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MANAGEMENT ALTERNATIVES FOR LIVESTOCK WASTE WATER AND FEEDING

LIFE+ FUTUR AGRARI

1. Introduction

The growth of intensive livestock production in recent decades has been driven by profound changes in production systems that have enabled the growing demand for foods of animal origin to be satisfied at an affordable price for the entire population, contributing significantly to the development of social wellbeing. At the same time, this intensification of livestock production has aggravated the environmental problems associated with livestock farming in those areas where growth has been disordered.

Pig production is one of the major causes of agricultural pressure on the environment as it has been concentrated on increasingly larger and more specialised farms. As a result, it has become increasingly decoupled from the land, to the point that in Catalonia, for example, the pig population accounts for 28% of the Spanish total while arable land in Catalonia only accounts for 5% of the Spanish total.

Large concentrations at local or regional level entail a high risk for the environment as manure output is not balanced with land availability and crop requirements. This imbalance creates a nutrient surplus, a large part of which sooner or later ends up in the water (nitrates and phosphates) and in the air (ammonia and nitrous oxides) if they are not exported away from the region.

Slurry output is concentrated mostly in 10 regions. The three regions with highest slurry output are Segrià, Osona and La Noguera, with more than a million cubic metres per year in each. The remaining seven regions have slurry outputs ranging between 350,000 and 550,000 m^3/year and are El Bages, El Pla d'Urgell, Urgell, Alt Empordà, La Segarra, Les Garrigues and El Berguedà.

The type of waste created in pig farms is slurry, with an estimated volume of about 1.65 m^3/fattening pig per year and a nitrogen output of 7.25 kg nitrogen/fattening pig per year. Nitrogen output from sow slurry is 15 kg N/sow per year, with a volume of 5.1 m^3/sow per year.

Current waste management mostly consists of applying it directly on the land as fertiliser, although in some parts of Catalonia this method is very expensive. This is because, on the one hand, the areas with a high livestock density are a long way from the land that can use the slurry as fertiliser, and, on the other, this slurry consists of 95% water, which must also be transported, increasing fertilisation costs.

2. Current management alternatives

2.1 Reduction at source

Good slurry management at the farm requires, first of all, taking preventive measures to reduce the amount of slurry produced and, accordingly, reduce the need for corrective measures later on.

There are three main reasons why pig farmers should focus on reducing the volume of slurry generated on their farms:

1. Environment: reducing discharges into the environment is one of the main tenets of sustainable development (reduce, recycle, reuse)
2. Economy: slurry management represents a fixed cost per m^3
3. Legislation: those farms requiring an integrated environmental authorisation (IEA) are under the obligation to implement the best available techniques (BAT) for controlling and reducing the volume of slurry they produce.

There are two alternative ways to manage livestock waste by reducing at source:

- Reducing the volume of waste, which, in the case of slurries, involves reducing and optimising water content.
- Reducing nutrients and other pollutants contained in the slurry. In this case, there are basically two strategies, reducing and/or replacing these substances in the diet, or improving digestion efficiency so that they are absorbed by the animal and are not excreted.

2.1.1 Water optimisation

Being the item with highest consumption on the farm and indispensable for the animal's life, water is the factor that contributes most to variability in the volume of slurry generated on the farm.

Water is provided in accordance with animal welfare regulations (Royal Decree 348/2000), which states that all animals must have free access to water at all times.

The balance between water consumption and water loss is influenced by many factors, including the pig's state of health, the composition of the pig's diet and the environment. Consequently, it is difficult to know what is normal water consumption in pigs. As a reference, water consumption in pigs with free access to food is approximately 2.2–3.0 times the food intake.

Table 1. Average water consumption (litres/animal per day).

Animal type	litres/animal per day
Closed cycle pig	59.82-73.12
Sow with piglets until weaning (from 0 to 6 kg)	14.00-17.11
Sow with piglets until 20 kg	20.97-25.63
Cull sow	10.44-12.76
Piglet from 6 to 20 kg	2.70-3.30
Pig from 20 to 50 kg	5.40-6.60
Fattening pig from 20 to 100 kg	7.47-9.13
Pig from 50 to 100 kg	10.80-13.80
Boar	14.76-18.04

Source*: Guía de Mejores Técnicas Disponibles del Sector Porcino* (Best Available Techniques Guide for the Pig Industry), 2007

Even though most pig farms are increasingly precise in their management of the use of water, there are aspects that should be improved as they contribute to increasing water consumption and, consequently, to increasing the volume of slurry that must be handled on the farm. In addition to improving production yields, good water management also decreases pollutant discharge and reduces costs for the pig farmer.

