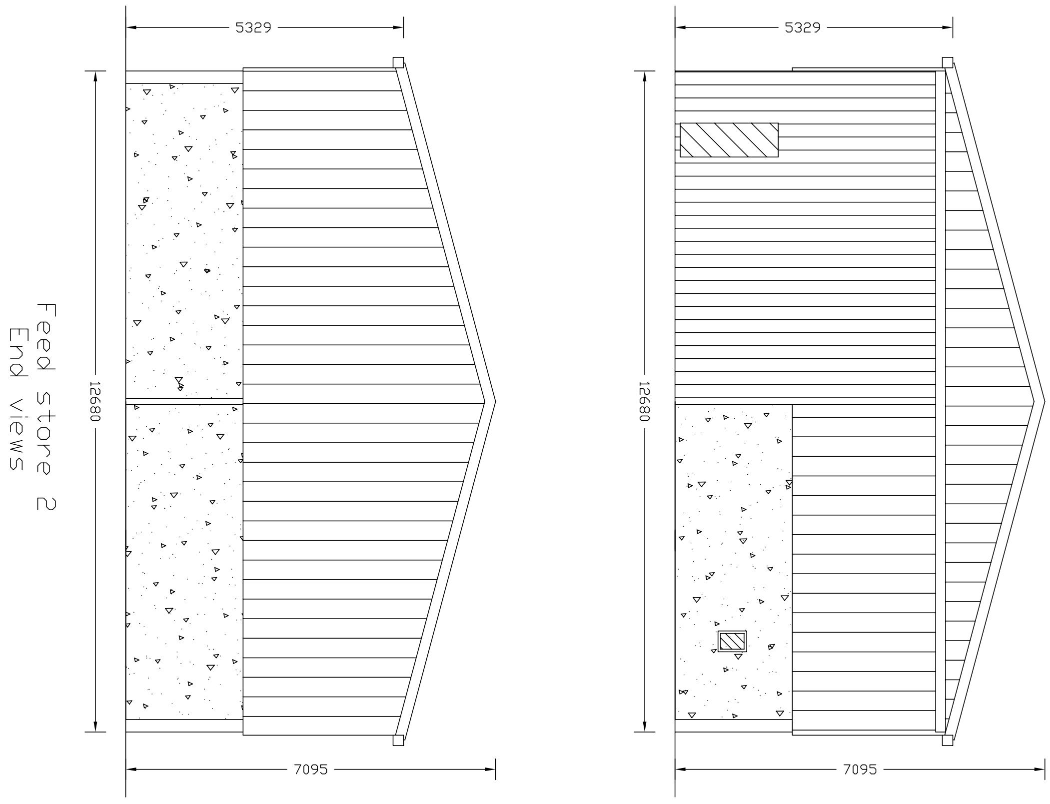
A big effort is made to ensure the grain is no more than 16% MC. This makes management during the storage period much simpler and reduces preservation costs. A spear is used for aeration if a hot spot develops. This unit works very well and is very suitable for this scale of operation but the moisture content at harvest is critical. The grain must be inspected on a regular basis to ensure there are no hot spots, as poor management of a grain store can result in significant losses. The cost of this store is €50,400 plus VAT, or €223/m^2. See the cost of construction in Table 1 and itemised costings of this store are presented in Table 2.



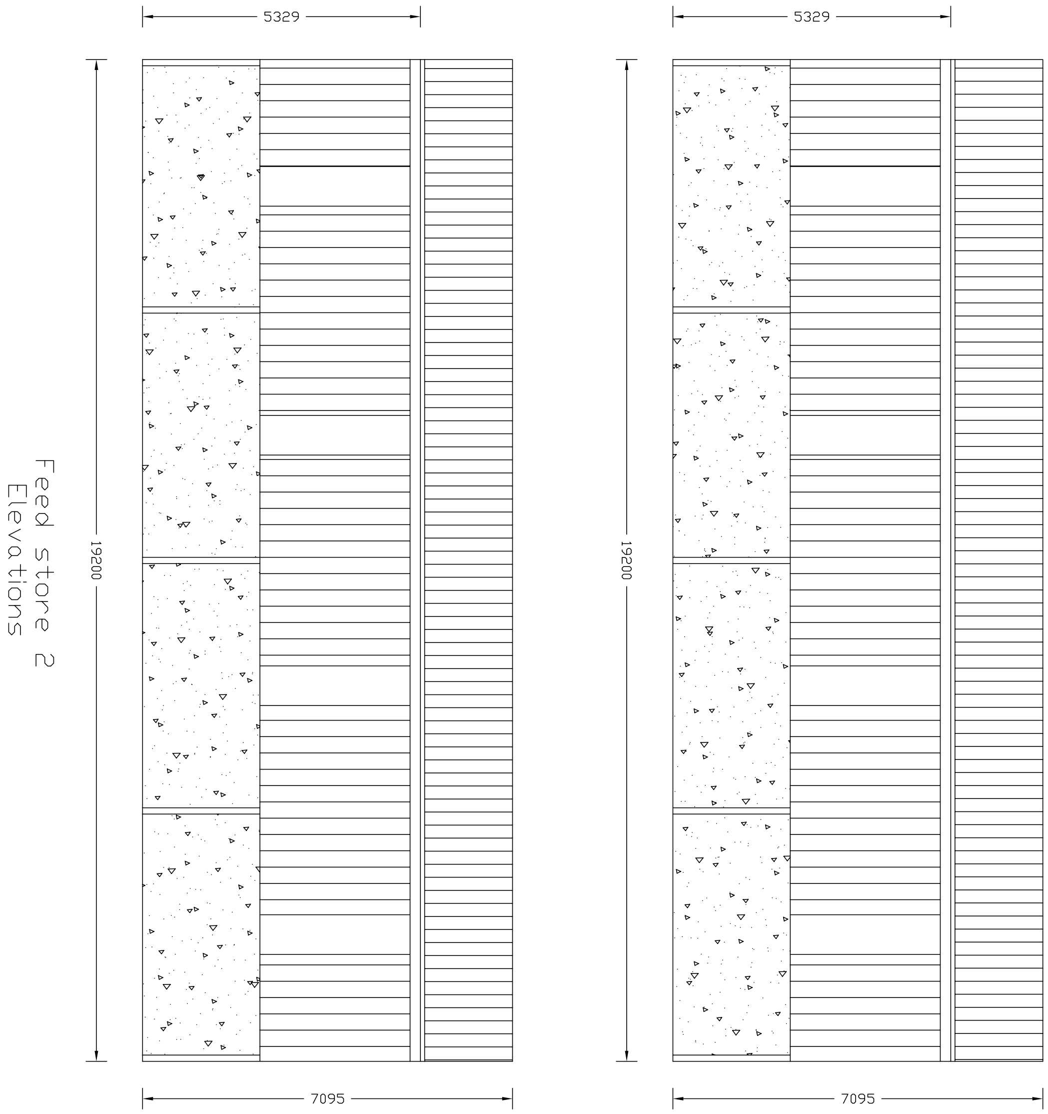
Drawing of Feed Store 2 (a)



Drawing of Feed Store 2 (b)



Drawing of Feed Store 2 (c)



Drawing of Feed Store 2 (d)

Feed Store 3

This is a conversion of a standard round roof shed into a feed store. There are four seperate bays with each having internal dimensions of approximatly 4.5m x 7.6m. With an average grain height of about 2m, the capacity of each bay is around 95 tonnes, or 380 tonnes in total in the store.

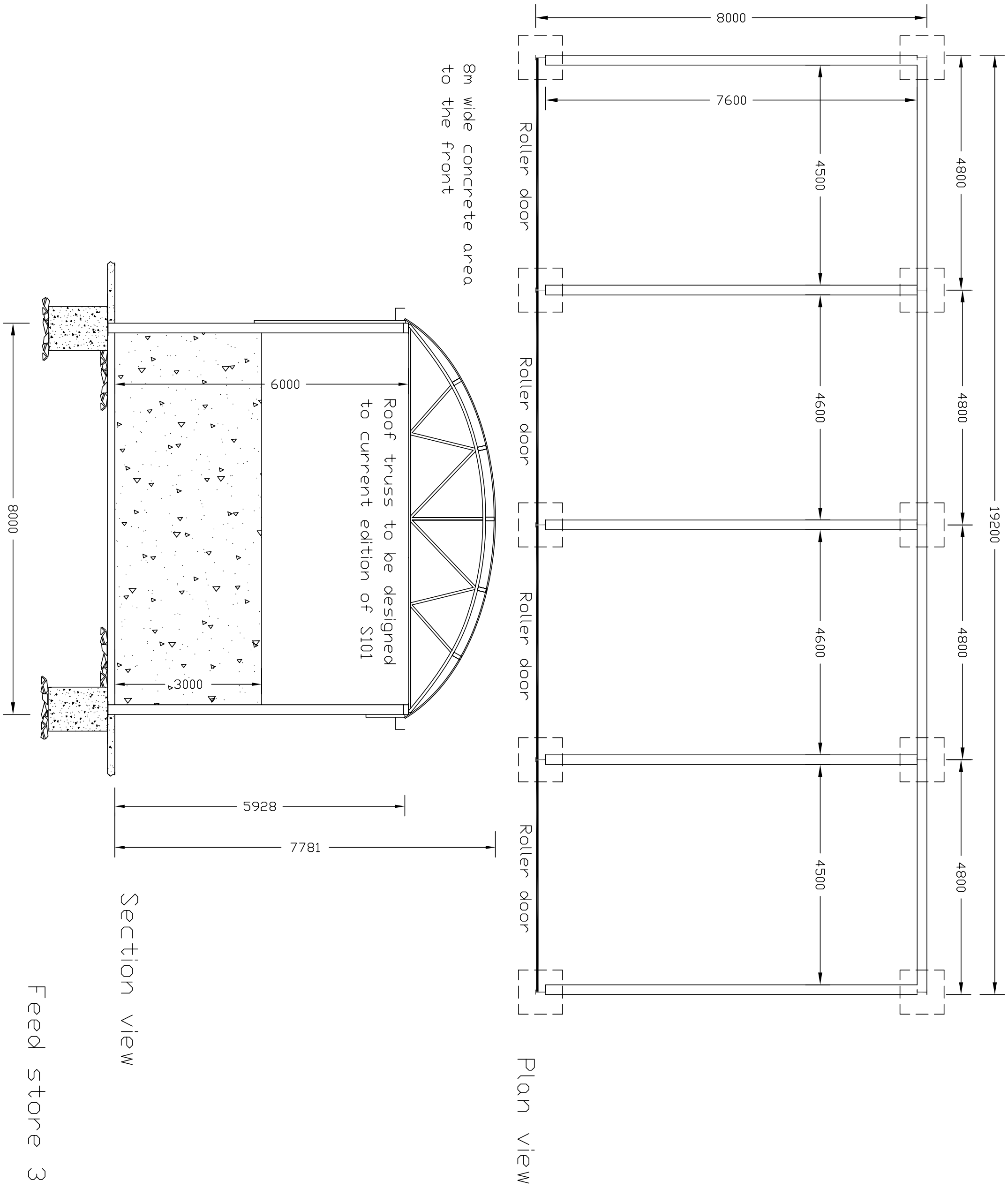
The eave height shown is 6m. The higher the eave the more access there is for tipping trailers. Access to each bay is via a roller door at the front. The width of each opening is around 4.5m and the clearance is 5.7m. With this type of design it is much easier to install roller doors than either sliding or swinging doors. Sliding doors would not be as user friendly and it would be difficult to correctly set up the running gear. Swinging doors should be avoided if possible because they are unsafe in windy conditions.

The cost of this feed store is approximatly €37,000 plus VAT, or €242/m^2. The cost of the construction of Feed Store 3 is given in Table 1 (page 28). This is very expensive because there are a lot of reinforced walls and roller doors. Also, the storage bays are not very long at 7.6m which increases the cost per square metre. The same size store with a new roof would cost approximately €11,500 extra and would be poor value for money. For those with an existing shed suitable for conversion into a feed store it is more cost effective to design it like Feed Store 2, as the internal reinforced concrete walls and many expensive doors are not required.

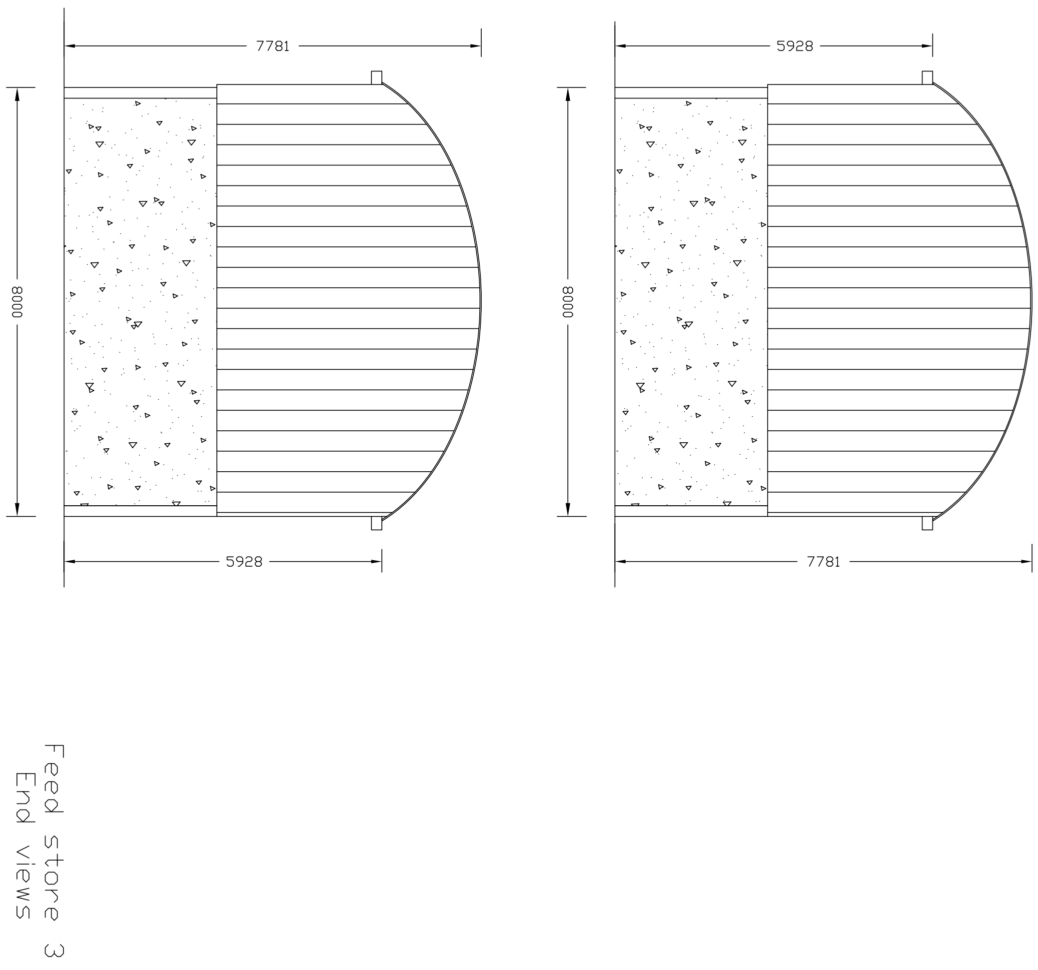
Converting existing silage facilities

A very cost effective solution, that is quite common, is to convert an existing roofed walled silage pit into a feed store. Very often all that is required is to add, replace or extend side cladding down to the walls and possibly build a back wall and install a roller door and people access door cum front wall. The cost of this work would be in the range of about €5,000 to €15,000. Some plastering of the silage walls and small floor repairs may be needed in some cases. Putting a roof over an existing walled silo could also provide a cost effective feed store in some situations.

