EU PiG

EU PiG Innovation Group

Technical Report

Precision Production

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1. Introduction

Within the project EU-PIG is for each challenge written a technical report. The purpose of the technical report is to formulate a working paper by technical experts in the area covered by the challenge validating the information regarding the selected best practices. The present working paper represents the scientific evaluation of the described best practices for the challenge “Using precision production to reduce the emissions from pig farming and slurry storage (reduce odour, reduce emissions, enhance the fertiliser value)” and is the background material for production and the end user material described on the website for the project “EU-PIG”.

Challenge: Reduce emissions

Emissions from pig housing units relate to ammonia, odour, greenhouse gases (methane and dinitrogenoxide) and dust.

Ammonia emissions from animal production can cause environmental impacts by eutrophication of sensitive nature areas near housing units and decrease air quality in general. At the same time, the uncontrolled losses of ammonia reduce the fertilizer value of the manure used for land application. The EU BREF document (BAT- Reference-document) concerning intensive rearing of poultry and pigs presents the requirement for e.g. ammonia emissions. The BREF document is renewed every eight years and was last renewed in 2017[1]. The EU countries must then meet the requirements laid down in the BREF document through their own regulations.

Odour emissions from large housing units, particularly from large units with finishers, can cause unacceptable nuisances to neighbours more than one kilometre from the production site, which can be a huge problem. Odour emissions are included in the BREF document, but not with a fixed value, and the regulation of odour emissions in the EU countries differs to protect neighbours of animal production units from smell nuisances.

At COP21 in Paris in December 2015, the EU presented a single reduction contribution on behalf of the member states. The contribution is a 40 per cent reduction in greenhouse gas emissions by 2030 compared to 1990, which was distributed among the EU countries in October 2017. In the pig production industry, greenhouse gas emissions originate from the carbondioxide emission from the consumed energy for electricity and heat, methane emissions from digestion and manure storage and dinitrogenoxide emissions from the land application of manure.

Dust from animal production is divided into particles below 10 and 2.5 micrometer, respectively (PM_{10} and $PM_{2.5}$). These particles can contain microorganisms and endotoxin and therefore cause health impacts on people living next to the production units and the farmers. Dust emissions are also included in the BREF document, but not with a fixed value, and the regulation of dust emissions in the EU countries differs.

It will be difficult, but desirable to have a technology that can reduce the emissions of all gases and particles at the same time. However, such a technology must not be too expensive, as the cost will be paid by the farmers' gross margin from the pig production. Often, reductions in ammonia and odour emissions will be the main priority, but in some countries, dust emissions will be a priority. Greenhouse gases are yet not a priority, but we expect some national regulations in the coming decade.

1. Addressing the Challenge

The challenge for the present section of the Technical report was "Using precision production to reduce the emissions from pig farming and slurry storage (reduce odour, reduce emissions, enhance the fertiliser value)". This area is of high focus in EU and many regional projects and legislative initiatives have focus on this area. Additionally, many companies are developing technologies to reduce emissions and odour from pig farms. In the consortium of the EU PIG project was collected a total of 28 good practices addressing the challenge of reducing emissions or odour. Good practices are farmers own examples addressing the challenge. From these 28 good practises was selected the top 5 denominated "Best Practice".

2. EU PiG Best Practice

In order to identify the top five best practices by applying precision production on water management with the aim to increase feed efficiency across all the EU PiG regions a series of criteria aiming at measuring the effectiveness of the collected practices to match the specific challenge were defined.

The following set of criteria have been scored for each practice.

- **Excellence/Technical Quality**
    - Clarity of the practice being proposed;
    - Soundness of the concept;
    - Knowledge exchange potential from the proposed practice;
    - Scientific and/or technical evidence supporting the proposed practice.

- **Impact**

- The extent to which the practice addressed the challenges pointed out by the Regional Pig Innovation Groups (RPIGs);
- Clear/obvious benefits/relevance to the industry;
- Impact on cost of production on farm and/or provide added value to the farming business or economy;
- The extent to which the proposed practice would result in enhanced technical expertise within the industry e.g. commercial exploitation, generation of new skills and/or attracting new entrants in to the industry;

- **Exploitation/Probability of Success**
    - The relevance of the practice to each Member State (MS) or pig producing region/system;
    - Timeframes for uptake and realisation of benefits from implementation of the proposed practice are reasonable;
    - Level of innovation according to the Technology Readiness Level (TRL)
    - The extent to which there are clear opportunities for the industry to implement the practice/innovation;
    - Degree of development/adaptation of the practice to production systems of more than one Member State

Scores had to be in the range of 0-5 (to the nearest full number). When an evaluator identified significant shortcomings, this was reflected by a lower score for the criterion concerned. The guidelines for scoring is shown below (no half scores could be used).