The volume of water to be managed consists mostly of water provided for the animals, water used for cleaning and cooling water. Water consumption depends on a number of factors including **environmental factors** (temperature, humidity and ventilation), those related with the **facilities** and **drinker handling** (type, flow rate, height, angle, location, balance between the number of drinkers and the number of heads), **feed types and form of presentation**, among many others.

According to the best available techniques (BAT), the drinker used should minimise water waste.

- The use of bowl drinkers reduces water consumption by 24% compared with nipple drinkers. This gives a reduction in slurry volume between 5% and 14%.
- The use of wet-dry or single-space feeder systems for fattening pigs reduces water consumption by 20% and the total slurry volume between 4% and 12%.

Water supply has an effect on the animal's growth. Hence the importance of water flow in the drinkers, which must be enough to cover the pig's water requirements but should not be too much as this would lead to higher water use. The optimal flow rate will vary depending on the production stage.

Table 2. Optimal flow rate for each production stage.

PHYSIOLOGICAL STATUS	Flow rate (l/minute)		
	BOWL	NIPPLE	SHOWER
Nursery piglets	0.5	0.5	
Weaner piglets	1.0	0.5	
Fattening pigs	1.0	0.8	1.0
Confined breeding sows		1.5	1.5
Grouped sows	3.0	1.5	
Sows in pig	3.0		3.0

Optimal drinker flow rate for each production stage (Abaigar et al., 2005)

A low drinking water outlet pressure (0.8 to 2.0 kg) enables increased operation of the drinkers, decreasing the volume wasted and system failures.

However, equally as important as an adequate water supply is water quality. The variables in water quality include: mineral content and the presence of microbes. The degree of bacterial contamination is traditionally calculated by measuring the coliform concentration, which is an indicator of faecal contamination and a potential source of disease. The main pathogenic bacteria associated with water contamination include: *E. coli*, *Salmonella* and *Leptospira*.

To ensure adequate water quality on farms, a series of guidelines are followed. First, the quality of the source water must be monitored; it is wise to perform regular checks (physical-chemical-microbiological quality). It is recommendable to install filters, if possible in sufficient number and size, in those places where impurities accumulate (before pumps, at tank outlets, before flow meters, etc.) and also to clean them regularly. Filters should never be removed if a low flow rate is observed. Install larger filters instead. Lastly, it is increasingly common to treat the water, using methods that comply with the following premises:

1) decontamination must be quick and effective,
2) the treatment prevents recontamination of the water on the farm,
3) the treatment prevents germ proliferation in the animal's digestive tract,
4) it is safe for the animals, workers and facilities, and
5) it is easy to handle and maintain.

The products recommended are peroxides, sodium hypochlorite and buffered organic acids.

Nowadays, a practical design recommendation when building new farms is to have several water lines for cleaning water, normal drinking water and medicated drinking

water, so that the system can be thoroughly cleaned after medication without disrupting normal water supply and it is also possible to medicate each batch separately.

According to the industry's Best Available Techniques guide, water handling is one of the critical points within the activities carried out in pig barns. Reducing water consumption is a simple, easy and relatively cheap exercise. And the benefits obtained will always be greater than the effort invested.

2.1.2 Nutrient reduction through diet

2.1.2.1 Reduction at source

In recent years, farms have implemented new technologies that increase efficiency in feed management with the resulting improvement in feed efficiency. As a result, phosphorus absorption in the diet has also improved through the use of phytases, with decreased phosphorus excretion in the faeces. These phytases also play a significant role in the absorption of other nutrients.

Nutrient reduction and optimisation in pig diets can be achieved using various strategies which can be classified in three main groups:

1. Decrease feed efficiency
    - 1.1- Decrease wasted feed
    - 1.2- More easily digested ingredients
    - 1.3- Additives (enzymes, growth enhancers...)