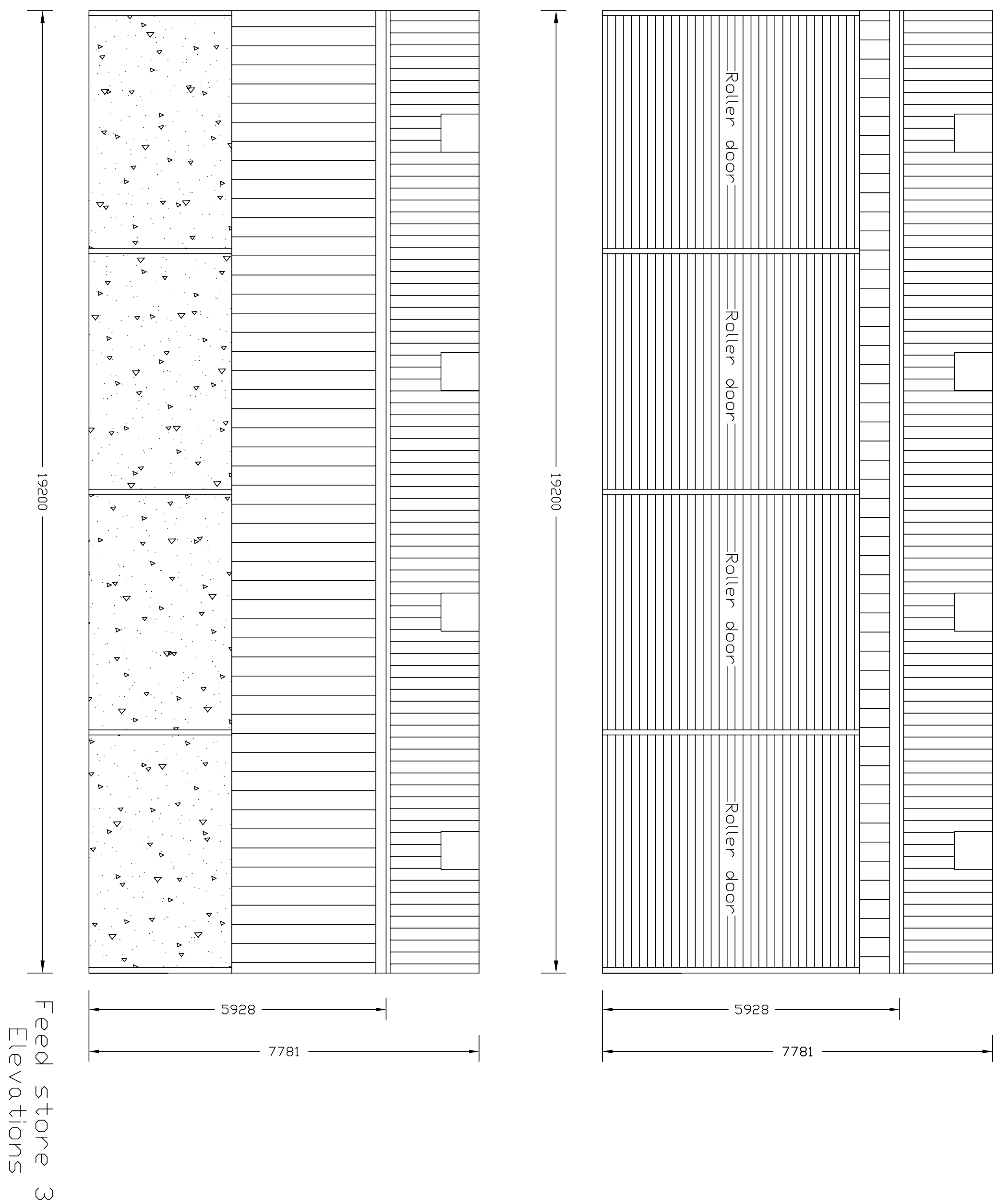
On livestock farms where an existing walled silage pit is in need of repair to prevent effluent leakage, consideration should be given to building a new silage base and converting the roofed walled or walled silage pit to a feed store or for some other purpose.



Drawing of Feed Store 3 (a)



Drawing of Feed Store 3 (b)



Drawing of Feed Store 3 (c)

Feed Store 4

This type of store is a very innovative approach to storing feed. It consists of a fairly straightforward lean-to structure with four standard 4.8m bays. Its unique feature is that sections of the roof slide backwards and upwards to provide access for trucks to reverse fully into the bays and tip off their loads (see page 25 end view drawing of Feed Store 4 which shows how an artic would look tipping a load).

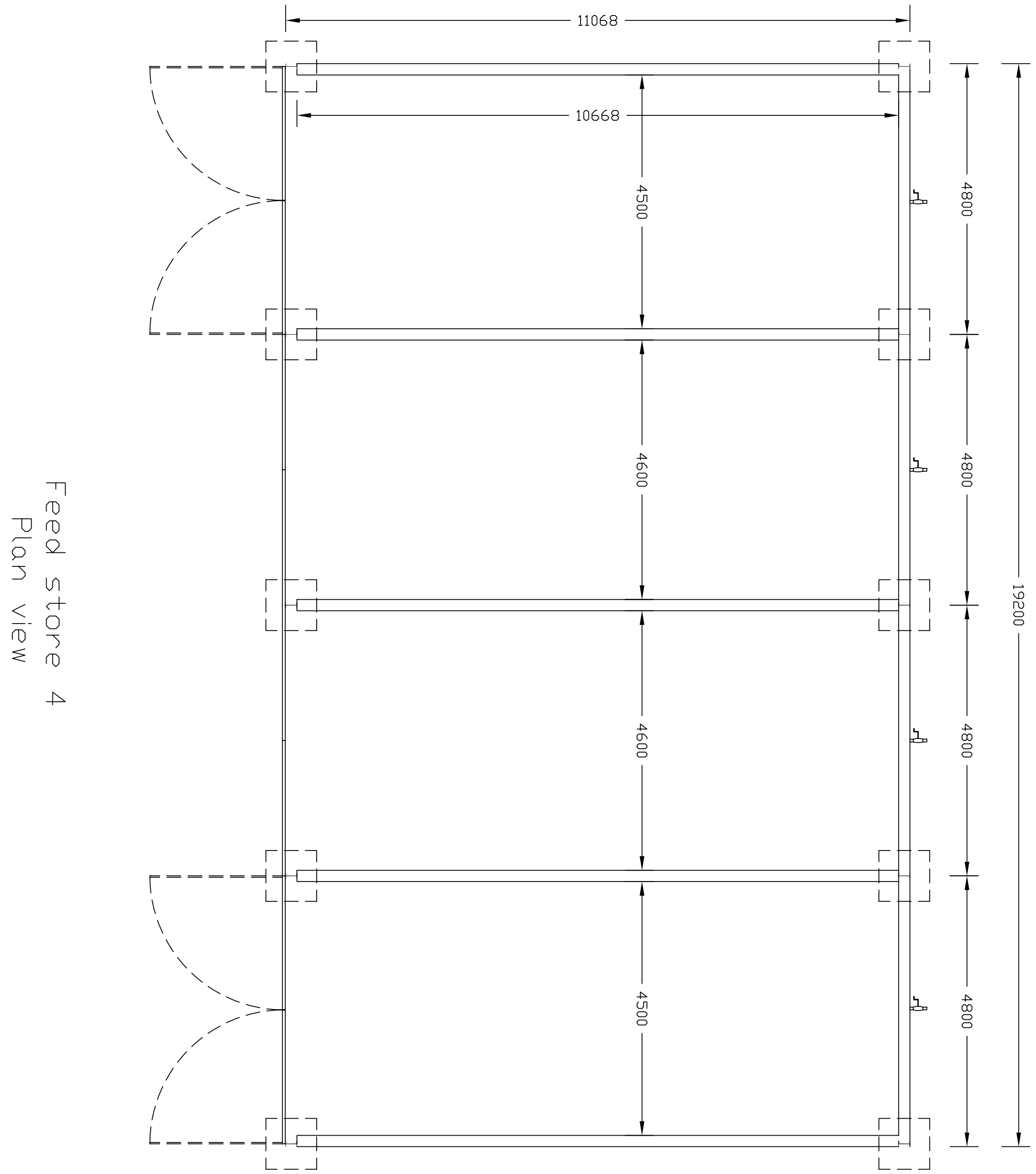
There is quite a bit of design detail in the roof. The front two sections of the roof in each bay can slide back telescopically in under the fixed rear section. A hand winch system, steel cable and pulleys are used to move the sections back. A roller door type winch motor can be used to automate this, if desired. The sliding roof sections for each bay are independent of those in the other bays, as can be seen in Image 6.

The challenge for the roof designers in this case was to ensure trouble free easy operation and rain tightness at a reasonable cost. A gutter is mounted along each front section and slides back with that section. Rain water from each gutter must discharge freely into the rainwater pipe. One slight disadvantage is neither roller nor sliding doors can be used, because their running gear would impinge. The swinging doors are fine and work very well but they must be well secured when open to prevent serious injury or fatalities from uncontrolled swinging in windy conditions. They should be easy to open and secure while in an open position.

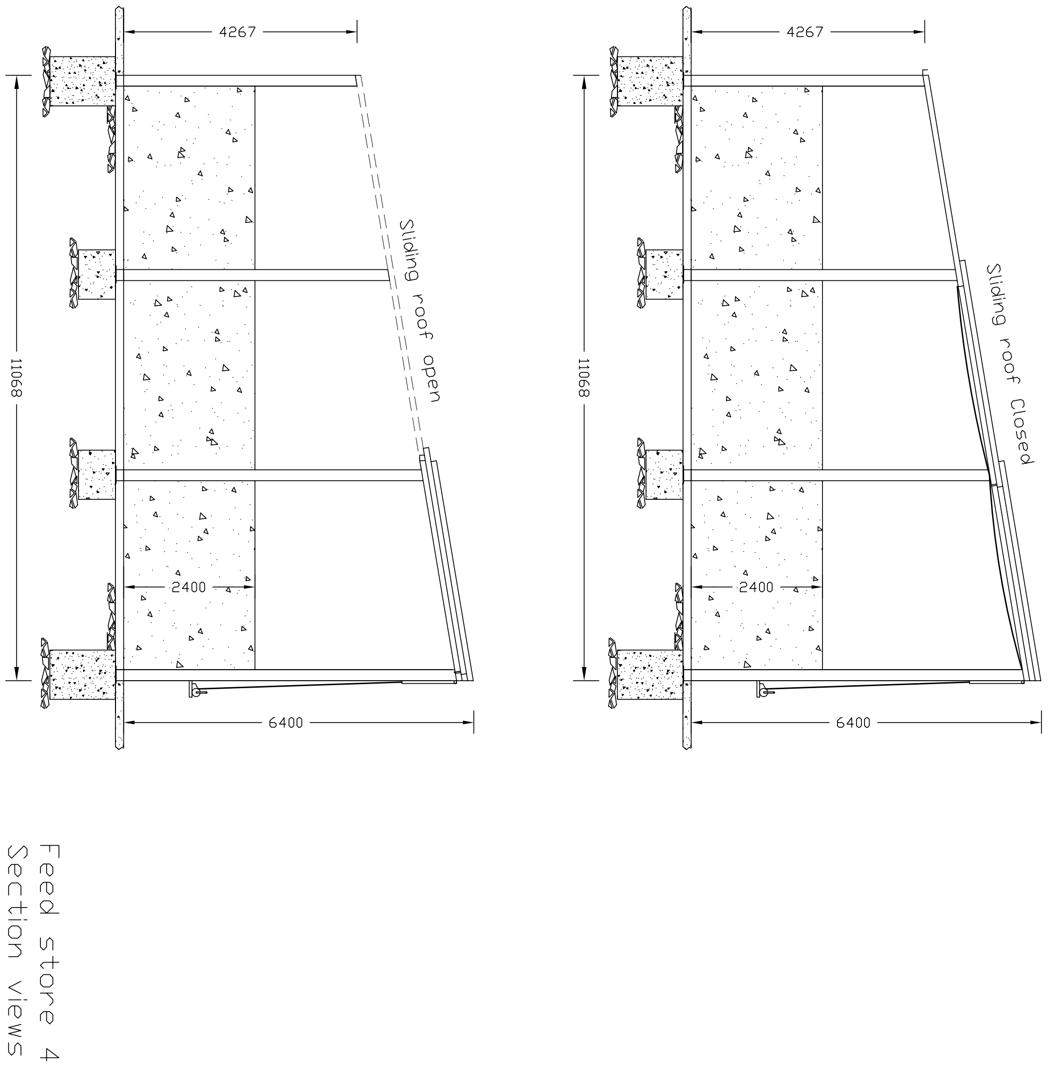
Each bay is about 10.7m by 4.5m. Therefore, each bay has the capacity to store approximately 135 tonnes if the average height of grain is about 2m, or 540 tonnes in total. The store cost €55,000 plus VAT, or €283/m^2.This is also quite expensive. The cost saving benefit of the longer storage bays is somewhat lost by the extra cost of the elaborate roof. This type of store is perhaps more suited to where there is a large throughput of grain and concentrate ingredients, which are delivered by articulated trucks. See the cost of construction in Table 1 (page 28).