0	The practice cannot be assessed due to missing or incomplete information.
1 – Poor	The practice is inadequately described, or there are serious inherent weaknesses.
2 – Fair	The practice broadly addresses the criterion, but there are significant weaknesses.
3 – Good	The practice addresses the criterion well, but a number of shortcomings are present.
4 – Very Good	The practice addresses the criterion very well, but a small number of shortcomings are present.
5 – Excellent	The practice successfully addresses all relevant aspects of the criterion. Any shortcomings are minor.

The selection of the top five practices followed a procedure in six steps:

1. All members of the Thematic Group (TG) had the opportunity to send their scoring sheets to the TG leader
2. The TG members provided brief comments to the first 10 practices they have chosen as best practices, as these comments facilitated the discussion about the first five
3. The TG leader standardized all individual scores by calculating Z-scores
4. The first 10 practices have been ranked according to the average Z-scores of all participants of the TG. All other lower ranked practices have been excluded.
5. The TG leader collected all the comments of the individual members of the TG for each of these 10 practices and sent them around to the TG.
6. In a dedicated meeting, the TG discussed the results and finally decided on the top five best practices for each challenge based on the comments provided by the group.

2.1. Validation of the top five best practices

Trying new ways reaps benefits: Heavily N- and P- reduced fattening pig feeding in practice

This best practice originating from Germany is described as: “*With the heavily N- and P-reduced feeding, adapted to the different fattening phases, the nutrient surplus can be significantly mitigated and costs can be reduced by saving space and lessening the production of manure. In addition, this relieved the metabolism of the animals. For an exact supply without luxury consumption, the feeds are designed on the basis of digestible nutrients. On the one hand, we combine "ideal protein" with the energy rating according to the net energy. On the other hand, we calculate the feed based on digestible phosphorus. The metabolism of the animals is relieved and the N and P excretions are further reduced. To ensure fattening and slaughter performance, 9 protein digestibility-corrected amino acids are now factored in. As a result, all amino acids are sufficiently contained as building blocks for meat production. In addition, the reduction of crude protein in the feed leads to less metabolic heat loss. The animal thus has more available energy for growth*“.

Feed is the major production cost in pig production and about 70 per cent of the feed is used by fatteners from 30 kg to slaughter. Therefore, many universities, organisations and feed companies are exploring the pigs’ need for nutrition during the different fattening phases in order to maintain a high feed efficiency with the lowest feeding costs and nutrient excretion. Nitrogen excretion from the animals is regulated in the BREF document where the BAT (Best Available Technology) level is provided. The excretion from fatteners should be kept under 13 kg N per pig place per year[1]. In comparison, the standard feeding in Denmark contributes to an excretion of 11 kg N per pig place per year[2] with fattening pigs from 30 kg to 110 kg. This is with one phase feeding. To reach this level, the farmer needs to reduce the protein content in the feed by adding synthetic amino acids to the feed to obtain the “ideal protein” combination. The ideal protein is the combination of essential amino acids where no single amino acid is limiting the growth. Often, the first limiting amino acid is lysine. Consequently, the use of synthetic amino acids in the feed is crucial to obtain a low nitrogen excretion from fatteners.

Surplus of phosphorus is a problem because it is a limited resource and a surplus of phosphorus in the fields will potentially wash out to the marine environment. Phosphorus is therefore regulated in the BREF document[1] where the BAT level is provided. The excretion from fatteners should be kept under 5.4 kg P_2O_5 per pig place per year[1] which corresponds to 2.4 kg phosphorus per pig place per year. To reach this limit, the farmer often needs to use feed with a high phosphorus digestibility or add phytase to the feed.