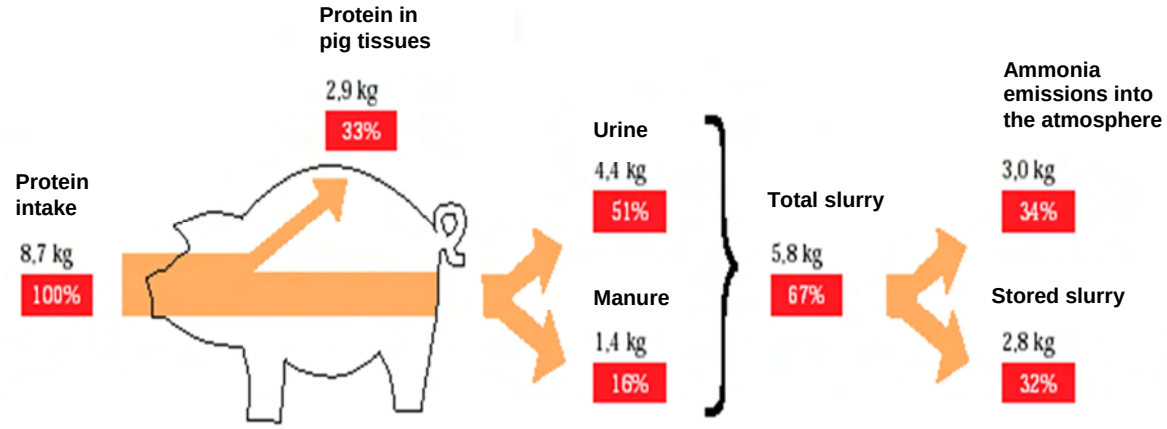
2. Reduce the raw protein (RP) content of feed by:
    - 2.1- Reducing non-protein nitrogen
    - 2.2- Improving the protein balance
    - 2.3- Ingredients with complementary amino acid profiles
    - 2.4- Using synthesized essential amino acids such as Lysine (Lys), Threonine (Thr), Methionine (Met) and Tryptophan (Trp)

3. Matching protein intake to production requirements
    - 3.1- Multiphase feeding
    - 3.2- Wet feeding
    - 3.3- Robotic precision feeding

Basically, the goal is to increase nitrogen efficiency in the animals' diet.

2.1.2.2 Nitrogen balance in pig nutrition

Growing pigs only use between 30% and 35% of their daily nitrogen and phosphorus intake (Babot et al., 2004). Even so, thanks to advancing knowledge in pig nutrition, improvements in production technologies and feed supply, it has been possible to reduce the total quantity of nitrogen excreted in animals fed diets that take into account their characteristics and growth stage.



Protein consumption, use and losses during production of a pig weighing 108 kg

Figure 1.- Nitrogen balance (consumed, absorbed and excreted) during production of a fattening pig with a live weight of 108 kg. The mother's relative contribution is also included. Source: Dourmad and Sève, 1997

As can be seen in Figure 1, Dourmad and Sève observed in 1997 that a fattening pig only absorbs 33% of its nitrogen intake, excreting the remaining 67%. Of the 67% of nitrogen that is excreted, approximately 3/4 is excreted in the urine and 1/4 in the faeces. This low efficiency, added to the cost of managing the nitrogen in the livestock waste, means that it is very important to maximise retention of the nitrogen supplied in the diet.

This is even more important in areas with a high livestock density, as the nitrogen that can be absorbed by farm land as fertiliser may be less than the nitrogen generated. In these areas, there is an excess cost in nitrogen imports in the form of food and in subsequent nitrogen exports in the form of waste or as a by-product of a treatment.

2.1.2.3 Nitrogen reduction strategies

2.1.2.3.1 Decrease feed efficiency

a) Decrease wasted feed:

The first step in reducing the volume of nitrogen in the slurry is to reduce the feed wasted in the feeders, as this goes directly to the slurry pit, increasing the volume of nitrogen requiring management. About 5% of the feed used on a farm is thrown away, increasing by 7% the volume of slurry to be managed (Torrallardona, 2007).

How the feed is supplied is very important. If it is supplied in pellet form, wastage is less than when it is supplied as meal. Furthermore, fine-tuning feed supply from feeders, the type of feeder used, the farm's environmental conditions, and facility maintenance and inspection will prevent wastage from being even greater.