Image 5:
Feed Store 4

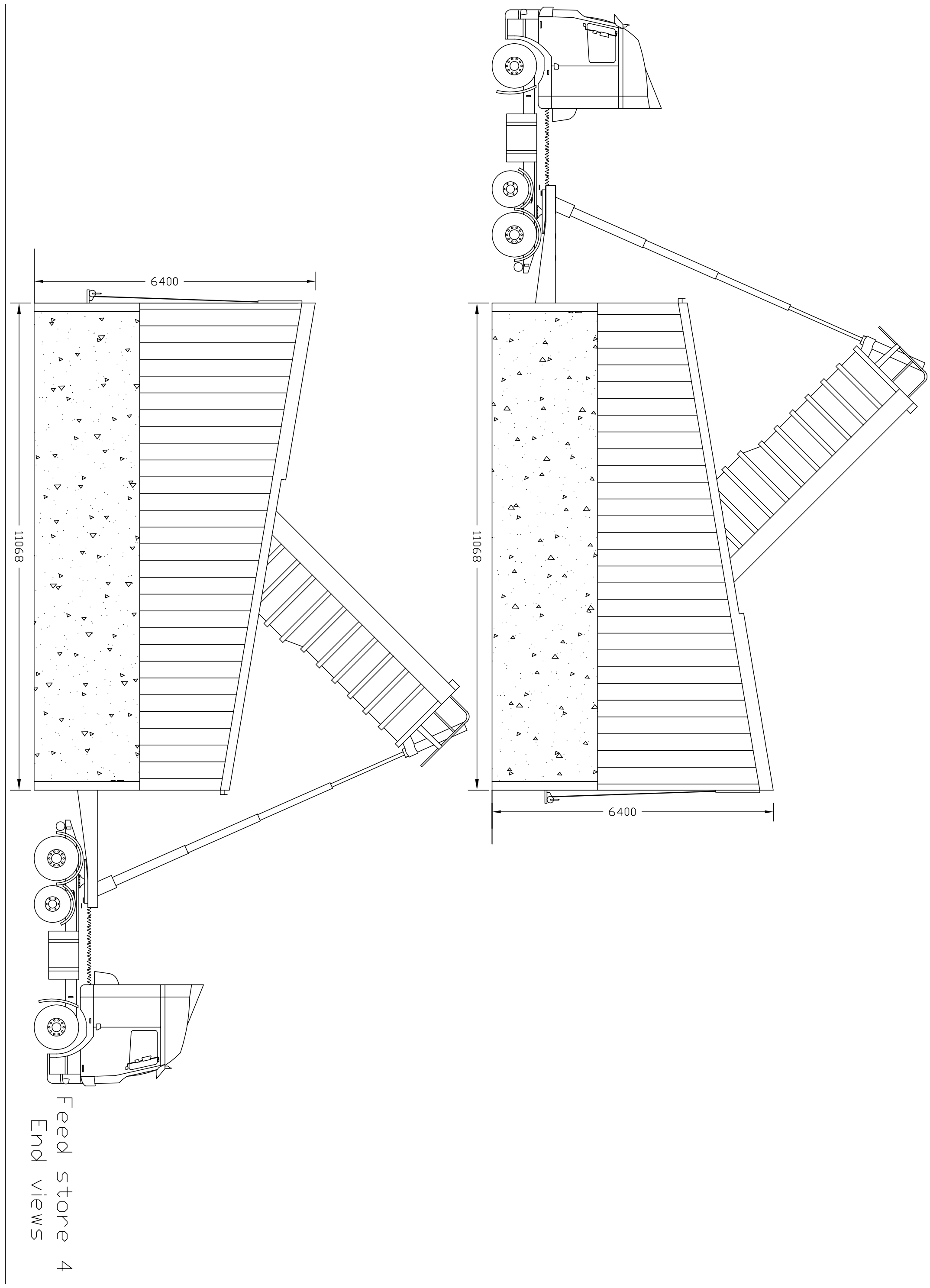
Image 6:
Feed Store 4



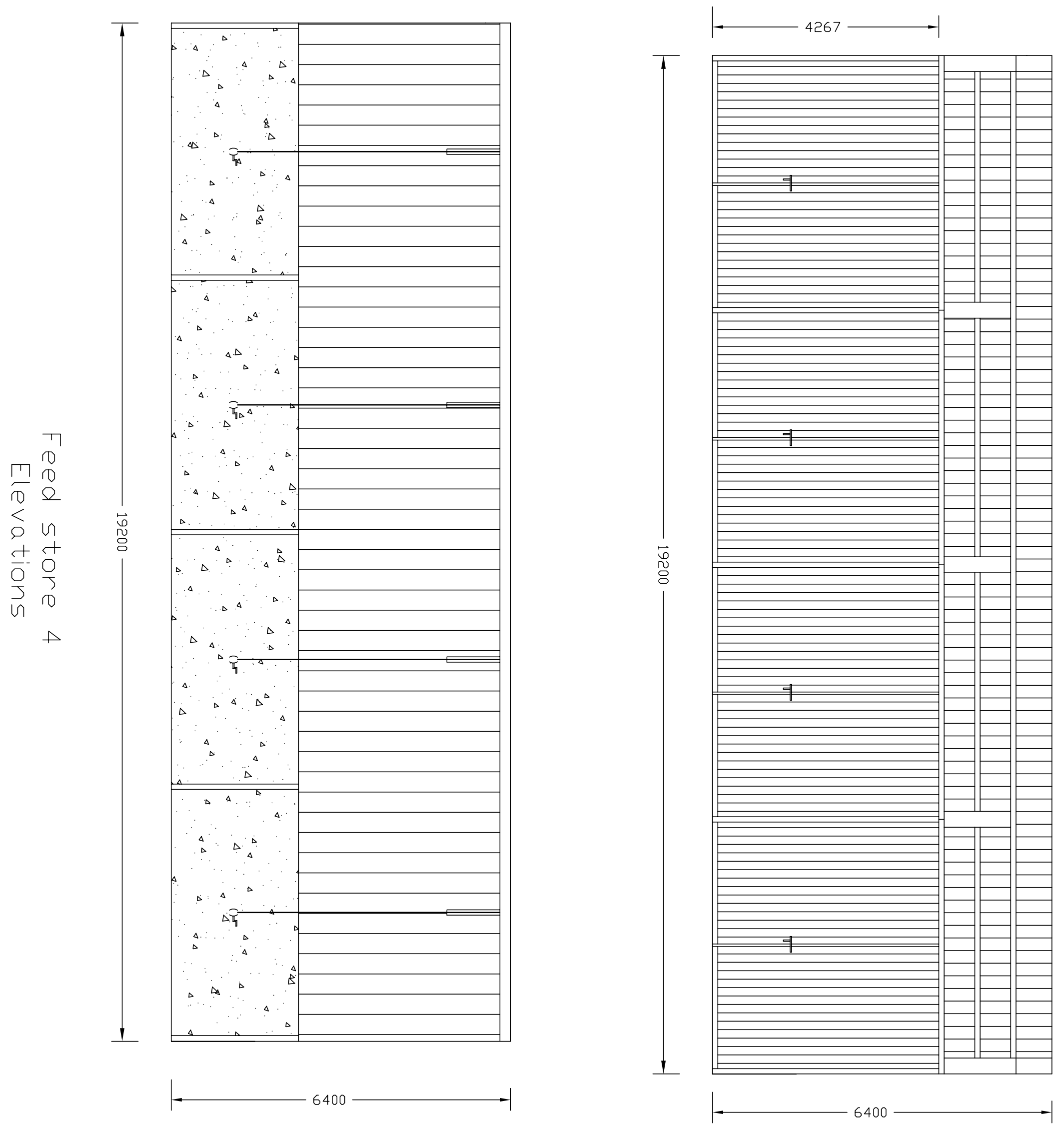
Drawing of Feed Store 4 (a)



Drawing of Feed Store 4 (b)



Drawing of Feed Store 4 (c)



Drawing of Feed Store 4 (d)

Design and Construction Recommendations for Feed Stores

The general design and layout of a feed store must suit the needs of the farm. Deciding on the location, length, width, eave height, wall heights etc are all important. The storage capacity, size and number of bays, doors, ventilation equipment and handling and rolling equipment need careful consideration also. Every situation is different, it is only by carefully assessing all of the options and the costs that the right choice will be made.

Feed/grain stores need to be constructed to a high standard if they are to perform as expected and withstand the test of time. A number of specifications are detailed on the Department of Agriculture, Fisheries and Food website at www.agriculture.gov.ie. These are: S100 (concrete), S101 (roofs), S102 (cladding), S105 (general purpose stores), S109 (grain stores) and S129 (farmyard drainage). Following these specifications carefully ensures quality materials will be used and a good standard of workmanship acquired.

While S109 covers all aspects of grain storage construction it may be necessary to use the services of a chartered engineer for some aspects e.g., roof super structures for very large stores, reinforcing steel scheduling for walls, etc. Teagasc has a computer programme that calculates the amount of reinforcing steel required for various storage scenarios such as crop type, storage height, surcharge and wall thickness. This information is useful for a structural engineer who may not have the relevant detail on the pressure exerted by different crops, angles of repose etc. The programme is available through the Teagasc advisory service.

Important aspects of design and construction

- Location of the door(s) should be suitable for easy access by tractors and trailers and trucks.
- Concrete the area in front of the store for cleanliness, waste prevention and handling efficiency.
- Shed space is used a lot for manoeuvrability. Before deciding on the floor plan, do a trial to see what space is needed i.e., mark out the proposed floor plan (with lime and bollards) and try it out with the loader etc to see if there is enough room.
- It is generally recommended to allow persons access without having to open the sliding door, a separate persons door incorporated into the sliding door is recommended. If a roller door is used then a separate persons door is required.
- Drip flashing along the wall is recommended because it prevents rainwater from running down the outside of the wall. It also prevents any vermin from gaining access and makes the installation of the side cladding more precise.
- It is essential to have close fitting door(s).
- Good wall and floor finishes enable easy hygiene.
- Do not skimp on the reinforcing steel.

- Correct spacing and sealing of the wall and floor joints prevents cracks and aids store hygiene.
- Ensure a good standard of electrical installation.
- Take levels to ensure that the store is at the right level in relation to the surrounding yards and buildings. Ensure that the roof and yard rainwater is properly drained to a clean water outfall. Internal floors should be level and concrete aprons should slope away from the store. Remember that concrete areas used for tipping trailers must be reasonably level to prevent overturning.

Table 1: Summary of the capital costs associated with the construction of Feed Stores 1, 2, 3 and 4

	Feed Store 1	Feed Store 2	Feed Store 3	Feed Store 4
Potential weight stored tonne (t)	865	639	387	544
Internal length, metre (m)	17.58	18.7	7.6	10.67
Internal width, (m)	17.58	12.2	18.2	19.2
Internal area, square meter (m^2)	309	228	138	194
Effective grain depth, (m)	2	2	2	2
Capacity, cubic meters (m^3)	618	456	277	-
Total costs, €	**65,830**	**50,400**	**37,133**	**54,902**
Cost, € per m^2	**213**	**223**	**242**	**283**

Table 2: Itemised costs for the construction of Feed Store 2

Item being Costed	Measurement factor	Cost per measurement factor €	Area linear metres each etc for the building	Costs €
Roof	per m^2	73	243.46	17,042
Stanchion bases	each	55	12	660
Concrete floors	per m^2	28	228.4	6,395
External walls	per linear metre	275	57.3	15,758
Internal walls	per linear metre	200	12	2,400
Roller doors	per m^2	110	30	3,300
Electrical work	per m^2	5	243.46	1,217
Concrete apron adjacent to gable end	per m^2	28	101	2,828
Total costs	-	-	-	**50,400**
Cost per m^2 (of roof area)				**223**

Feed Bins

Feed bins are an alternative option for on-farm grain/feed storage. Meal bins are very suitable for storing and protecting many types of feed. With hoppered bins it is easier to ensure they are bird and rodent free, in accordance with the Department of Agriculture, Fisheries and Food (DAFF) Feed Hygiene Regulations (Appendix 3). The bin system also has the advantage that grain handling can be automated and will most likely be cheaper than a new on-floor store. However, on-floor grain stores can be used for other purposes throughout the year and for alternative uses in the future should the farming system change.

The two options are outdoor flat-bottomed bins and hoppered bins. Traditionally, the outdoor flat bottomed bins (Image 7) were most popular but now farmers are tending towards the hoppered bins (Image 8). Recently the availability of a grant for meal bins has increased the popularity of hoppered bins on many farms. However, the Farm Improvement Scheme is currently suspended. The capacity of feed bins is up to 5,000t. These high capacity bins are more suitable for large tillage farmers and grain intake merchants. For many livestock farmers, bin capacity ranging from four to 50t is most suitable. Bins can be fitted with aeration and auger systems to suit. The costs associated with these bins are presented in Table 3.

Bins may not suit certain types of feed (e.g., feeds or ingredients that do not flow freely or those inclined to bridge). The fitting of an aeration system to a hoppered bin is a means of storing and preserving grain. Aeration systems can be fitted to bins of various sizes, from small farm bins to industrial size bins. A single fan can be used to aerate a number of bins with the aid of branch pieces and damper valves.

It is recommended that feed bins are inspected regularly and cleaned; annually on cattle/sheep units and preferably twice or more per year on intensive pig/poultry units.

Image 7:
Flat bottomed bins

Image 8:
Hoppered bins

Key points include:

1. Bins should be empty at inspection.
2. Check for any possible leaks: damaged joints/seals, corrosion etc.
3. Repair damage so that the bin is damp proof, bird and vermin proof.
4. Check bins for structural damage such as bent trusses and loose or broken fasteners. Urgent repairs of damaged structural elements should be carried out.
5. Check for caked feed residues on bin surfaces and in augers.
6. Clean bins thoroughly, if necessary powerwash and allow to dry fully before refilling.
7. Clearly label each feed bin i.e., pigs, dairy, beef.

Safety Warning

Entering or cleaning bins presents health and safety risks:

1. Consult the Health and Safety Authority (HSA) "Code of Practice for Working in Confined Spaces" available on the HSA website at www.hsa.ie. This is particularly important in relation to entering grain bins.
2. Feed bins and stores can contain substantial amounts of dust which are hazardous to health. Dust can go on fire and cause an explosion.
3. Carbon dioxide or other gases may build up in bins or confined stores and can be extremely dangerous. Good ventilation is essential.
4. Stores may also contain dangerous fungal spores. Wear a suitable dust mask with an appropriate particulate filter, according to EN149, P2 or P3.
5. Vermin and bird contamination also pose a risk (e.g., weils disease - from contact with rat urine). Wear protecive clothing and gloves, and a suitable face mask. Cover any broken skin or cuts before working near or cleaning .stores/ bins.
6. Threading very dry grain poses a risk of engulfment/suffocation.
7. Beware of entanglement in augers.

Table 3: Approximate cost of bins and associated accessories (VAT Excl.)

	€/Unit
Bin capacity (t)	
10-12	3,000
30-40	9,000
50	11,000
>50	20,000
Concrete base	
3.6m x 3.6m x 0.3m (for 30t bin)	650
4.2m x 4.2m x 0.3m (for 50t bin)	750
Augers	
100mm emptying auger, motor + starter	750
150mm filling auger, motor + starter	1,500 - 3,500
Tractor driven hydraulic auger	1,500 - 5,000
Truck blown	-
PTO driver sucker blower	7,000
Aeration Unit	500 - 750

Image 9: Aeration system for multiple bins

Storage Pits for Treated Grains

There have been significant developments in the technologies for the preservation of high moisture grain on-farm. Where grain is to be used as feed on the farm, there are various methods of harvesting at moisture contents up to 40% and storing and feeding without the need for drying and rolling. A winter's feed supply can be stored, in a single operation, from harvest through to feeding out of grain. Some of these high moisture grain storage options, such as crimped or ammoniated grain, ideally require a walled pit (similar to a silage pit). There are two options for the construction of a pit for the storage of high moisture grain:

1. **Construction of a new storage pit for crimped/ammoniated grain storage (Feed Store 5).**

   This involves the construction of a three wall structure on a greenfield site. Table 4 outlines the dimensions and costs for a range of pit sizes.

Table 4: Construction of a new silage pit for crimped/ammoniated grain storage (Feed Store 5)

	Storage pit			Apron			
Pit capacity t	Length m	Width m	Area m^2	Length m	Width m	Area m^2	Total cost of silo €
50	8.3	4	33.2	4	4	16	8,089
100	12	6	72	6	6	36	12,930
150	16.7	6	100.2	6	6	36	16,826
200	17.5	7.6	133	8	7.6	60.8	19,651
250	22	7.6	167.2	8	7.6	60.8	23,615
300	24	8.3	199.2	8	8.3	66.4	26,313

Costs are based on: 1.8m high walls, 1.5m high pit face, a feed density of $1m^3/t$, two side walls, one back wall, concrete floor, front channel, small apron across front and a safety rail on walls. The ideal location is either on a greenfield site unroofed or it can be under an existing or new roof. The cost of the roof is not accounted for.

2. **Construction of a storage pit for crimped/ammoniated grain storage alongside an existing wall (Feed Store 6).**

   In this situation a new storage pit alongside the outside wall of an existing building or silage pit is constructed (see Image 10). It requires the construction of one side wall and an end wall. Table 5 outlines the dimensions and the costs for a range of pit sizes. The existing side wall must be suitably reinforced to withstand the loads involved. Itemised costs are presented in Table 6.

Image 10: Ensiling crimped grain in a pit constructed alongside an existing shed

Table 5: Construction of a storage pit alongside an existing wall - one new side wall and end wall (Feed Store 6)

	One Side Wall and End Wall			Apron			
Pit capacity t	Length m	Width m	Area m^2	Length m	Width m	Area m^2	Total cost of silo €
50	8.3	4	33.2	4	4	16	5,458
100	12	6	72	6	6	36	8,226
150	16.7	6	100.2	6	6	36	11,533
200	17.5	7.6	133	8	7.6	60.8	14,230
250	22	7.6	167.2	8	7.6	60.8	16,768
300	24	8.3	199.2	8	8.3	66.4	18,610

Costs are based on: 1.8m high walls, 1.5m high pit face, a feed density of $1m^3/t$, one side wall, one back wall, concrete floor, front channel, small apron across front and safety rail on walls. Ideal location is either adjacent to an existing suitably reinforced mass concrete wall or it can be under an existing roof, or it can be unroofed.