Feeding according to the animals’ nutrient requirement during the fattening phase will contribute to an averagely lower content of protein and phosphorus in the feed and thereby reduce the excretion from the animals. However, as pigs often are housed in groups where there is weight difference between the animals of +/- 10 kg or more throughout the fattening phase, the feed must be adjusted to the average pig (or slightly smaller than average). This means that many pigs are not fed according to their needs. Therefore, only a limited effect on the overall N and P excretion of about 5 per cent is to be expected. This corresponds to a reduction of the excretion per finisher pig of about 0.5 kg of N and 0.1 kg of P. Nevertheless, phase feeding and feeding that follows a general standard in the EU is a good idea as it can be implemented on many farms within a short period of time. So even though the reduction per pig is low, it can add up to a rather large impact on the environment. In addition, maybe, in some parts of the EU, the feed as a standard contains too much protein and phosphorus relative to the animals’ need.

Chilling of manure with cooling deck system coupled with a heat pump

This best practice originating from Belgium is described as follows: “*Eddy is the only farmer in Flanders who already uses the ‘chilling of manure’ via a cooling deck system that’s coupled with a heat pump. There is a heat exchanger that floats in the manure, and it draws heat out of the manure. This leads to a lower temperature of the manure, which means that a lower ammonia emission is reached. The extracted heat from the manure is the heat source for the heat pump. With the heat the farrowing house (piglets) are warmed. This means that there is almost no need for natural gas or gasoline. There’s just a backup in case of emergency or extreme cold. The system already works for 5 years and only one time extra heating was needed. The chilling technique is not an end of pipe technique like the air scrubber but prevents the ammonia to form. This way it also results in a better life and work environment for the pig and the farmer. The climate in the stable is also much better. This concept is proven by the responsible institute from the government.*”

The cooling deck system is a system where the cooling elements are floating in the manure so that the manure is cooled at the surface. The evaporation of ammonia originates from the surface of the manure, and when the manure is cooled the evaporation will decrease. Measurements show that the evaporation of ammonia decreases by 7-8 per cent per degree Celsius the manure surface is cooled[2]. When the manure is not cooled, the temperature of the manure surface will follow the air temperature in the stable, which is between 17 °C to 25 °C depending on which group of pigs, which season of the year and which country we are looking at.

A heat pump converts the heat energy from the manure into useful heat energy that is used in the heating system of the farm. The heat pump uses 1 kWh of electricity to collect about 2.5 kWh of heat energy from the manure (cooling the manure) and converts it into about 3.5 kWh of heat energy in the heating system. The costs of the heat energy are therefore low, e.g. if electricity costs € 0.1 per kWh the cost of heat energy will amount to approx. € 0.03 per kWh. In comparison, the cost of heat energy from oil costs about € 0.07 per kWh. However, the investment and maintenance of the cooling system and the heat pump must, of course, also be taken into account.

The restriction of this technology is that it only cools the manure when heat is needed on the farm. That is why it is mostly used on sow farms where heat energy is needed for the farrowing pens and to warm the piglets. In Denmark, we expect the use of heat energy in the sow herds ranges between 150 kWh and 200 kWh per sow per year, and for the weaners between 3 kWh and 10 kWh per produced pig. On farms with fattening pigs, it will be a less economic technology because the need for heat energy is rather low. In Denmark, the use of heat energy for fatteners is between 2 kWh and 6 kWh per produced pig. The use of cooling of manure and a heat pump is, of course, more economic in the northern countries of EU, where there is a greater need for heating.

Acidification of slurry

This best practice suggested by Denmark is described as follows: *"In this "best practice" slurry is acidified with sulphuric acid to reduce emission of ammonia. This technology was implemented on the farm in order to obtain an environmental approval. The farm produces app. 28,000 slaughter pigs per year. Ammonia is a gas, which can evaporate from the slurry, while ammonium is present in the slurry as an ion. There is a chemical equilibrium between ammonia and ammonium. By lowering the pH of the slurry, it is possible to shift the equilibrium towards more ammonium and less ammonia and thereby reduce the emission. The system also provides other benefits. Each night the slurry is pumped to a process tank where sulphuric acid is added until the pH is 5.5. Subsequently, the slurry is returned to the stable. As the system is automatic it is not necessary to remove plugs manually as it would* *be in a regular system. Also, the slurry is more concentrated regarding nitrogen. On this farm, the acidification system is produced by JH Agro."*