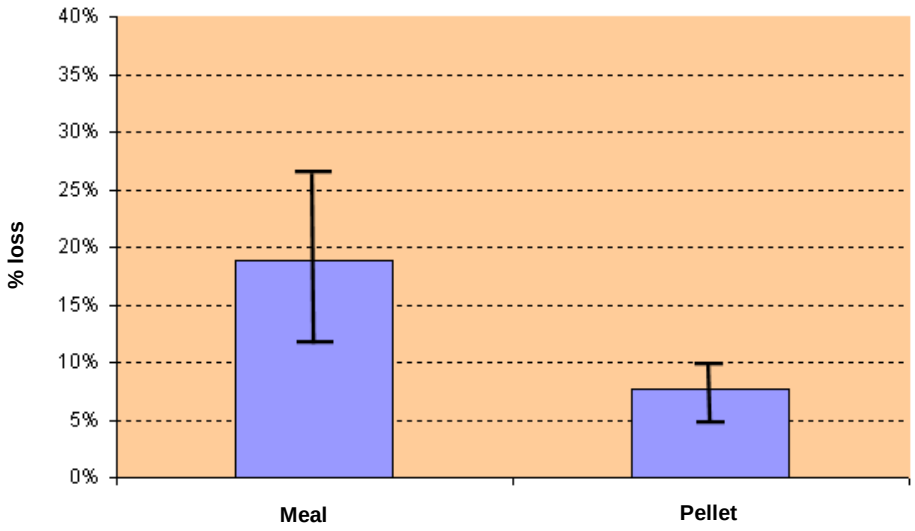


Figure 2.- Percentage feed wastage depending on presentation (7 farms supplying the feed as meal and 3 supplying it as pellets). Source: Adapted from Willis S., 2001

b) Increase the digestibility of the raw protein.

Improving the digestibility of the raw protein by 1% can reduce nitrogen excretion by 1.4%. (Torrallardona, 2010). Therefore, it is very recommendable to use highly digestible raw materials and adjust the feed's processing conditions so that the protein is not denatured.

c) Additives, enzymes and growth enhancers.

The use of additives and enzymes has a direct or indirect effect on nitrogen generation in livestock waste. The use of additives and/or enzymes makes the food easier to digest, improving its bioavailability and absorption. For increased protein absorption, and therefore, a more efficient nitrogen use, the addition of proteolytic enzymes in the diet may increase amino acid digestibility (proteases, endopeptidases, exopeptidases).

In the case of piglets, the use of acidifiers (organic or inorganic acids) helps improve digestibility.

It should not be forgotten that all those additives that improve average daily weight gain (AWG) and reduce feed efficiencies (FE) usually decrease nitrogen as well.

2.1.2.3.2 Reduce the raw protein (RP) content of feed

a) Reduce non-protein nitrogen

As regards absorption of the nitrogen in the feed by the animal, a large number of studies have been performed applying different nitrogen reduction strategies in the diet. To optimise nitrogen absorption, and therefore, reduce nutrient excretion, diets must be formulated with greater precision with a more digestible protein level, using more

digestible ingredients, avoiding non-protein nitrogen in the formulations and improving digestibility by means of treatments in preparing the feed and use of enzymes.

b) Improve the protein balance

Proteins are sequences of amino acids. Once eaten, they are digested by enzymes that break the peptide bonds, releasing amino acids, which are absorbed and used in protein synthesis for growth and maintaining the animal's requirements. Accordingly, in order to optimise efficiency in the diets' nitrogen content, it is necessary to know the animals' amino acid requirements, based on genotype and growth potential.

Like all other animals, pigs can synthesize some amino acids but there are others that they synthesize at a lower rate or cannot synthesize at all. These amino acids are called essential amino acids and their number may vary depending on the animal's production or physiological stage.

The most important amino acids in pig production are Lysine (Lys), Threonine (Thr), Methionine (Met) and Tryptophan (Trp).

Torrallardona et al., 2003, have already shown that when the same feed is provided during the first 47 days of fattening but with different raw protein concentrations (from 19% to 12% RP) in each study batch, the amount of nitrogen excreted could be decreased by up to 41% without affecting the production parameters (see Table 1). The RP is decreased by decreasing the percentage of soy bean and supplementing with barley and essential amino acids.