Table 6: Itemised costs for a storage pit for crimped/ammoniated grain storage with one new side wall and an end wall (Feed Store 6, capacity 100t)

Items being costed	Measurement factor	Cost per measurement factor (€)	Area, linear metres, each, etc., for this building	Costs (€)
Side walls 1.8m high	per linear metre	250	12	3,000
End wall 1.8m high	per linear metre	250	6	1,500
Floor including front channel	per m^2	32.5	72	2,340
Working apron - no channel	per m^2	30	36	1,080
Safety rail	per linear metre	17	18	306
Capacity	Tonnes	-	100	-
Net Cost	€	-	-	8,226

Costs are based on: 1.8m high walls, 1.5m high pit face, a feed density of $1m^3/t$, one side wall, one back wall, concrete floor, front channel, small apron across front, and safety rail on walls. The ideal location is either adjacent to an existing suitably reinforced mass concrete wall or it can be under an existing roof, or it can be unroofed.

CHAPTER 2 - GRAIN PRESERVATION OPTIONS

Low Moisture Grain Preservation Options

The primary purpose of any grain drying/storage system is to keep deterioration in the feed quality of the grain to a minimum during the storage period. Control of insects, moulds and mycotoxins in storage are key quality aspects for which the control of grain moisture and temperature is crucial. Three approaches are possible: the grain may be dried in a high-temperature dryer, the grain may be ventilated with an appropriate rate of ambient air or, a preservative based mainly on organic acids may be applied. Dried or treated grain is still at risk from insect attack, so some level of ventilation is required in all cases to reduce both temperature and insect propagation rate.

Safe moistures and temperatures

In most years, green grain from the combine has a short shelf life. To maintain the grain quality, the temperature and/or moisture must be quickly reduced to levels that will slow the onset of mould growth and infestation by insects or mites. Grain for conventional storage over six months should be stored at a maximum of 16% moisture although preferably 14.5% and kept cool. At 18% moisture, it should be stored for a maximum six months and kept cool with low volume ventilation fans. Figure 1 gives a guide on the temperatures and grain moistures that need to be achieved.

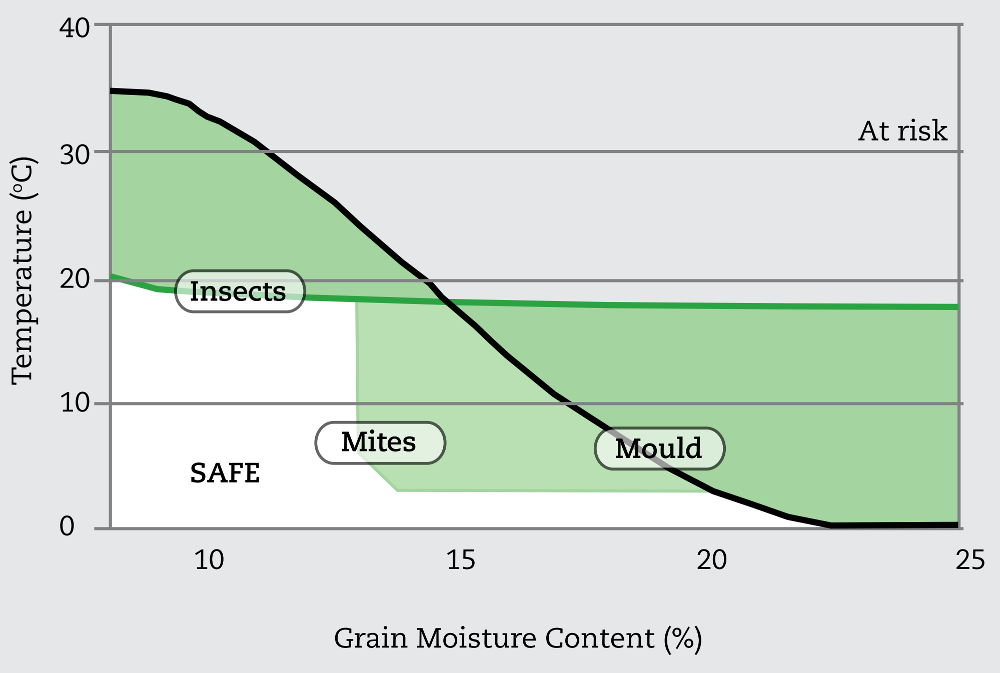


Figure 1. Safe grain moisture and temperature

Drying

Drying grain for on-farm use is the preserve of farmers handling large quantities of grain. Batch and continuous-flow driers are available in mobile form and this type of drier is an option for the livestock farmer who wishes to store grain on-farm without incurring the capital cost associated with a fixed drying facility. In most cases, the tractor PTO provides all drives to fans, loading augers etc and the only connection required is fuel supply. Loading and unloading of the batch type must be carefully managed, while the provision of continuous-flow type may limit their use on some sites. As sites are often improvised, the disposal of dust and exhaust air can often cause problems. Adequate ventilation/dust collection should be provided to control these problems.

In practice, for most livestock farmers considering the on-farm storage of grain, investment in drying facilities is not cost effective because the economies of scale do not exist. For this reason drying grain on livestock farms is not addressed in this publication.

Ventilation

Image 11: Example of a pedestal

Summary

Grain will store safely for 30 weeks with the correct ventilation rate (an air-flow of about 35m^3/h/t, provided the moisture content is not above 16% and the temperature is kept below 10^{o}C. It is very important that one is clear from the start of the maximum initial moisture content that the system is intended to handle, that adequate air is provided for that purpose, and that the ducts are big enough and at the correct spacing.

1. What grain moisture content can the store handle?
This is the most important issue to be decided in the initial planning of a ventilation system. Where any but the smallest lots of dried grain are stored, it is prudent to provide some level of ventilation to ensure that the grain can be kept cool and insect attacks can be controlled. A ventilation rate of $10m^3/h/t$ (6 cfm/t) is a minimum requirement for this purpose. For green grain from 16 to 20% to be stored for a period of time, an air-flow of about $35m^3/h/t$ (20 cfm/t) should be provided. This will keep the grain cool and achieve some drying in early autumn if the weather conditions are favourable.

Table 7: Ventilation rates required to cope with expected intake moisture content

Intake moisture content (%)	Minimum ventilation rate needed	
	$m^3/h/t$*	Cfm/t**
<16 or treated	10	6
16-20, untreated	35	20
20-22, untreated	70	40

* Cubic metres per hour of air per tonne of grain stored
** Cubic feet per minute of air per tonne of grain stored

On-floor storage and drying of grain at higher moisture is possible but increased ventilation rates and more powerful fans would also need to be provided as well as closer lateral ducts. It is very important that one is clear from the outset as to the maximum initial moisture content that the system can handle, that adequate air is provided for that purpose, and that the ducts are big enough and at the right spacing. Table 7 gives a guide to the ventilation rates needed for various starting moisture contents.

2. What storage space is needed?
One tonne of barley occupies about $1.4m^3$ (50 cubic feet). Wheat occupies about $1.3m^3$ (45 cubic feet). This allows the total required storage volume to be calculated. For example, to hold 200t of barley, a storage volume of $280m^3$ (10,000 cubic ft) will be required.

The next decision to be made is on the storage height. If a low ventilation rate (c. 10 to $20m^3/h/t$) has been selected the grain can be piled as high as the piling equipment, the roof height, or the height the retaining walls will allow. Remember that grain exerts a high sideways pressure on walls and at any height above 1.5m the possibility of this pressure knocking the wall must be considered.

In the case of the store for 200 tonnes, if a height of 3m (10ft) is chosen, a floor area of 93m^2 (1,000 sq ft) will be needed.

3. Should horizontal or vertical ducting systems be used?
Either is acceptable. Vertical ducts (pedestals) are suitable for the low ventilation rates needed for dry or treated grain. Horizontal ducts are more suited for the higher ventilation rates needed for wetter grain.

Horizontal ducting systems
Specifying the size of fan required
The fan can be specified in terms of the air volume and pressure required. The volume can be calculated from the tonnage and ventilation rate. The crop resistance can be estimated from Table 8. Add about 10mm w.g. to this figure to allow for duct losses and this will give a rough estimate of the fan pressure required. In the case of the fan for 200 tonnes, if a ventilation rate of 40m^3/h/t is chosen, a fan to deliver 8,000m^3/h against a pressure of 30mm w.g. (20 crop + 10 duct) will be needed.

The other decision to be made is whether to fit one big fan or several smaller ones. For bigger stores with single-phase electricity, more than one fan may be necessary. Otherwise, one big fan will usually cost less than two small ones.

Table 8: Approximate resistance to airflow in stored cereals

Ventilation rate m^3/h/t	grain depth (m)				
	2	3	4	5	6
	Airflow resistance (mm w.g.)				
10	2	4	8	13	18
20	4	9	17	27	39
30	6	14	26	42	62
40	8	20	36	59	88
50	11	25	47	77	116
60	13	31	59	97	147
70	16	37	71	118	180

Duct spacing
For low-moisture systems, horizontal duct spacing should not be more than 80% of the storage height. For wet-grain systems, the closer the better (false floors are ideal), but not more than one metre between centres. Pedestal spacing should be adjusted to provide the ventilation rates given in Table 7.

Duct size

The main duct in a horizontal system should have at least 1m^2 of cross-section per 36,000 m^3/h (1 sq. ft./2,000 cfm) of fan capacity. It should also be big enough to walk in so that lateral ducts can be opened and closed. This means a minimum size of 2m high x 0.75m wide (80 x 30 inches). The lateral ducts should be sized to achieve about 18,000 $m^3/h/m^2$ (1,000cfm/sq. ft.). This means that the system can work efficiently with half the lateral ducts closed off.

Pedestals

Pedestals are movable vertical ducts through which air is sucked from the grain. Their big advantage is that they are very easy to install and remove, and no changes are needed in the building structure. They are likely to be widely used for low-volume ventilation in the future. However, pedestals have limitations as well as their advantages:

1. When pedestals are used at the normally recommended spacings, the ventilation rate is likely to be in the region of 10 to 20m^3/h/t (5 to 10 cfm/t), i.e., the band suitable for maintaining the temperature of dried or treated grain. If they are used for moist grain, the spacing would need to be reduced to provide the higher air-flow rates as recommended in Table 8.
2. Pedestals are commonly supplied with one fan-motor unit to be moved between a number of them. This diminishes the ability of the system to cope with wet grain. The moving of the fan units from one pedestal to the next at the correct time interval requires a regular time input and attention to detail. Growers need to think carefully if they can provide this management input on a continuous basis.

Image 12: Extraction Fan on Gable

3. Pedestal ventilation transfers heat and moisture from the heap to the overhead space in the store. Another ventilation system is required to move this warm, moist air out of the shed, otherwise it will be re-circulated back through the grain. Provision for ventilation of the space above the grain should be made in all stores. In most cases, stores should have an extraction fan in one gable wall, in smaller sheds a natural draught may be enough. An extraction fan is particularly desirable where the space between the grain and roof is small, and where the roof is not insulated.
4. In conventional pedestal systems, the fans draw the air up through the pedestal and discharge it into the space above the grain. The cooling effect of pedestals reach a greater tonnage of grain when blowing rather than drawing the air. A facility to switch readily from one mode to the other is the ideal.
5. Pedestals are convenient tools for providing a low level of ventilation for dry or treated grain. Their use with moist untreated grain may stretch them beyond their capacity.

Controls

Fan thermostatic or time switches

The main purpose of most ventilation systems is to keep the grain temperature as low as possible. It follows that the fan should blow only when the air temperature is lower than the grain temperature. Blowing in periods of high air temperature is not only wasteful but it may wet the grain nearest the duct. The solution to this problem is to install differential thermostats to control the fans. Potato growers have been using these for many years and they are now available at reasonable prices.

Temperature monitors

It is good practice, and a requirement of the Grain Assurance Scheme, that the temperature of stored grain be monitored and recorded. Temperature monitoring equipment may vary from simple temperature probes costing not much more than €100 each to multi-channel recording systems as used by the bigger potato growers.

Image 13: Grain preserved using organic acid

Organic Acid Preservation

Traditionally, organic acid treatment (e.g., propionic acid) was widely used to preserve moist grain at a moisture content of 17 to 25% for home feeding on small farms with no drying facilities. For those with grain for use where drying is not essential this approach is worth consideration.

In recent years, it has become popular to roll grain at the time of organic acid treatment using a crimping machine and to store the grain aerobically in a clean, dry vermin proof store. This has the advantage of eliminating the workload attached to rolling at the time of feed-out and ensures the acid is uniformly applied. However, to control insects, the grain temperature must still be reduced after treatment so some ventilation is still necessary.

Treatment

- Whatever the application method, even application throughout and at the correct rate is vital for successful storage. It is preferable to treat grain using a crimping machine or with an acid applicator attached to a grain auger (application of the acid at the base of the auger ensures good coverage of the grain). Many medium/small feed operators will roll and treat grain simultaneously using a crimping machine.
- The flow rate of the organic acid is determined by multiplying the moisture content of the grain by the throughput of the auger. It is important to estimate moisture content of a representative sample before treatment and by using a dependable moisture meter. The grain moisture meters used by grain merchants are generally

not accurate above 25% moisture content. The cost of organic acid treatment can be prohibitive at high moisture contents.

- Where grain has a high and variable moisture content it is very difficult to avoid patchy results with acid. It is advised, where grain has a variable moisture content, to apply propionic acid at the rate for the higher moisture content grain.
- Application rates: the application rate depends on the moisture content of the material. As moisture content increases, susceptibility to mould and bacterial contamination increases and thus more acid per tonne of grain is required. Table 9 presents the application rates per tonne of grain.

Table 9: Application rate of propionic acid, depending on the moisture content of the material

Cereal moisture content %	Litres/tonne (Propionic Acid Solution)
16	5.5
18	6.5
20	7.5
22	8.5
24	9.5
28	11.5
32	14.5
40	20.5

- It is well established that under treatment of grain will not halt mould and bacterial activity.
- For long-term storage of grain, rolled and treated off the combine, increase the application rate by 10%. For pulses also increase the rate by 10%. When moisture content is less than 25%, it will be necessary to crack pulse seeds prior to treatment.

Storage

- Acid treated grain should be stored on a dry clean floor which has been lined with clean plastic sheeting.
- The treated grain must be kept cool, otherwise insects can become a problem.
- It is important that the grain is stored in shallow piles preferably with some ventilation. The acid treatment will not control insect pests, and they may become a problem if the temperature creeps up. Ideally, the ventilation rate in this situation would be quite low and thermostat-controlled, so the level of ventilation would do little to remove the acid from the crop.
- Do not store untreated grain with treated grain as it can draw in moisture and heat
- The costs associated with treatment/processing are presented in Table 12 (page 51).

Safety

Organic acids are inflammable corrosive liquids and must be handled with care. Protective clothing should be worn and any acid on the skin should immediately be thoroughly washed off. Eye contact requires prompt washing for at least 15 minutes and medical attention should be obtained without delay. If swallowed, do NOT induce vomiting – give water or milk.

To avoid high concentrations of acid in the air, treatment should be completed in the open air. If this is not possible, a suitable mask should be used and an artificial draught created.

High Moisture Grain Preservation Options

Cereal grain of less than 14% moisture can be safely stored for an extended duration. As grain moisture content rises the duration of safe storage becomes shorter and the requirement for aeration initially, and then for drying or other preservation treatments, progressively increases. Alternative technologies used in recent years facilitate systems of successfully conserving grain harvested at up to 40% moisture.

The main challenge with the storage of high-moisture grain is the control of mould growth. In some treatments this is achieved by storage in air-free conditions, in others by treatment with chemicals such as organic acids or caustic soda. Some treatments also alter the physical characteristics and modify the nutritive value of the grain.

Research studies suggest that as the grain dry matter (DM) of cereals (including winter barley, wheat and triticale) advances from 55 to 80%, grain DM yield as well as nutritive value and harvesting losses remain constant. This indicates that farmers harvesting grain, produced using high input practices under Irish conditions, can employ a range of conservation technologies without compromising the yield or quality of the harvested grain.

Grain DM concentration can increase by an average of 1.6 to 2.9% per day. Therefore, grain needs to be monitored daily if a target DM concentration is to be achieved at harvest. This can have implications for the grain conservation strategy chosen as individual conservation systems have preferred moisture contents at which they operate.