The system is a process tank of 300-400 m^3. The manure from up to 1,000 m^2 of manure channels is flushed or pumped into the process tank once a day. In the process tank, two pH electrodes are rinsed with water automatically before the manure enters the process tank. After 10-20 minutes of manure stirring, sulphuric acid (96%) is added to the manure during stirring. When the pH reaches a level of 5.5 the supply of sulphuric acid and the stirring are stopped. After 10 minutes of rest the pH is checked and the manure is pumped back into the manure channels until it reaches a fixed level of e.g. 20 to 30 cm in the channels. The surplus of manure in the process tank is then pumped into a storage tank until a pre-set level in the process tank is reached. Because the system pumps manure with a pH of 5.5 to the storage tank, there will be a minimal evaporation of ammonia from the tank and therefore the farmer does not have to cover the manure in the storage tank.

Several tests are made to measure and confirm the reduction of the ammonia emission by acidification of the manure. The described system from JH Agro is also VERA approved[3], where the obtained reduction of ammonia emission was 64%.

The acidification of manure has no documented effect on odour. However, daily acidification in combination with separation of the manure in a dewatering drum sieve, during the daily treatment with sulphuric acid, has shown in two stables a reduction of the odour emission by 53% and 49%, respectively[4].

In addition to the reduction of ammonia emissions from the stable the low pH in the manure will inhibit the methanogenic bacteria and therefore the production of methane in the manure will also be reduced. Trials have indicated a reduction in methane emission of 40-60% from the stable. The enteric methane is about 20-30% of the methane emission from the stable which causes the methane emission from the manure to be reduced by 55-80% by acidification. Laboratory trials on cattle manure have shown a methane reduction between 67 and 87% when the manure was acidified to pH 5.5[5].

The acidification system is rather expensive and therefore only established on large farms, e.g. with more than 4,000 fattening pigs in the stables. Establishment costs of the system amount to roughly € 200,000, not including costs for sulphuric acid of € 1 (6-7 kg) and electricity of € 0.2 (2 kWh) per produced fattening pig. Depending of the size of the farm, the total cost for this system will amount to € 1.7-2.0 per produced fattening pig. If the farmer adds the dewatering drum sieve called "JH Smellfighter" to the system, costs will increase by about € 0.3 per produced fattening pig. The disadvantage of the acidification with sulphuric acid is that the manure contains a high level of sulphur, which in some areas/regions is considered a problem when the manure is applied on the land. Furthermore, it can also present a problem in the biogas plant if the fraction of acidified manure exceeds 10-20%.

Daily manure removal

This best practice suggested by the Netherlands is described as follows: "*De Hoeve Innovatie has developed a system that removes fresh manure from the stables every day. This results in a healthier stable climate and has advantages for animals, humans and the environment. The animals are healthier, grow faster and you have less costs for feed and veterinarian. This results in higher animal health and the possibility of keeping antibiotics-free pigs. In addition, fresh manure delivers up to 40 m^3 of biogas per cubic meter. By reducing the manure every day, less ammonia is produced. Emission reduction is tackled at the source by collecting the manure in pits or gutters. The Ammonia level is therefore much lower in the barn. As a result, more ventilation can be provided and conditioning is applied, which further improves barn climate (including CO2 content). By applying day disinfection there is no need for air scrubbers with high energy costs and unusable residual flows. They have already started this initiative in 2013."*

In this system, the pens for fatteners are designed with solid floors. In front of the pen, there is a "water" channel which should be at least 0.6 m wide and be filled with 0.1 m of water at the start of the fattening period. The manure from this channel is only flushed when needed, but at least once per production period. The feeder is placed on the slats above the water channel. In the back of the pen, there is a manure channel. In the manure channel, the surface area of the manure is reduced by \ / shaped walls with a slope of more than 45°, so that the width of the surface does not exceed 0.6 m. Typically, the depth of the manure channel is around 1 m. The solid floor should be more than 0.5 m^2 per pig place and be placed between the two channels. The daily removal of the manure from the manure channel is handled by a flushing system with fresh manure and water.

Removal of the manure from the stable every day will lead to a reduction in odour concentration in the air and consequently a reduction in the emission from the pig house[6]. The limited manure surface area will reduce the evaporation area for ammonia and thereby reduce the ammonia emission. This system reduces ammonia, odour and methane (because there is no manure storage in the pens): ammonia the least, followed odour and methane the most. Dust is not likely to be reduced in this system.