In addition to decreasing the nitrogen content of the waste, diets with lower protein contents help reduce ammonia emissions, nitrogen excretion in ammonia form, pH, water intake and, therefore, the volume of slurry produced (Babot et al., 2008). Odours are also reduced due to the decrease in volatile organic compounds and ammonia emissions. Ajinomoto describes the potential when raw protein content in the feed is reduced by 1%.

PROTEIN REDUCED BY 1%
Excreted nitrogen reduced by 10%
Ammonia (NH_3) content in the slurry reduced by 10%
pH reduced by 0.14 units
NH_3 emissions into the atmosphere reduced by 10%
Water consumption reduced by 2-3%
Total slurry volume reduced by 3-5%

Source: Ajinomoto, 2000, taken from Areny J., 2010.

c) Ingredients with complementary amino acid profiles

In order to reduce environmental pollution, feed must be formulated using clean energy in order to provide the necessary energy for the animal's maintenance and growth. And to cover the animal's protein requirements, the feed must be formulated in accordance with amino acid requirements, supplying digestible essential amino acids.

Formulating low-protein diets with synthetic essential amino acids added helps decrease the nitrogen content in the waste without affecting the production parameters. The reduction in nitrogen excretion can range between 30% and 50% in the weaning stage and up to 40% in the growing and finishing stages (Babot et al., 2004).

d) Use synthesized essential amino acids such as Lysine (Lys), Threonine (Thr), Methionine (Met) and Tryptophan (Trp)

The decreased raw protein (RP) content in the feed in some cases may be offset by adding synthetic essential amino acids, such as Lysine (Lys), Threonine (Thr), Methionine (Met) and Tryptophan (Trp) in order to not limit growth and, consequently, not affect production parameters.

Table 3.- Results of decreasing raw protein (RP) in the feed by decreasing the percentage of soy bean and supplementing with barley and essential amino acids for fattening pigs weighing 20 to 56 kg.

	Starting Weight	Final Weight	Production parameters			Nitrogen excreted (g N/day)
			Consumption (g/d)	Growth (g/d)	Feed efficiency (FE)	
T-1 (19% RP)	20.6	55.7 a	1634 a	748 a	2.18 a	26.1 a
T-2 (15% RP)	20.8	56.5 a	1655 a	759 a	2.18 a	18.8 b
T-3 (14% RP)	20.7	54.8 a	1552 ab	724 a	2.14 a	15.4 c
T-4 (12% RP)	20.8	50.9 b	1480 b	639 b	2.31 b	14.5 c

The letters represent the level of significance. Source: Torrallardona, et al. 2003.

2.1.2.3.3 Match protein intake to production requirements

Raw protein requirements vary depending on the animal's production stage. Thus, in the case of fattening pigs, their raw protein and essential amino acid requirements decrease as they age (see Figure 3).

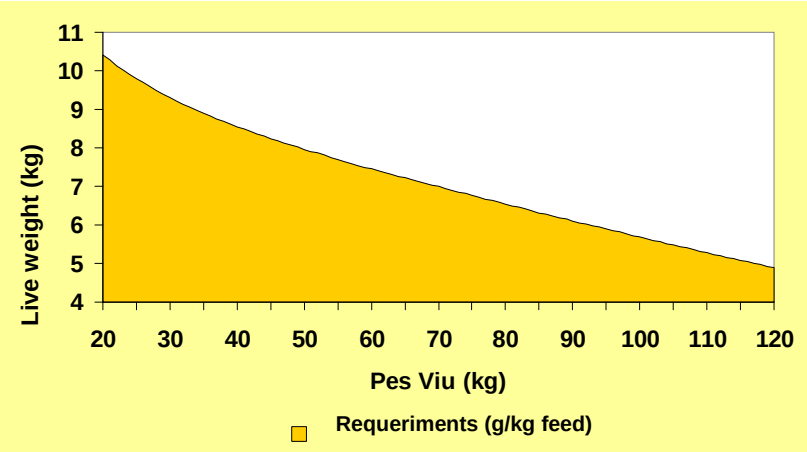


Figure 3.- Lysine requirements per kg of feed in a fattening pig (20-120 kg)

Source: Adapted from Torrallardona, 2007

Therefore, the most effective way to optimise the RP ration is to adjust it to the animals' needs. A range of strategies can be used to achieve this goal:

- ***Multiphase feeding:*** Supply various feeds during the different stages of fattening, varying protein content in accordance with their physiological requirements.
    - Advantage: The pig farm does not have to change its feed storage and distribution system.
    - Problem: There are logistic challenges in supplying more than 4 different feeds during fattening.
- ***Wet feeding***: A premix and/or precook before supplying the wet food to the feeders.
    - Advantage: It increases nutrient digestibility, it is easier to adjust nutrient content to the pigs' requirements (multiphase feeding).
    - Problem: The farm must be adapted to the wet feeding system.
- ***Robotic precision feeding***: Using individualised electronic identification, it is possible to supply food adjusted to each animal's individual needs.
    - Advantage: individualised diets can reduce protein and phosphorus consumption by 25%, decreasing nitrogen and phosphorus in the slurry between 35% and 45%.
    - Problem: The technology is still not widely implemented.

a) <u>Multiphase feeding</u>

Multiphase feeding is supplying various feeds during different stages of the fattening process, thereby varying protein content depending on physiological requirements and supplementing with essential amino acids, if necessary. Multiphase feeding enables a

better balance to be obtained between requirements and consumption during the entire fattening process.

Table 4.- Production parameters, slurry volume and nitrogen balance for three different fattening pig diets with a mean raw protein (RP) content of 17.55%, 16.06% and 14.84%.

PROGRAMME	Production parameters		SLURRY VOLUME m^3/pig	Nitrogen balance		
	GROWTH	FEED EFFICIENCY		kg EXCRETED	kg EXCRETED (PER YEAR)	% N REDUCTION
PROTEIN 17.55%	**656 g/day**	**2.56**	**0.296**	**3.70**	**3.70 (8.14 kg.)**	**3%**
PROTEIN 16.06%	**656 g/day**	**2.49**	**0.267**	**3.07**	**3.07 (6.75 kg.)**	**20%**
PROTEIN 14.84%	**638 g/day**	**2.59**	**0.248**	**2.87**	**2.87 (6.25 kg)**	**25%**

* With respect to the value of Decree 136/2009.

Source: Author, from the data provided by Nuri i Espadaler, SL, 2010.

Table 5.- Financial cost (€/pig) of the three different fattening pig diets with a mean raw protein (RP) content of 17.55%, 16.06% and 14.84%, taking into account raw material prices for 2007, 2008, 2009 and 2010.

€/pig	End 2007	End 2008	April 2009	May 2010
1) RP 17.55%	48.4	40.49	39.85	42.70
2) RP 16.06%	47.4	39.10	37.88	40.59
3) RP 14.84%	50.1	40.86	38.93	41.67
Diff 2)-1)	**-1.0**	**-1.39**	**-1.97**	**-2.11**
Diff 3)-1)	**+1.7**	**+0.37**	**-0.92**	**-1.03**

Source: Author, from the data provided by Nuri i Espadaler, SL, 2010.

Even if providing diets with a raw protein content more closely adjusted to the animals' needs would entail a cost increase in most cases, the overall economic balance could continue to be favourable as the possible cost increase in diet management could be offset by a decrease in the subsequent costs of waste management, due to the lower volumes of nitrogen to be treated.

In 2004, an agreement was approved between ASFAC (Composite Feed Manufacturers Association), the ACA (Catalan Water Agency, the ARC (Waste Agency of Catalonia) and the DAAM (Ministry of Agriculture, Livestock, Fisheries, Food and Natural Environment) which favoured a reduction in nitrogen generation in swine if a low raw protein diet was given. There were three levels of reduction in this agreement:

a) Level 1 with a 5% reduction in nitrogen generation in fattening pigs if they were given three different types of feed during the fattening period.

b) A second level called Level 2 with a 12% reduction that affected all production stages (fattening and farrowing) with a multiphase diet with certain maximum raw protein values.

c) Level 3 with a reduction as approved by the DAAM after it validated the one-year demonstration study carried out in a significant number of farms.

This agreement was subsequently transcribed in **Decree 136/2009** *approving the programme of action applicable to vulnerable areas in relation to nitrate pollution originating from agricultural sources and management of livestock manure.* This encouraged the feed manufacturing industry to progress in improving pig nutrition, feed technologies and feed handling.