High moisture grain, if left in a pile, will heat quickly. It is advised that the processing and ensiling process be completed quickly (within 24 hours) to avoid losses. Vermin can be a problem with some high moisture grain storage options, ensure adequate bait points are positioned around the clamp/store (see Appendix 3).

The most common high-moisture treatment/storage options are outlined in the following pages.

Crimping

This involves harvesting grain at 30 to 45% moisture, crushing the grain and storing it anaerobically until feeding time. Under these conditions the grain undergoes lactic acid fermentation. Suitable crops include barley, wheat, triticale, oats, maize, peas and beans. Crucial to the success of this system is achieving and maintaining strictly air-free conditions throughout storage and minimising the duration of access to air during feed-out. The use of mould-inhibiting additives (bacterial innoculant, acid or ammonia based), prior to ensiling, helps to limit spoilage of the grain during feed-out.

Harvesting

- Harvest three to four weeks before conventional harvest date when the grain is at 30 to 40% moisture. Monitor the grain daily if a target DM concentration is to be achieved at harvest. Grain moisture content can change very rapidly when an extended duration of wet weather is followed by dry weather conditions. This can be quite restrictive and the timing of harvesting crucial.
- When the settings on the combine-harvester and its forward speed are set appropriately, grain losses at the front of the harvester or via the straw are similar to those achieved with conventional dry grain. It is commonly noted that the rate of harvesting is slower. Straw can be baled conventionally after three to four days drying.
- Target moisture contents of 30% or greater. Grain has been successfully crimped below this moisture content but compaction, sealing, fast and careful feed-out etc must be excellent.
- The moisture content of the crop should be estimated. Most moisture meters are not reliable above 25% MC. The alternative is to use a laboratory tested oven dry matter.

Treatment

- Crimping (rolling) cracks the seed coat and the additive is applied via an additive pump. The quantity of additive needed will depend on the crop being ensiled, the moisture content of the crop and the type of additive used.
- Water may also be added at crimping.
- Bacterial innoculants, acid or ammonia based additives may be used. For further information on the reliability of the additive options, contact your local Teagasc adviser.

Storage

- The exclusion of air to promote anaerobic conditions and consequently fermentation as quickly as possible is critical. The ensiled crop ferments and stabilises at a pH of 4 to 4.5. This should be done as quickly (within 16 to 24 hours) as possible to prevent the grain from heating. Poorly packed processed grain is susceptible to air infiltration and thus to extensive mould growth.
- The clamp should be on a concrete base. For a temporary structure, silo walls can be constructed with plywood or 4 x 4 bales covered in a polythene sheet. However, if this is a long-term strategy for the on-farm storage of grain, an existing or new silage pit should be used.
- When ensiling crimped grain, it is imperative to keep the grain clean and avoid dirt such as soil getting into the clamp. Prior to crimping ensure that the concrete on which the grain is tipped is clean and the wheels of machinery are also kept clean.
- The sides of the clamp should be lined with good quality 500 gauge polythene sheeting. It is also important to prepare a top sheet to cover the whole clamp.
- The grain should be rolled and compacted thoroughly. Make sure that the clamp is wide enough that the tractor can roll the width of the pit.
- The grain can be stored at heights of between 0.5m and 2.5m. Long narrow clamps work best in minimising grain exposure to air. Wider pits will work well if the pit is managed exceptionally well. Ideally, the pit face should be removed two to three times per week. Pit management is essential to the successful use of crimped grain.
- As a rule of thumb, one tonne of crimped grain occupies approximately one cubic metre of storage space.
- It is important that bait points are placed around the silo to ensure that rodents do not become a problem.
- Costs associated with treatment/processing are presented in Table 12.

Safety Warning

Acids are dangerous corrosive chemicals. Storage should be secure and the safety instructions provided by the supplier followed. Extreme care is required during handling and full protective clothing is essential.

Ammoniation

Urea is the most common source of ammonia used to treat grain harvested at 30 to 35%, but anhydrous or aqueous ammonia could also be used. The whole grain is stored under sealed, air-free conditions (e.g., sealed beneath conventional silage plastic sheeting) to prevent ammonia loss. The ammonia prevents mould growth and when it binds with moisture in the seed-coat of the grain the resultant hydroxide effect is expected to replace the need to roll the grain. This is not always the case, particularly at low moisture content (26 to 28%). Urea treated grain can be fed whole to cattle without the need for rolling. However, if the grain is dry, losses of grain in the faeces may be high and some physical processing (i.e., rolling) may be necessary. This is a significant disadvantage to the ammonia treatment option. The grain is ensiled in a sealed clamp/silo. The urea increases the protein content of the grain (depending on application rate), but otherwise, the feeding value on a dry matter basis is unaltered.

Harvesting

- The grain should be harvested three weeks before normal harvest at 30 to 35% moisture content (MC). It is important that the grain is not harvested at less than 30% MC. Moisture content should be estimated prior to treatment. The grain should be of a firm doughy texture at this stage and also can be split with a thumbnail.

Treatment

- It is important to treat the grain soon (three to four hours) after harvest. A ready made solution of feed grade urea can be purchased or alternatively it can be mixed on the farm but it must be mixed correctly. Urea is poisonous, make sure to break up all urea lumps before application. There are a number of urea based additives available on the market. The cost effectiveness of these should be checked before selection with a Teagasc adviser.
- Treating grain with urea is generally done with a mixer wagon. Using a feed wagon to mix the urea, the grain is weighed into the feed wagon, the appropriate amount of liquid urea is added to the wagon and mixed for two to three minutes (Table 10). Thorough mixing is essential. It is then emptied into the pit. Alternatively, grain can be crimped and treated with a urea based additive.

Table 10: The relationship between grain moisture content and water required (litres/t)

Moisture Content %	Urea Solution litre/t	
	Wheat	Barley
25	40	53
30	43	57
35	46	62

Storage

- The storage procedure is similar to crimped grain.
- Treated grain can be stored in a silage clamp or on a concrete pad. Using a concrete pad silage bales can be used to form pit walls with plastic sheeting used to line the inside.
- Seal the pit well to prevent ammonia leakage. Anaerobic conditions are not required but it is important to retain as much ammonia in contact with the grain as possible. It is not neccessary to tightly roll the clamp.
- Grain should be left for four weeks before feeding to allow the urea to hydrolyse to ammonia which renders the seed coat more digestible. Do not feed urea treated grain along with other urea treated feeds e.g., whole crop or molasses based urea liquids. Excess urea in the diet can be fatal.
- Costs associated with treatment/processing are presented in Table 12.

Safety Warning

Urea is poisonous if consumed by animals. Ensure animals do not drink the wash water from the machine. It should be stored securely and the safety instructions provided by the supplier followed. Extreme care is required during handling. Full protective clothing is essential.

Alkali Treatment

The treatment of grain with sodium hydroxide (caustic soda) disrupts the seed coat of the grain so that the grain can be fed directly to cattle without further processing. Whole grain harvested at up to 30% moisture is soaked in or sprayed with sodium hydroxide solution. This grain is then stored aerobically. The grain is harvested at the conventional stage or slightly earlier (15 to 30% moisture).

Treatment

- Grain can be treated effectively with sodium hydroxide using a diet feeder.
- As with any feed store, cleanliness is critical. Ensure both the loader, feeder and the storage area are clean.
- The application rates are:
  - For wheat, add 3% sodium hydroxide or 30kg per tonne of grain. If wheat is dry, it may be necessary to increase the rate to 4%.
  - For barley, add 5% sodium hydroxide or 50kg per tonne of grain.
- Grain is treated in a feeder wagon. Add the grain, typically three to four tonnes, with the feeder rotating, add the caustic soda evenly to the feeder using the grain bucket. Dry mix the caustic soda with the grain for five minutes, then add the water and mix for at least 10 minutes. Water (litres or kg water per tonne of grain) is added according to the scale below (Table 11).

Table 11: The relationship between grain moisture content and water required

	Grain Moisture Content %				
	20	18	16	14	12
Immediate feeding	100	130	165	210	225
Longer storage	40	60	80	100	140

Thorough mixing for 10 to 15 minutes is essential. As treatment progresses, the grain becomes darker in colour. Aim to take grain to approximately 22% MC for storage longer than three months and 27 to 30% moisture for earlier use.

- Empty the wagon and allow the treated grain to stand in a heap for four to six hours. This allows the heat of the caustic soda to break down the grain coat. The treated grain should then be spread out, not more than 1ft high, to cool down. It is important that the grain is allowed to cool thoroughly before final heaping and storing for any period of time. Otherwise, the heap may be rock hard and difficult to feed.
- The stored grain will have a white 'bloom'. This is not mould but sodium bicarbonate formed from the reaction of caustic soda with atmospheric carbon dioxide. Moulding can occur if the grain is contaminated with dirt.
- Clean out the feeder after mixing with either hay, straw or silage. Mix these in the feeder for 10 minutes. Do not feed this material to cattle for 24 hours.

Storage

- Store grain in clean dry conditions. Soda grain can be stored under cover for long periods following thorough cooling. As a precaution, check the stored grain regularly for signs of heating, condensation and spoilage.
- Soda grain is unpalatable to both birds and rodents and can be stored for long periods.
- Soda grain should not be mixed with other feeds prior to storage. Feeding can commence after four days.
- Soda grain stored for long periods of time dries out. Digestibility may be reduced where this occurs and whole grain may be evident in the cow dung. Stored soda grain should be wetted before feeding to soften the grain and ensure good utilisation. It should be moistened before feeding by adding 150 to 200kg of water per tonne of grain.
- Costs associated with treatment/processing are presented in Table 12.

Safety Warning

Caustic soda is a dangerous corrosive chemical. It should be stored securely and the safety instructions provided by the supplier applied. Extreme care is required during handling. Full protective clothing is essential. Accidental contact between caustic soda and skin will cause severe burns if not washed with liberal quantities of running water immediately.

Minimise the handling of bags and always use full bags – do not handle or store part bags. Avoid windy conditions when preparing caustic grain and always add water carefully.

Mixing in a diet feeder is not without hazard. Do not attempt to add caustic or water by climbing onto the feeder or by standing in the loader bucket. Use the loader bucket to fill the diet feeder wagon. All surfaces in contact with caustic grain are slippery and dangerous.

Table 12: Costs associated with grain preservation options

	Dried	Crimped[5]	Ammonia[6] treatment	Alkali[7] treatment	Acid[8] treatment
Moisture content at harvest %	20	35	35	20	20
Price of grain @ 20% moisture	120	120	120	120	120
Cost of grain @ harvested MC%	120	98	98	120	120
Costs					
Drying[1]	18				
Additive		8	14	21	12.4
Processing (rolling or mixing)[2]	15	15	7	7	15
Ensiling		0.3	0.3		
Moisture loss[3] €	7.7				
Invisible loss[4] €	2.8	6	3.6	4.4	4.4
Total treatment costs/tonne fresh[9]	43	29	25	32	32
Total treatment costs/tonne DM	54	45	38	41	40
Total treatment costs @ 18% MC	44	37	31	34	33

Assumptions

[1]Grain dried from 20% MC to 15% MC.

[2]Hired contractor costing €70/hr (includes tractor and diet feed + loader + two labour units), treating 10 tonnes of grain per hour.

[3]Moisture losses: see Appendix 1, invisible losses 1.8%.

[4]Crimped grain - 5% losses; ammonia treated grain - 3% losses; alkali treated grain - 5% losses; acid treated grain - 3% losses.

[5]Crimped grain additive: €8/t.

[6]Urea: €460/t of feed grade urea, application rate 30kg/t.

[7]Sodium hydroxide prills: €700/t, application rate 30kg/t.

[8]Propionic acid: €1.5/l of propionic acid, application rate 8.25l/t, grain is acid treated and rolled concurrently.

[9]No cost has been included here for the storage structure used or for ventilating dried or organic acid treated grain.

CHAPTER 3 - CHOICE OF SYSTEM

Whatever the type of investment in drying/storage system is being considered, it is very important to fully evaluate the costs. This is particularly so where the option of purchasing green grain direct from the combine (or growing one's own grain) is being compared with dried, rolled grain purchased as required. Table 13 presents the preservation options and the type of storage structure needed for such grain. The storage structure (existing or new) on the farm will dictate the most appropriate preservation option.

Table 13: Options for preservation and storage of grain

Preservation Option	Optimum moisture content %	Requirement for ventilation	Storage unit
Dried	14	Yes	Feed store or bin
Green	15-16	Yes	Feed store or bin
Organic acid treated	18-22	Yes	Feed store or bin
Crimped	30-40	No	Ensiled anaerobically
Ammonia treated	30-40	No	Ensiled and sealed
Alkali treated	18-22	No	Feed store

As is evident in Table 13 above, there are a number of options available to most farmers. The two primary costs associated with on-farm storage are the store and the preservation costs.

Storage

The cost of storage per tonne of feed stored is presented in Table 14. Three different utilisation rates are assumed 100%, 50% and 25%. Utilisation rate is assumed to be the percentage of the shed storing feed. For example, Feed Store 1 has the capacity to store 865 tonnes of feed. If this unit is operating at a utilisation rate of 25% of capacity, 216 tonnes of feed will be stored.

Table 14: Estimates of the cost of storage per tonne of feed stored for Feed Stores 1 to 6

	Gross cost €	Storage capacity/t	% of capacity utilised	Cost €/tonne	Potential extra tax savings €
Feed Store 1	65,830	865	100	12	24,770
Feed Store 1	65,830	865	50	18.6	24,770
Feed Store 1	65,830	865	25	31.9	24,770
Feed Store 2	50,400	639	100	12.2	18,946
Feed Store 2	50,400	639	50	19.1	18,946
Feed Store 2	50,400	639	25	32.9	18,946
Feed Store 3	37,133	330	100	15.2	13,952
Feed Store 3	37,133	330	50	25	13,952
Feed Store 3	37,133	330	25	44.7	13,952
Feed Store 4	55,000	544	100	14.2	20,665
Feed Store 4	55,000	544	50	23	20,665
Feed Store 4	55,000	544	25	40.7	20,665
Feed Store 5	12,930	100	100	16.6	4,865
Feed Store 5	12,930	100	50	27.9	4,865
Feed Store 5	12,930	100	25	50.5	4,865
Feed Store 6	8,226	100	100	12.5	3,091
Feed Store 6	8,226	100	50	19.7	3,091
Feed Store 6	8,226	100	25	34.1	3,091

Feed Stores 1, 2 and 4 are new feed storage units,
Feed Store 3 is an existing round roofed shed converted to a four-bay feed store
Feed Store 5 is a new silage pit for crimped/ammoniated grain storage
Feed Store 6 is a new two wall structure, alongside an existing wall for crimped/ammoniated grain storage

Assumptions

- The useful lifespan of the store is 20 years.
- The value of the building at the end of its useful life as a percentage of the initial cost is 80%.
- The structure will not depreciate down to zero.
- The 80% of the initial investment cost allows for the flexibility to use the store for alternative uses in the future.

- The inflation rate is 2%.
- The borrowing interest rate is 5%.
- The length of the loan is 10 years.
- The savings are zero.
- The marginal rate of tax is 50%; it is assumed it would be difficult for an individual paying the lower rate of tax to justify the unit.
- The ventilation cost is €1.30/t of the feed stored. The ventilation output is adequate to hold grain at 16% MC. This includes the capital cost for the pedestals and motor as well as the air extraction unit. It is assumed that ventilation is required for organic acid treated grain and green grain stored at 18% MC or less.
- The grain store repairs and maintenance cost is 1.5% of the initial investment cost, including cleaning, lighting, store repairs and motor repairs for ventilation unit and extraction fan.
- The capacity utilised is 100%, 50%, 25%. In practice, many farmers operate at between 20 to 50% of the storage capacity of the store. This additional space could be used for ease of manoeuvrability in the unit or storing machinery etc. However, it is impossible to value this space but individual farmers should consider its value.
- No costs are included for preservation apart from low level ventilation in the stores.
- The average storage period for working capital is five months, green grain price of €120/t and an interest rate of 3% above the borrowing interest rate.
- For the crimped and urea treated grain storage pit, all assumptions are as above with repairs and maintenance costs assumed to be 0.33% of the initial investment cost.
- Full capital allowances are not utilised above due to the low level of extra income generated relative to the capital investment. The 'potential extra tax saving' is the total, net extra saving in tax. This will be saved over the seven years that capital allowances can be claimed only if there is sufficient income from other sources that could be used to offset against the capital allowances (tax rate assumed at 50% for each of the seven years). The total figure is reclaimable over the full seven-year period and there is no time value of money included in this portion of the calculation.
- The above costings are a general guide only as facilities and scale of operation at individual farm level will vary.