There are no known trials that confirm that the productivity of pigs increases when the concentration of ammonia, carbon dioxide, hydrogen sulphide etc. are decreased. Nevertheless, during the winter, when the ventilation rate in the stables is minimal, the concentration of these substances can be quite high, and the removal of the manure each day could therefore improve the well-being of the animals.

The advantage of this system is that once it is established in the stable, the costs are very low. By then, costs only include the use of water in the water channel and for the daily flushing of the manure. However, the use of water can be expensive, because the farmer has to store the water in the manure storage and later spread it on the land as fertilizer. The overall disadvantage is that the system should be integrated during the construction or (re)construction of the stable, which means that it will be a long time before it is widely used.

Air Scrubbers and Re-use of Heat

This best practice suggested by the Netherlands is described as follows: "*A total of 9 air scrubbers are present at his company. Special is that it concerns: 6 biological air scrubbers (1 control), 1 chemical air scrubber (1 control) and 2 combined air scrubbers (each separately controlled). The combination of air scrubbers can be kept within the permissible emission ceiling. The chemical LW reduces ammonia and fine dust, the organic LW reduces ammonia by 85% but also the odor. This meets the requirements for odor, particulate matter and ammonia. > everything on air scrubber, meets the future vision. After washing the air, the heat is reused in the company, heating floor for the pigs.* "

Air scrubbers are highly effective to reduce emissions from animal housing. Biological air scrubbers can reduce ammonia, odour and dust at the same time. Tests have shown that they are able to reduce ammonia by 80 to 90 per cent and odour by 70 to 80 per cent[8,9]. Chemical air scrubbers can reduce ammonia and dust and there is evidence that they reduce ammonia emission up to 90 per cent[10,11]. The combined air scrubbers which consist of a chemical and a biological air scrubber can also reduce both ammonia and odour. Tests have shown that ammonia emission can be reduced by 91 per cent and odour by 82 per cent[12].

Air scrubbing is a rather expensive technology. Costs (investment costs plus costs for acid, water and electricity) will amount to € 3-3.5 per produced fattening pig when all the air from the animal house is cleaned. To reduce this cost per pig, the farmer can choose to clean e.g. the first 20 per cent of the maximum air needed in the stable, also called 'partial air cleaning' (if, for instance, the stable has five ventilators, only one ventilator is connected to the air scrubber and the last four ventilators will be turned on when the first ventilator reaches its maximum). By using partial air cleaning, the farmer can reduce the costs to about € 1 per produced fattening pig and still reduce ammonia up to 60 to 65 per cent[13]. However, partial air cleaning is less effective to reduce odour emission: up to 15 per cent can be reached.

The ventilation air passing through the air scrubber can also pass a heat exchanger. The heat-exchanged water is lead through a heat pump whereby a higher temperature is created in the water of the heating system. The harvested heat can also be reused in the animal house to heat the inlet air during the winter time and thereby create a higher ventilation in the winter time to keep the humidity at a low level.

Air scrubbing is a technology with a high reduction of ammonia and dust and for biological scrubbers also odour. The disadvantage of biological air scrubbers is that they do not reduce methane emission and that they can produce nitrous oxide, which also is a greenhouse gas. Air scrubbers also have a high consumption of electricity.

2.2. Cost and benefit analysis of the EU PiG Ambassador

Best practice 'Daily manure removal' from the Netherlands was chosen as EU PiG ambassador 2018 for the challenge of reduced emissions. De Hoeve Innovatie has developed a system that removes fresh manure from the stables every day by water flushing system.

The costs and benefits of this system have been analysed taking into account the changes in technical performance parameters. Basing on the real farm data and calculations with the Interpig model, the following parameters of the farm have been observed and assumed for calculation:

<u>Benefits:</u>

- finishing daily weight gain increased by 100g (to 900 g/day).
- finishing feed conversion ratio improved by 0.26 (to 2.32)
- the mortality parameters improved and are on the low levels (sow mortality 0.5%, pigs born alive per litter 15.2, pigs born dead per litter 0.8, pre-weaning mortality 8%; rearing mortality 1% and finishing mortality 1%).
- animals are healthier - veterinary costs per sow are 31% lower (€60/sow/year) and per slaughter pig by 58% lower (€0.4/slaughter pig (finishing)). Production is possible with almost no antibiotic use.