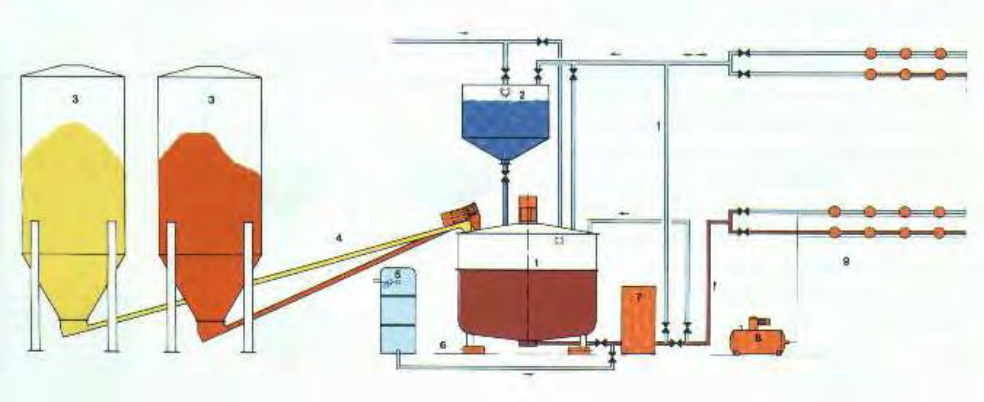
In 2010, with advancing knowledge of pig nutrition and the improvements achieved in feed production and supply technologies, the Ministry of Agriculture, Livestock, Fisheries, Food and Natural Environment (DAAM) changed certain criteria as regards application of the reduced levels of nitrogen excretion measured in swine as a result of dietary improvements. The purpose of **Order AAR/506/2010**.

This Order developed **level 3** of nitrogen reduction in swine by dietary measures, differentiating between two sublevels depending on the percentage reduction to be achieved. **Level 3a**, the reductions are calculated using a simple method which is acceptable for reductions from 12-18% with respect to the reference values. And **level 3b,** which is for reductions above 18%, for which a specific study must be submitted that shows that this level of reduction is attainable in commercial pig farming conditions. By April 2014, the DAAM had approved 101 fattening pig diets with reductions of up to 18%. These diets have been submitted by a total of 43 feed manufacturers.

The Ministry of Agriculture is currently preparing a new Order which will modify the level 3 of nitrogen reduction by dietary measures in pig production. In particular, level 3a will be amended for fattening pigs to a maximum of 25% with validation of a system of calculation and level 3b will be amended to reductions between 25% and 45%.

b) Wet feeding

With wet feeding, by-products from the food industry and/or other raw materials are mixed with water on the farm itself. This diet is often formulated electronically in accordance with the animals' needs. Wet feeding was developed to find a use for by-products from the food industry. However, given the advantages it offers, the number of farms using this system has been steadily increasing. Figure 4 shows a diagram of a wet feeding facility.



1) Mixing tank
2) Water tank
3) Silo
4) Feed screw
5) Fresh water tank
6) Electronic scales
7) Pump
8) Compressor
9) Feed valves

Figure 4. Diagram of a wet feeding facility.

Apart from being able to dose the food according to the animals' needs, the advantages offered by a wet feeding system include the flexibility of using different raw materials, improved precision in the formulation, increased intake with temperature pretreatments and improved digestibility, among others.

c) Robotic precision feeding

A further step in optimising pig feeding is to be able to provide a diet that is exactly matched to each individual's needs, taking into account parameters such as sex, genotype, growth rate and any others that could affect production yields.

By achieving this goal, it is possible to minimise nitrogen and phosphorus content in the slurry, among many other advantages, such as simplifying feed manufacture and distribution, decreasing labour requirements, and early detection of certain diseases.

The system is based on reading the pig's electronic ear tag when it comes to the feeder, providing it with a volume of feed with the required nutrients according to the information programmed. This feed is prepared by mixing two base feeds.

Source: Pomar, J., Pomar, C. (2010).

Pomar, et al. (2008) compared a precision diet (multiphase) with a three-phase diet. The study showed a 12% reduction in the nitrogen of the slurry compared with a three-phase fattening diet.

A multiphase feed improves the production yields and decreases nitrogen excretion; with a 25% decrease in protein and phosphorus consumption, nitrogen and phosphorus content in the slurry is decreased between 35% and 45%.

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