Example

A farmer intending to build Feed Store 1 will use, on average, 432 tonnes of feed each year for 20 years. The utilisation rate is therefore 50%. The cost of storage will be €18.6/t of feed for each of 20 years. This cost does not include losses (moisture losses or invisible losses), preservation costs (apart from minimal ventilation), labour requirements or capital investment/running costs for ancillary machinery.

Comments

1. It is critical, in selecting a storage structure that the total cost of the construction and the cost per tonne of feed stored is accounted for in the decision making process. Crucially, it is the cost per tonne of feed stored on the farm, compared to the cost per tonne of feed purchased as required, which will dictate the economics of on-farm storage. The cost per tonne of feed stored must include the cost of the storage unit as well as storage losses, working capital and preservation costs.
2. The utilisation rate of the storage units is the single biggest variable contributing to the cost per tonne of stored feed. For example, Feed Store 2 has the capacity to store 639 tonnes of feed. At 100% utilisation, the storage cost associated with every tonne of feed over the 20 year lifespan of the unit is €12.2. However, if the unit is only operating at 25% of capacity, or 160 tonnes, then the storage cost associated with every tonne of feed is €32.9, making the unit totally unviable. It is the experience of the authors that, in reality, many storage units are operating at significantly less than 50% of capacity.
3. In Feed Stores 1 and 2, in particular, it is unlikely that the full capacity is utilised and there is a lot of extra floor space to allow for ease of loading/unloading, mixing etc. There is a significant cost attached to this under-utilised floor space. It could be argued that this area can be used to store machinery etc at different times of the year. In the above calculations, no additional value is placed on this floor space.
4. Many farmers considering the on-farm storage of grain, may consider the alteration of an existing building. Feed Store 3 is such an example. An existing round roof shed is converted to a four-bay storage unit with individual roller doors on each of the bays. This unit does not have floor space for loading/unloading, mixing etc and all such operations must be done on a concrete apron at the front of the store. It might be expected that this store would be somewhat cheaper per tonne because it is an alteration to an existing building rather than a greenfield site. It is evident from Table 14 that initial capital investment in this unit (Feed Store 3) is €37,133. The capital cost of this unit is high because of the cost of the four sets of roller doors, the internal dividing walls and the low capacity, relative to Stores 1 and 2. No opportunity cost was attributed to the alteration of the existing shed in this case, which is now no longer available for alternative uses. This further increases the cost of this unit. It is also worth noting that Feed Store 3 does not have the same degree of flexibility as Feed Stores 1 and 2 for alternative uses in the future.
5. The preservation of high moisture grain for on-farm use has become popular in recent years. The total capital cost associated with these

structures is low relative to enclosed storage units. For many, this option will not entail the construction of a new pit but the alteration of an existing pit, as in Feed Store 6. With the feed store operating at 100%, 50% and 25% of capacity, the cost per tonne does not differ much from that of either units 1, 2, 3, 4 or 5. In reality, for most moderate sized livestock farms, units 1 and 2 will only operate at 20 to 30% of capacity, while a silo with a capacity for 100 to 200 tonnes will probably operate at close to 100% of capacity.

6. In selecting an appropriate storage unit for feed on-farm, the scale of the operation i.e., the tonnes utilised per annum will dictate the percentage of capacity utilised on each of the units and the likely cost per tonne. With a capacity of 639 tonnes the utilisation rate is 25% of capacity. The cost per tonne of feed stored would be €32.9/t for each of the 20 years. This excludes the costs associated with the preservation of the grain. Consequently, the storage unit should match the scale of the operation.
7. The capital outlay involved in constructing a purpose-built storage unit is high and is unlikely to be economical for most livestock farmers. The modification of an existing building may be an option, but only where throughput is high and the initial capital investment is not high. The expectation would be that Feed Store 3, the alteration to an existing shed, would be the most cost effective however when the construction of roller doors and internal walls is included it remains expensive, particularly at low utilisation rate.

Preservation

Grain preservation systems incur treatment, processing and storage costs as well as visible and invisible losses. For some, there is additional capital investment in the handling facilities for treatment and feeding out. Table 12 presents a guide on the costs associated with the treatment and preservation of grain. There are differences of up to €14/t of grain treated, with drying being the most costly. Relatively small differences exist between the treated grain options. Preservation cost cannot be examined in isolation. The storage costs associated with the alkali or organic acid treatments are likely to be higher than for either the crimped or urea treated grain.

The advantages and disadvantages to each of the preservation options include:

1. High moisture grain preservation options (crimping and urea treatment) allow an earlier harvest and re-use of the cereal field. They may also allow better utilisation of the combine harvester by extending the harvest period. On the other hand timely co-ordination of a number of activities during the harvest-process period is required and which may clash with conventional harvesting on the farm.
2. Some preservation options may enhance feeding value. For instance, ammoniation treatment will increase protein level in the feed. However, this is not always as significant as figures might suggest.
3. Labour is one of the most limiting factors on many livestock farms today. Rolling grain on a weekly basis to feed stock is an inefficient operation. Many farmers have either automated the rolling process or alternatively contracted out the operation to mobile crimping units, who will process the grain at regular intervals throughout the winter. With high moisture grain preservation options, many have removed the requirement for rolling through preservation and processing at the time of harvesting.
4. To date, high-moisture grain has been grown, stored and fed on the same farm and this is likely to remain the most common method of utilisation. However, short-distance transport of the harvested grain from the grower for ensiling by the feeder should be easy to organise. Ensiling in sealed, transportable bags is another possibility that requires research. These approaches may attract non-feeding growers to become involved with high-moisture grain preservation systems.
5. Dried rolled grain is more easily traded from the feed store than any of the high moisture grain options. Organic acid treated grain as well as crimped ammonia treated and caustic treated grain can only be used for animal feed.

Deciding Factors on Preservation Options	
Capital Investment	**What capital investment is needed in storage facilities?**
Storage and treatment costs	What moisture content will the grain be harvested at and what is the most appropriate grain preservation option? Do I have the facilities to ventilate organic acid treated grain? Do I have access to a diet feeder if I intend ammoniating or caustic treating grain? Is there a crimping machine in the area to roll grain as I need it? Is there a mobile dryer in the area?
Existing facilities	What are my existing facilities on the farm? Is there a shed that could easily be converted into a grain store? Is there a silage pit in the yard that could be used?
Handling equipment	Do I need to invest in additional machinery for the treatment or handling of the grain; the investment in a diet feeder, loader or crimping machine can make many storage options unviable, unless there is a significant scale of operation involved.
Flexibility	Some treatment options allow more flexibility in terms of selling grain subsequently, if there is a price rise. It is a lot easier to trade dried grain than it is to trade ensiled, crimped or urea treated grain.
Harvesting	The window for harvesting grain for some of the treatment options is short. Do I have access to harvesting and processing equipment at short notice?
Labour	Is there a significant labour input required for each option? Labour is a scarce commodity on many farms. Crimped grain has a limited labour requirement when it is treated and ensiled. While caustic treated grain has a higher labour input, labour is scarce on many farms and on-farm storage of grain can complicate an otherwise simple feeding system.
Risk analysis	What are the likely risks associated with on-farm storage of feed? Is vermin likely to be a problem? Will farm management skills be adequate to minimise storage losses?
Storage losses	What are the likely storage losses associated with each option? If treated correctly, each option can have low losses.
Alternative uses for the storage structure	What are the alternative uses for the storage structure if, in five years time, cattle are not being fed. The feed bin has only one storage use while a storage shed can be used for alternative purposes, some of which include machinery storage, straw, woodchip etc.
Management skills	Do I have the management skills to operate a storage system on-farm? Home mixing requires the purchase of concentrate ingredients to balance the home-stored cereal. It can take significant time and skill to assess the markets and ensure good value for money. It is important that other practices on the farm don't suffer as a result of setting up on-farm storage.
Legislation	Will the feed storage unit meet the requirements of the DAFF for on-farm storage of feeds.

Case Studies

Scenario 1 – Beef farmer finishing 150 cattle annually
The total concentrate feed input is 150 tonnes per annum. It is assumed that 100 tonnes of cereal and 50 tonnes of a balancer feed are used. The farmer is considering ensiling the 100 tonnes of grain as crimped grain in a pit constructed alongside an existing silage pit. A new side wall and end wall must be constructed (see Feed Store 6, Table 5). Feed Store 6 will be utilised at 100% of its capacity. The 50 tonnes of balancer will be stored in a 12-tonne feed bin and filled four times annually. What are the costs associated with this option?

The initial capital costs associated with the silage pit and feed bin are assumed to be €8,226 and €3,650, respectively. The costs per tonne, associated with the storage and preservation of the crimped grain are presented in Table 15. Preservation costs include processing, additive treatment, ensiling and storage losses.

Relative to purchasing rolled grain as required, the price differential between green grain (20% MC) and rolled grain must exceed €53/t to justify crimped grain storage in this scenario.

Table 15: Costs associated with the storage and preservation of 100 tonnes of cereal as crimped grain

	€/t
Storage	12.5
Processing (crimping)	15
Additive	8
Ensiling	0.3
Storage losses	6
Total cost of storing and treating crimped grain @ 35% MC	€41.8/t
The total cost equivalent @ 18% MC[1]	€53/t

[1]It is assumed that rolled grain is traded at 18% MC and for comparison purposes the crimped grain is expressed in the same terms, but the crimped grain is stored at 35% moisture content in this case

For the feed bin, working capital is assumed to be for one-quarter of the year and utilisation of capacity is assumed to be 400% (capacity is 12 tonnes, filled four times annually). All other assumptions are as above for other feed stores. It is also assumed that there is no additional processing or treatment costs for the balancer feed and the only cost is the storage cost. The cost of storage for the balancer feed is estimated at €10.10/t.

The total cost of feed stored and preserved (crimped grain + balancer) is €5,805 per annum for 150 tonnes [(53*100)+(10.1*50)].

In individual farm situations, it could be argued that an existing silage pit would be used and therefore there is no capital cost for the pit but the pit could have alternative uses and therefore there is an opportunity cost associated with it.

It is assumed that the handling equipment needed for feeding out is already present on the farm and no additional investment in ancillary machinery is required. Any additional investment in handling/feeding out equipment will add significantly to the cost per tonne of feed stored.

The 'potential extra tax saving' is €4,398, the net extra total saving in tax to be paid over the seven years that capital allowances can be claimed, if there is income from other sources that could be used to offset against the capital allowances.

Scenario 2 - Dairy farmer with 200 spring-calving dairy cows using 100 tonnes of concentrate feed on an annual basis.

It is assumed the farmer will use 40% cereal in the concentrate mix and 60% balancer (two concentrate ingredients and a mineral mixture). Green grain can be purchased from a local tillage farmer at €120/t, delivered. Assuming the grain will be delivered at 20% MC, the farmer will treat the grain with an organic acid (e.g., propionic acid), roll concurrently and ventilate in storage. An existing round roof shed will be converted into a four-bay feed storage unit, similar to Feed Store 3. Bay 1 will be used to store cereal, Bays 2 and 3 will store concentrate ingredients and Bay 4 will store minerals, milk replacer and other feed supplements.

The capital cost associated with the conversion of the round roof shed to a four-bay feed store is estimated at €37,133. Assuming that this store has the capacity to accommodate 400 tonnes of feed, the current dairy production system is only operating at 25% of the store's capacity.

The cost of preservation applies only to the 40 tonnes of cereal utilised. The cost of preservation of the grain is €31.8/t (12.4+15+4.4, Table 16).

The total cost associated with the preservation and storage of feed (grain + concentrate ingredients) on this farm is €5,750/annum or €57.5/t. Therefore, an additional €57.5/t needs to be added to the price of green grain and other concentrate ingredients purchased for storage, in order to compare on-farm storage to buying a balanced concentrate feed as required.

There may be additional tax benefits to the construction of this unit. The 'potential extra tax saving' is €13,952, the net extra total saving in tax to be paid over the seven years that capital allowances can be claimed, if there is income from other sources that could be used to offset against the capital allowances.

Table 16: Costs associated with storing 100 tonnes of feed in a four-bay unit

	€/tonne
Cost of grain preservation and storage	
Acid	12.4
Rolling	15
Losses	4.4
Storage	44.7
Total cost per tonne of grain stored at 20% MC	76.5
Total cost per tonne of storage for the concentrate ingredients	44.7
Total cost of preservation and storage € per tonne grain and concentrate ingredients[1]	57.4

[1]Note: ((40*76.5) + (44.7*60))/100

It is assumed that the handling equipment needed for feeding out is already present on the farm and that no additional investment in ancillary machinery is needed. Any additional investment in handling/feeding out equipment will add significantly to the cost per tonne of feed stored.

Scenario 3 - Dairy farmer with 300 spring-calving dairy cows using 150 tonnes of concentrate feed annually.
It is assumed that he will use 40% cereal in the concentrate mix and 60% balancer (two concentrate ingredients and a mineral mixture). Green grain can be purchased from a local tillage farmer at €120/t, delivered. Assuming the grain will be delivered at 20% moisture content, he will treat the grain with an organic acid (e.g., propionic acid), roll it concurrently and ventilate the grain in storage. The farmer has an existing unused covered silage pit which he intends to convert into a feed store (See Feed Store 3, Chapter 1 for details). This unit will have the capacity to store 459 tonnes of feed. Therefore, it will be operating at 33% of capacity. What will the cost of the feed stored be?
The initial capital cost associated with the conversion of the existing covered silage pit is assumed to be €12,750. An opportunity cost should be attributed to this unit, as it is no longer available for alternative uses.

Table 17 presents the costs associated with the preservation of the grain on-farm and the storage of the grain and concentrate ingredients. The cost of preservation applies only to the 60 tonnes of cereal utilised. The total cost associated with the preservation and storage of the feed on this farm is €3,738/annum or €24.9/t of feed. Therefore, an additional €24.9/t would need to be added to the cost of every one tonne of grain and concentrate ingredient purchased.

There may be additional tax benefits to the construction of this unit. The 'potential extra tax saving' is €5,039, the net extra total saving in tax to be paid over the seven years that capital allowances can be claimed, if there is income from other sources that could be used to offset against the capital allowances. The current volatility in the dairy markets means that there could be a big question mark over this.

[1] 1 Note : ((60*44) + (12.2*90))/150

Table 17: Costs associated with storing and preserving 150 tonnes of feed in an altered existing shed, similar to Feed Store 2

	€/tonne
Acid	12.4
Rolling	15
Losses	4.4
Storage	12.2
Total cost for storing and preserving grain	44
Cost per tonne of storage for the concentrate ingredients	12.2
Total cost of preservation and storage of all feed (grain + concentrate ingredients)[1]	24.9

Weather conditions at the time of harvest will have a major impact on the moisture content of grain and the preservation requirements in storage. In situations where grain can be harvested at 16% MC or less, ventilation may be adequate to ensure preservation over the winter feeding period, assuming the output of the pedestals is adequate (see Chapter 2 above).

It is assumed that the handling equipment needed for feeding out is already present on the farm and no additional investment in ancillary machinery is needed. Any additional investment in handling/feeding out equipment will add significantly to the cost per tonne of feed stored.

Scenario 4 - Tillage farmer with 93 hectares of spring barley with average yield over the past five years at seven tonnes per hectare.

The construction of a 640-tonne grain shed is considered. This unit would be fully equipped with a ventilation system but the farmer intends taking a risk on not investing in permanent drying facilities. The hope is that the grain will be harvested at 16% MC or less and that he will be able to store it for six months with adequate ventilation. What increase in price is needed to justify the capital investment in storage facilities?

The initial capital investment in a grain store with the capacity for 639 tonnes of grain is €50,400 (See Table 1) or €207/m^2. Assuming 100% of utilisation, the cost of storage is €12.2 per tonne. If utilisation is reduced to 50%, then the cost of storage is €19.1/t.

There may be additional tax benefits to the construction of this unit. The 'potential extra tax saving' is almost €19,000, the net extra total saving in tax to be paid over the seven years that capital allowances can be claimed, if there is income from other sources that could be used to offset against the capital allowances.

Not having processing facilities poses a major risk with this option. In a year where harvesting conditions are poor and moisture content is high, grain cannot be stored in this unit unless it is either dried using mobile driers or treated with an organic acid. Acid treatment and rolling will add an additional €32/t to the costs.

Table 18 presents sensitivity analysis to the effect of altering the value of the building at the end of its useful life and increasing or decreasing interest rates. The value of the building at the end of its useful life is having a relatively small effect on the breakeven price needed. A doubling of interest rates would add €9.92/t to the breakeven price needed.

Table 18: Sensitivity analysis on the breakeven price needed to justify the construction of a Feed Store 2 (capacity = 639 tonnes)

		Cost per tonne	Variance from baseline	Total cost per annum per tonne
319 t (50% utilised)				
Value of the building at the end of the useful life (20 years)	0%	€24.59	€5.5	+€1,754
	100%	€17.71	-€1.39	-€443
Borrowing	8% Building (11%WC)	€24.57	€5.47	+€1,745
Borrowing	10% Building (13%WC)	€28.28	€9.92	+€3,164
Building utilisation	25%	€32.9	€13.8	+€4,402
Building utilisation	100%	€12.2	-€6.9	-€2,201

Marginal tax rate	**Unused capital allowances**	**Tax refund if enough income from other sources (over 7 years)**
0%	€38,116	0
25%	€38,116	€9,473
50%	€38,116	€18,946

Note: Baseline for 639t store, worth 80% of initial cost at end of useful life, 50% utilised, building interest 5%, working capital 8% (€19.1)

CHAPTER 4 - APPENDICES

Appendix 1. Loss in Crop Weight from Drying

The formula required to calculate the weight of a dried crop from the known wet weight before drying is:

$$\text{Weight of dried crop} = W_1 - \frac{(W_1 (M_1 - M_2))}{100 - M_2}$$

Where

W_1 Weight of the undried crop (tonnes)

M_1 Moisture content of the undried crop (%)

M_2 Moisture content of the dried crop (%)

Example: What is the weight of 100t of wheat at 20% moisture content when dried to 15% moisture content?

$$\text{Weight of dried crop} = 100 - \frac{(100 * (20\text{-}15)}{100 - 15}$$

$$= 100 - \frac{500}{85}$$

$$\text{Weight of dried crop} = 94.12 \text{ tonnes}$$

Appendix 2. Preparation of a Grain Store

Grain store structure, equipment and residues all threaten the quality of harvested grain. It is important that action is taken well in advance of the harvest to ensure a pest and contaminant free environment. Care must be taken to ensure feed is stored in a hygienic manner on-farm. A building for storing grain should be well sited, free from dampness, weather and vermin-proof, and well ventilated.

The storage facilities should be maintained at the highest standard of cleanliness and free from excess moisture so that spoilage is controlled and the conditions under which contaminants such as mycotoxins and *Salmonella* flourish are minimised.

Most empty stores contain pests which can contaminate newly stored grain. Cleaning alone will not control these. Good hygiene, effective grain drying and cooling and well-targeted pest control all combine to maintain the quality of the grain in the store.

Prevention

Good store hygiene is essential in preventing/limiting infestation. When stores have been emptied all remaining grain residues should be removed and burnt. Stores should then be thoroughly cleaned, vacuumed and treated with insecticide. Walls, floors, ceilings, ducts, roofing spaces, grain conveyors and their environs should all be cleaned. All cracks and crevices should be cleaned, disinfected and filled. Since many pests are 'secondary', in that they feed on previously damaged grain, new grain for storage should be good quality whole (unbroken) grain and be free of moulds. Drying to 13% moisture content or lower is important in preventing/limiting infestation. Lowering grain temperature to 15°C or lower helps to control insect pests (< 5°C for mites). Contamination during storage must be avoided.

Control

Pest eradication/control in stored grain is best carried out by the professionals who offer this service. Where moderate infestations occur the stored grain can be protected by admixtures of insecticides such as pirimiphos-methyl (Actellic). Fumigants, used for pest control, include methyl bromide, aluminum phosphide and carbon dioxide. Concerns about the effects of methyl bromide on atmospheric ozone has led to the investigation of alternatives such as carbonyl sulphide. Carbon dioxide is considered ineffective against weevils. Fumigants will eliminate an existing infestation but will not give any protection against re-infestation. Synergised pyrethroids can be applied to remove pests from elevators, bins, structures, etc by fogging or spraying. More recent methods of controlling stored grain pests have been the use of low oxygen and carbon dioxide-enriched atmospheres and the use of aerosols containing esfenvalerate, piperonyl butoxide, oil solvent and freon.

Good farming practice

In so far as it is practical, feed stores should be:

1. Clean, dry and free from dampness (feed should not be exposed to rain/damp for prolonged periods).
2. Protect from birds, vermin and other wildlife.
3. Guard against farm animals and domestic pets (cats, dogs).
4. Hazardous chemicals (e.g., weedkillers, waste oil, paints etc) should not be stored in the feed store area. If feed is stored in multi-purpose sheds it must be partitioned so that chemical spillages or leakages (e.g,. crop sprays) cannot reach the feed.
5. Stores should have adequate lighting (natural + artificial) if they are being used for home mixing or to store feeds/mineral + vitamins for different species.
6. Mineral/vitamin supplements for different species should be stored separately within the store (or in separate stores) and be clearly labelled.
7. Do not store compound feed for ruminants and non-ruminants in the same store.
8. Use clean equipment (free from manure or slurry) to handle or transport feed.
9. Avoid soiling feed with manure or slurry during the course of machinery operations.
10. Remove mouldy feed, it can cause abortion. It may leave undesirable residues (mycotoxins) in animal products e.g., milk.
11. Feed stores should be enclosed where possible. Doors should be tight fitting. Use bird netting or mesh to restrict bird access through any openings. Floors and walls should be smooth.
12. Cover feed where it is stored in open fronted sheds for prolonged periods. Use plastic or tarpaulin sheets.

Feed bins

It is recommended that feed bins are inspected (and cleaned, if necessary) at least annually on cattle/sheep farms and preferably twice or more per year for intensive pig/poultry units. Key points include:

- Bins should be empty at inspection;
- Check any possible leaks: damaged joints/seals, structural damage, corrosion etc;
- Repair damage so that the bin is damp proof, bird and vermin proof;
- Check for caked feed residues on bin surfaces and in augers; and,
- Clean bins thoroughly, if necessary (powerwash) and allow to dry fully before refilling.

Safety Warning

Entering or cleaning confined feed stores or bins presents farm safety risks:

- Feed bins and stores can contain substantial amounts of dust;
- Carbon dioxide or other harmful gases may build up in bins or confined stores;
- Stores may also contain dangerous fungal spores. Wear a suitable respirator mask with an appropriate filter;
- Never enter a bin alone; and,
- Vermin and bird contamination also pose risk (e.g., weils disease - from contact with rat urine). Wear protective clothing and gloves, and a suitable respirator mask. Cover any broken skin or cuts before cleaning bins or sheds.

Appendix 3. Risks with Grain Storage

The main risks associated with grain storage include:

1. Insects/pests
2. Vermin

1. Insects/Pests

The common pests associated with stored grain are weevils, saw-toothed beetles and mites. Grain weevils damage grain by feeding on the endosperm and the saw-toothed beetles and mites by attacking the germ. Grain weevils were the traditional pest of stored grain in Ireland because they bore into the grain. The saw-toothed grain beetle, a tropical species, became more dominant with the advent of the combine harvester which damaged grain sufficiently to allow feeding. In addition to injuring the germ, mites cause tainting and may carry fungal spores and bacteria such as *Salmonella*.

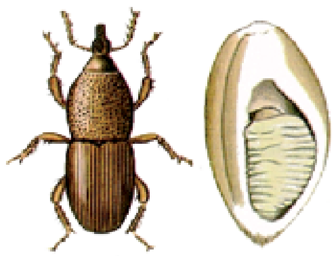


Figure 2: grain weevil

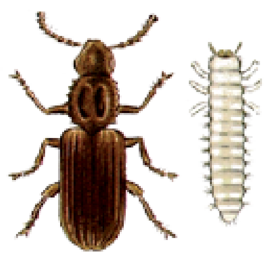


Figure 3: Saw toothed grain beetle

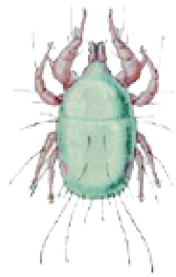


Figure 4: Mite

Prevention

There is no substitute for good hygiene practices, especially the cleaning and disinfecting of the store before filling. Main ducts should be big enough to allow easy access so that they can be swept out and all ducts should have smooth floors and walls. Grain stores should be damp-proof, well ventilated and free from cracks, crevices and dust traps. Mites can be controlled by pre-harvest store disinfection and the others by controlling grain temperature with an adequate ventilation system. Mites can tolerate temperatures and moistures so low that they cannot be completely controlled by drying and ventilation.

When stores are emptied all remaining grain residues should be removed and burnt. Stores should then be thoroughly cleaned, vacuumed and treated with insecticide. Walls, floors, ceilings, ducts, roofing spaces, grain conveyors and their environs should all be cleaned. All cracks and crevices should be cleaned, disinfected and filled. Since many pests are ‘secondary’ in that they feed on previously damaged grain, new grain for storage should be good quality whole (unbroken) grain and be free from mould. Drying to 13% moisture content or lower is important in preventing/limiting infestation. Insect, mite, fungal and mycotoxin development is controlled by temperature. At temperatures found in grain stores, biological activity insects, mites, fungi and grain itself doubles at every 10°C rise in temperature. Contamination during storage must be avoided.

Control

Pest eradication/control in stored grain is best carried out by the professionals who offer this service. Where moderate infestations occur the stored grain can be protected by admixtures of insecticides such as pirimiphos-methyl (Actellic). However, chemical control is becoming increasingly difficult with products that could be applied by the farmer being withdrawn from the market; the cost of bringing in specialists such as Rentokil are quite high. Therefore, prevention is the best means of control.

Fumigants used for pest control include methyl bromide, aluminum phosphide and carbon dioxide. Concerns about the effects of methyl bromide on atmospheric ozone have led to the investigation of alternatives such as carbonyl sulphide. Carbon dioxide is considered ineffective against weevils. Fumigants will eliminate an existing infestation but will not give any protection against re-infestation. Synergised pyrethroids can be applied to remove pests from elevators, bins, structures etc by fogging or spraying. More recent methods of controlling stored grain pests have been the use of low oxygen and carbon dioxide-enriched atmospheres and the use of aerosols containing esfenvalerate, piperonyl butoxide, oil solvent and freon.

Acid treatment is intended to control mould growth but not insects or mites. While this is not usually a problem with small lots, large piles of treated grain require a low level of ventilation to keep the temperature below insect-friendly levels.

2. Vermin - rodent and bird control

The principal risks from these pests are disease transmission, grain spoilage and contamination, and structural damage. Buildings should be vermin proof by ensuring that doors are close fitting and other outlets are covered with close mesh wire. The store surrounds should be clean so as not to attract rats or mice. Good management including frequent inspection and cleanliness is essential to keep stored grain free from pest damage.

Watch for signs of rodent activity and droppings; and identify runs, burrows and holes. Identify weaknesses in the store such as easy vermin access to leftover food, easy access to animal feed /grain stores/root crops, presence of 'tasty feeds' like maize silage, lots of clutter (older equipment, rubbish heaps etc) and cover around the yard and open drains, lack of gulley/drain covers.

Vermin control options

Rodenticides are a major help but they are not the total solution. Vermin control should start with clearing rubbish etc Store domestic refuse in suitable containers. Repair buildings and drains and minimise access to feed stores. The options for control include:

- Traps: Use only the approved type. Traps are unlikely to control heavy infestations of rodents, particularly rats. Place along vermin runs. Traps should not be readily accessible to small animals or birds. Check traps daily and remove dead rodents promptly
- Ultrasound repellents: Rodents communicate at ultrasonic frequencies (over 20Khz - kilohertz) that are inaudible to humans. Ultrasonic repellents emit sound frequencies designed to repel rodents. However, there is some doubt about their overall effectiveness.
- Pet cats and certain types of dogs can be useful vermin hunters. Remember that both cats and dogs can potentially transmit disease (e.g., toxoplasma abortion in sheep - cats, neospora abortion in cattle - dogs) if they soil animal feed.
- Rodenticides: Most rodenticides (rat poison) are based on anticoagulants which stop blood clotting and lead to internal bleeding and death. Anticoagulants are divided into first generation and second generation. Significant rodent resistance has developed to many of the first generation products such as Warfarin. Resistance has not yet developed to many of the second generation products. Seek advice from suppliers or professional pest control services if in doubt about what products to use.

Guide to bait control

- Double perimeter baiting (two rings of bait points around the farmyard) can intercept invading rodents. Perimeter baiting is useful for long-term control/ prevention. Where heavy infestation has already occurred more targeted baiting around the yard may be necessary.
- Baiting is only effective when access to alternative food is reduced/removed.
- Place the bait in places likely to attract vermin e.g., burrows, rubbish heaps, old buildings, discarded machinery etc.
- Be careful not to place bait where it is easily accessible to children, pets, wildlife or farm animals. (Pigs can be very susceptible to anticoagulants such as warfarin).
- Remove poisoned rodents promptly as they can cause secondary poisoning to other animals such as cats and dogs.
- Follow the manufacturer's instructions on bait preparation and dosage. This is crucial, otherwise rodent resistance may increase. Only use approved rodenticides.
- Inspect bait points daily and top up as necessary.

- Keep a drawing/sketch of the bait points and maintain an inspection log. The log may be required for some farm assurance schemes.
- Take the necessary health and safety precautions when handling/preparing bait e.g., protective clothing, gloves.

Birds contaminate grain. Infestations can cause direct (feeding) losses. Prevent entry by proofing the store. Use appropriate mesh or plastic curtains to 'seal' even larger spaces. Birds are attracted by food e.g., spilled grain - sweep up any grain spillage.

Safety Warning

Feed stores attract vermin. Take care when handling feed, cleaning the stores or when working in any area likely to be contaminated by rats' urine.

- Gloves are essential when handling vermin contaminated materials or surfaces. Cover cuts or broken skin with waterproof dressings/plaster.
- Wash after working in high risk situations. Always wash your hands before you eat (or smoke). Don't chew grain from your grain store. Never chew maize grain from the cob or in the silage pit.
- Ensure employees/contractors and family members are aware of the risks when working in known rat infested/contaminated areas.
- Keep bait in the original (or a clearly labeled) container and store safely out of the reach of children and away from other risks.

Appendix 4 Feed Hygiene: DAFF Regulations

Concerning Regulation (EC) 183/2005 of the European Parliament and the Council of 12 January 2005 laying down requirements for feed hygiene.

Purpose and scope
The objective of the hygiene rules as set out in this Regulation is to ensure a high level of consumer protection with regard to food and feed safety. Central to this regulation are two guiding principles which may be summarised as follows:

Primary responsibility for feed safety rests with the feed business operator
The onus of providing safe food lies with all the individuals responsible for producing that food. For the purposes of this Regulation feed business operators include: farmers at all stages of the production chain (tillage or livestock farmers), manufacturers of compound feed, hauliers of feed, importers of feed and individuals involved in the sale and distribution of feed to farmers.

The need to ensure feed safety throughout the feed chain, starting with primary production of feed, up to and including the feeding of food producing animals. Primary production of feed includes all tillage and grassland production, food producing animals include for example beef animals, beef and dairy cows, sheep, pigs, poultry, horses, goats, deer, ostrich, and fish, etc.

Approval and registration
Feed business operators must be registered or approved by the Department of Agriculture, Fisheries and Food depending on their activities (Table 19).

Table 19: Examples of operations that require registration and/or approval

Feed business operators who are required to be registered	Feed business operators who are required to be approved
Primary producers of feed materials (e.g., barley, wheat, grass)	Compound feed manufacturers
Farmers keeping cattle, sheep, etc	Manufacturers of premixtures/mineral mixtures for sale
Individuals involved in the importation, storage, sale and distribution of feed materials, compound feed etc.*	Individuals involved in the sale, storage and distribution of premixtures/mineral mixtures
Home mixers	

*Retailers of pet food excluded

Certain obligations are placed on the feed business operator by legislation. For example, they should ensure that all stages of production, processing and distribution under their control are carried out in accordance with, and satisfy the relevant requirements laid down in the above regulations. It is an offence to source and use feed from establishments or operators which are not registered or approved in accordance with the regulations. This is in order to ensure the complete application of the registration and approval system to all the feed business operators and consequently to guarantee full traceability.

Appendix 5. Handling Sprouted/Mouldy Grain

How can sprouted grain be stored?

Sprouted grain can be crimped, treated with an additive and ensiled under anaerobic conditions. Most grain is probably in the range of 20 to 25% moisture content at this stage and is somewhat less ideal for crimping (28 to 35% MC).

Alternatively, sprouted grain can be rolled, treated with an organic acid such as propionic acid and stored aerobically. The amount of acid depends on grain moisture content and the length of storage. For long-term storage of grain, rolled and treated off the combine, increase the application the rate by 10%. Application rates should be increased slightly (1 to 2kg) for sprouted grain. Ammoniation using urea based additives is also an option. Again application rates of additive may need to be increased.

What is the feeding value of sprouted grain?

It is suggested that there is very little reduction in the feeding value of sprouted grain, relative to intact grain, assuming the sprouting is not excessive. The germination process will expend some energy but this is likely to be minimal. Sprouted grain is generally associated with lower bushel weights. Bushel weight is not an accurate indicator of the feeding value of grain. Studies at UCD with pigs showed no difference in the energy value of barley at medium (60kg/hl) or high (68kg/hl) bushel weight and a slight reduction in energy value at low bushel weight (58kg/hl). Differences are likely to be less in ruminants.

What to do with mouldy grain?

If toxins are present in a crop at ensiling, they are likely to be substantially present at feed-out. It can be assumed that any grain with mould has the potential to be contaminated with mycotoxins and caution is needed in feeding this material. Mycotoxins will impact on the feeding value of grain through reduced intake and performance, as well as a higher possibility of abortion in pregnant cattle, and in some cases even death. Discard severely moulded grain. Avoid feeding mouldy grain to pregnant/lactating animals or high production stock. Monitor animal performance closely and as much as possible dilute down the feed with other feed sources. While crimping and ensiling or treating with an organic acid such as propionic acid may help reduce the vegetative state of the mould, there is no guarantee that there are not spores and mycotoxins still present on or in the grain, which will impact on its feeding value.

Appendix 6 Farm-to-Farm Trading of High Moisture Grain

The introduction of high moisture grain storage systems has made on-farm storage of grain a more attractive option. For it to be an economical option for both the tillage and livestock farmer, transparency in the method of agreeing a price is necessary.

Yield

All trailer loads of grain should be weighed at an agreed weighbridge or local merchant.

Image 14: Weighbridge

Quality and dry matter

It is assumed that with good grain crops, the starch content and feeding value varies little. Dry matter (or moisture content) must be measured, as yield at a particular dry matter (or moisture content) is the basis for price. Dry matter can vary significantly even during harvest over a day and consequently frequent sampling is needed. The following is a suggested procedure:

1. Each trailer should be representatively sampled when tipping the load by dipping a bag into the stream a number of times as the load empties (sample size = 0.5-1.0 kg per trailer-load).
2. Samples of moist grain should be stored in a refrigerator (4°C) prior to compositing.
3. Carefully mix all the samples and then take a representative 0.5 kg sample for analysis. Two representative 0.5kg samples should be taken for every 100 tonnes

of grain harvested or for each harvesting day where the crop is harvested over a number of days.

4. Samples should be tested for dry matter in an agreed laboratory. The laboratory testing method should ideally be based on oven drying of a ground grain sample as drying whole grain will tend to give a higher dry matter reading. The grain moisture meters used by grain merchants are generally not accurate above 25% moisture content.

Value and price

The value of high moisture grain should be based on the price that the grain would have achieved if it was subsequently sold to a grain merchant at 20% moisture content (80% dry matter), or the green grain harvest price (Table 20). Green grain price should be based on the regional price using an agreed merchant at an agreed date during the harvest. Normally, this price would be available at the end of the normal harvest period, but some of the larger merchants will only give an 'on-account' price at that stage with a final bonus given some months later, depending on grain markets. It is not appropriate to use a grain merchant's price reduction system for normal harvest grain as it deliberately penalises the delivery of high moisture grain.

Image 15: Articulated loading shovel

How to Calculate the Harvest – Equivalent Price of High Moisture Grain

Variables needed
Green grain price at 20% moisture content €/t
Moisture content (MC) of the grain for sale %

$$\frac{\text{Green Grain Price €/t}}{0.80} \times \frac{(100 - \text{MC of Saleable Grain})}{100}$$

Table 20: The price of grain at different moistures

Grain price off combine 20% Moisture €/t	Grain moisture content %		
	30	35	40
120	105	98	90
130	114	106	98
140	123	114	105
150	131	122	113
160	140	130	120
170	149	138	128
180	158	146	135

The value of grain presented here refers to the value of grain off the combine before processing and storage costs are accounted for. Contact your local Teagasc adviser for details on the costs associated with the processing and storage of high moisture grain.

Price to be paid
Other issues that may influence the price of grain include:

- The additional costs associated with combine-harvesting high moisture grain.
- An additional working window for the contractor/farmer, they may not seek to recoup the full additional costs.
- Transport costs, where extra transport is needed, should be charged using the extra delivery time needed and costed at the local hourly rate for tractor and trailer hire.
- Handling of high moisture straw. The unripe straw at harvest requires further drying before baling. This may require an extra straw raking treatment.

Appendix 7 Temporary Storage of Grain

Image 16: Articulated truck being loaded with feed barley

There are times when it is necessary to store grain on-farm for short intervals before sale. For temporary holding, the only requirement is that the grain should be kept clean and free from contaminants. The holding area should be cleaned before use and any possibility of grain contamination by materials such as fuel oils, fertilizer or rat bait should be removed.

In warm weather the safe storage period for moist grain may be no more than a few days (Table 21). In late August and September, it may be difficult to get the grain temperature below 15°C. At this temperature Table 21 shows that grain at 20% moisture can not be stored safely for more than two weeks, whereas grain at 16% moisture has a shelf-life of 30 weeks. There is a risk in temporarily storing grain at more than 18% moisture. It must be kept in mind that wet unventilated grain is always liable to heat rapidly.

Table 21: Estimated maximum number of weeks for mould-free storage of barley

	Moisture Content %			
Storage temperature °C	16	18	20	22
25	5	1	0.5	0.5
15	30	4	2	2
5	120	22	10	7

Some useful guidelines on the temporary storage of grain include:

- If grain is to be held for any more than 24 hours, it should be stored under cover. Outdoor uncovered storage will always incur some surface damage from rain. To minimise this, the grain could be piled high to reduce the surface area however, in doing this the risk of heating is increased.
- For temporary storage in unventilated buildings, grain should be heaped as shallow as possible. The higher the heap the quicker it will heat. The grain should be probed for temperature changes once fortnightly.
- Watch for hot spots. Turning will help if the heating is confined to spots in the heap. If the whole heap is warm and space is confined it will not be as effective. For hot spots, a grain spear with a fan at the end can be bought. It is quite effective if the heating is confined to hot spots.
- The overall message must remain that a properly designed ventilation system with a capacity matched to the moisture content of the grain is the most satisfactory storage system. The only means of extending this period is to provide a short-term store in which it is kept cool. This can be done by blowing small volumes of unheated air (0.01 m^3/sec, or 20 cfm per tonne) through the grain with a low-pressure fan. Lateral ducts can be used up to 1.5m apart, and one suitable 3HP fan will supply enough for about 200 tonnes. It must be realised that this airflow will not dry the grain, but will extend its safe storage period by keeping it cool.

Appendix 8. Vehicle Movement and Tipping Heights

Vehicle movement
The biggest vehicles coming delivering and collecting at the farm will have dimensions approaching those of the 15m articulated truck as shown in Image 20 and the drawing of the articulated truck on page 82. It is important to plan the farmyard and all the points of access to cater for such vehicles. Modern articulated trucks are much more manoeuvrable than in the past. The trailer very often has three axles. The front axle can be lifted up and the rear axle is usually a steer-axle, steered by the 'fifth wheel' which is a steering mechanism at the trailer hitching point. Image 18 shows the steer-axle and the lift-up axle in action. This type of truck can turn in a circle with diameter equal to about its length or tighter if reverse is used. However, a bigger turning circle is desirable in order to avoid tyre damage and possible damage to the yard surface (Image 19 - dragging of tyres).

Turning in at gateways is much easier with the steering axle because the trailer follows more closely the path of the tractor unit and doesn't cut in as much. Image 17 shows the tendency of the trailer to cut-in as it turns in the gateway. Also, the front of the trailer is inclined to swing out (also in Image 17) and could clip an entrance pier easily enough if care isn't taken. The ability of a truck to turn-in at a farm entrance depends on a combination of factors: the width of the road, the width of the gateway, distance of the piers from the road, the splay angle of the entrance, and the turn-in angle. On narrow country roads the truck will usually need the full width of the road to make the turn-in. It is reccomended to provide enough space for a truck to turn in clear of the road at entrances where gates are likely to be closed.

In reverse the artic can turn its trailer very tightly as the front end follows through. Truck drivers very often reverse into gateways because they may not have enough room to turn around inside. It is also much safer to drive out on the public road than reverse out. A truck can reverse in at gateways where there isn't enough room to drive in.

Rigid trucks use a lot of space relative to their length when turning, hence rigids are usually short enough not to cause turning problems.

Where new farm entrances are being planned or where building developments are taking place within the farmyard, it is important to make sure that they are designed correctly. Visits to see existing entrances that are working well are recommended. Another option is to setup a trial area using cones and manoeuvre a truck and trailer to define acceptable boundary limits.

Image 17:
Swing-out and cut-in at gateways

Image 18:
Trailer steering axle and lift-up axle

Image 19:
Tri-axle bulk grain trailer with front lift-axle and no steering axle. Notice the tyre mark on the concrete from the rear axle caused by making a sharp turn. The load on the trailer increases the damage caused

Safety Warning

Care when tipping trailers

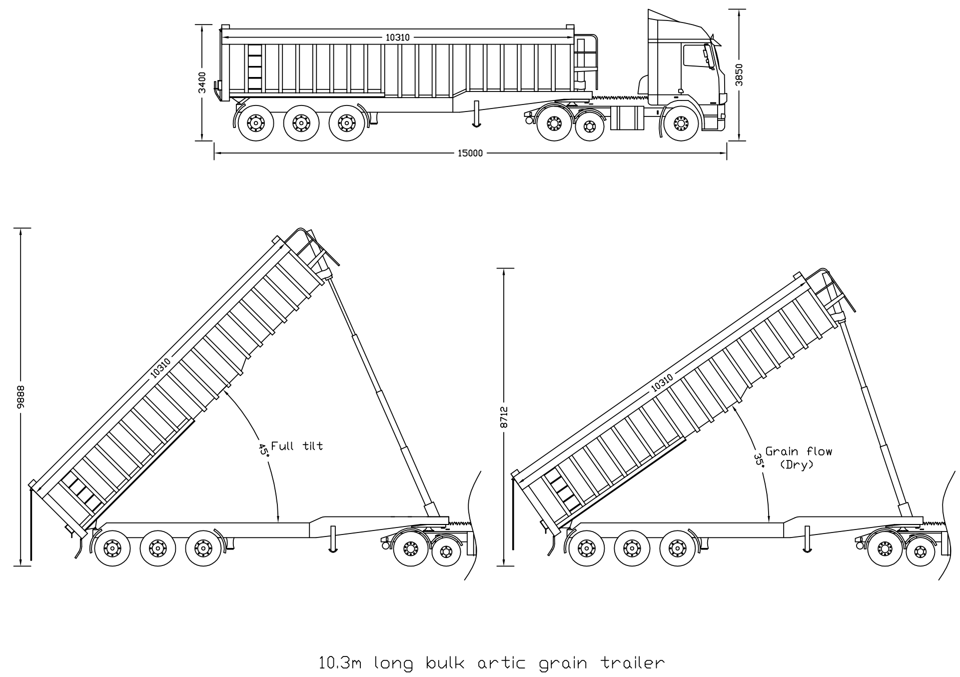
- Watch for overhead power lines when raising and lowering
- Take cognisance of the weather conditions particularly windy/blustery days
- Keep a safe distance from the trailer when tipping
- Be vigilant of uneven/sloping ground
- Guard against making contact with overhead wires, roofs, trees, etc.

Image 20: Articulated truck tipping

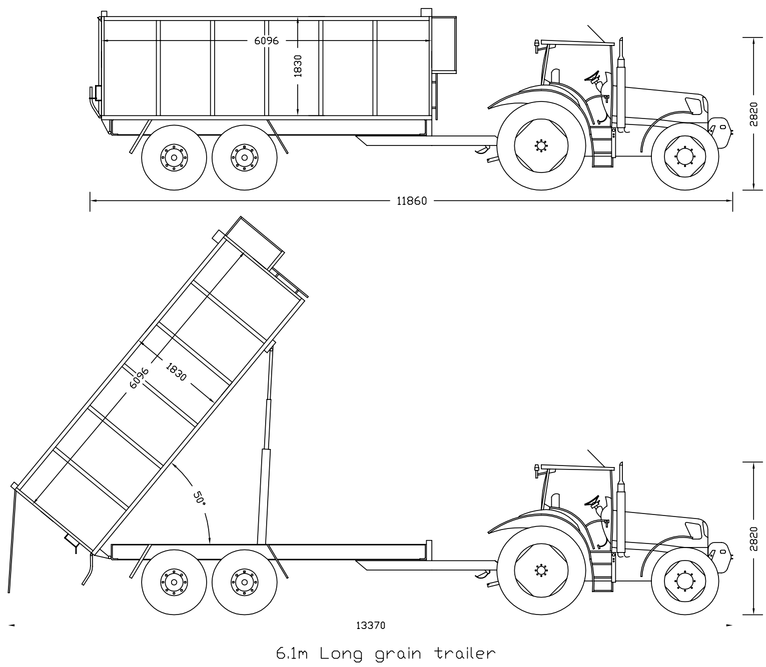
Image 21: 15m truck and trailer

Image 22: Tractor and grain tipper trailer

Image 23: Grain sucker/blower. This is a very versatile machine for handling grain. It can load and unload grain to and from trailers, trucks, bins and flat stores. The blower work rate is about 35 tonnes per hour. There is also a portable suction head to clean up the last of the grain from the yard or store.



Drawing of an articulated truck



Drawing of a tractor and tipping trailer