<u>Costs:</u>

- The costs of manure disposal through the water system are 30% higher (the cost is €8/slaughter pig) and the system increases the water costs by 20% as per slaughter pig (the cost is €2/slaughter pig).
- the system should be integrated in the stable during the construction or (re)construction of the stable.
  Based on these assumptions variable production costs after implementation of best-practice decreased by **5.4%** as per kilogram of slaughter weight, mainly due to lower mortality parameters and lower vet costs (additional costs of water and manure spreading costs had smaller impact than the efficiency gains, which resulted in reduced average variable costs per kg). Decrease was also observed in case of fixed

costs by **2.8%** per kg. As result, the total costs were **lower by 4.8%** per kg of slaughter weight (€ 1.46/kg vs € 1.53/kg hot slaughter weight).

2.3. Expert Analysis

To my knowledge, there are no known trials that demonstrate that the pig productivity will increase when the concentration of ammonia, carbon dioxide, hydrogen sulphide etc. are decreased. In a recent test, we tested the addition of heat versus no heat added to finishers in the beginning of the fattening period. The purpose was to show that in the stables with additional heat the productivity would improve because of a better ventilation and air quality, humidity etc. However, the trial did not show any significant effect (yet unpublished). Nevertheless, the removal of the manure should improve the air quality, which potentially could lead to a marginal increase in productivity. An increase of 100 g daily gain and 0.26 better feed conversion, which is about 10 per cent increase in productivity, does seem to be in the high end. Maybe the observed effects are attributed to other management initiatives in the period.

It is not yet shown in a test whether the productivity would increase using this manure system. Additionally, further testing is needed to demonstrate the effect on air quality with measurements of the air quality and the emissions from the stable in comparison to “normal” stables. In some EU countries, the reduced emission obtained using this system will have some economic value, as the farmer will not need to invest in other technological solutions to reduce emissions.

As presented in *4.2 Cost and benefit analysis of the EU PiG Ambassador*, the cost of the manure system and disposal of the manure is calculated to € 8 per slaughter pig in this system, which is 30% higher than normal manure systems. If we allocate € 2 to storage and spreading the manure, it amounts to € 6 per slaughter pig to the manure system in the stable, which is very expensive. However, in the Netherlands the cost for disposal of the manure can be rather expensive, which may be included in the € 8. The price was 30% higher than normal manure systems, though, which means that the extra cost of the system amounts to roughly € 2 per slaughter pig. This could be paid by a marginal increase in productivity and the value of a reduced environmental impact.

2.4. Conclusions and advice to industry

The system **‘Daily manure removal’** will provide a better air quality in the stable, which might lead to a marginal better productivity. However, no trials are found to support this supposition. Daily removal of manure will, however, result in a better air quality in the stable and reduce the emissions of ammonia, odour and methane from the stable. Therefore, it is an environmental technology which operate at most of the environmental parameters.

- The system **'Daily manure removal'** is a complete system, which means that you cannot take only a part of the solution if you would like to achieve the reduction of both ammonia, odour and methane by this technology.
- You can, however, achieve reduction of odour and methane by removing the manure daily by a scraper in the manure pit. If you would like to reduce the ammonia also, you have to reduce the surface area of the manure, too, which is done in this system by V-shaped manure pit.
- The system does not require training, but it requires a stable management of the system. In practice the challenge with this system could be that the farmers do not use it every day to remove the manure, but instead use it like a normal manure system, which means that it does not work as intended.

3. The Future

In the future, it is important that environmental technologies operate on all the environmental parameters, which means not only ammonia and odour, but also greenhouse gasses and at some locations also dust. The **'Daily manure removal'** will operate at ammonia, odour and methane, but not dust. Consequently, it is nearly a complete environmental technology, but the complete environmental technology is yet to be seen.

To strengthen this technology in the competition, it is recommended to make tests to demonstrate the air quality in the stables and the impact on the productivity of the pigs, which is claimed by the recommendatory country.

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Challenge: Increase sow and gilt productivity

1. Introduction

Within the project EU-PIG is for each challenge written a technical report. The purpose of the technical report is to formulate a working paper by technical experts in the area covered by the challenge validating the information regarding the selected best practices. The present working paper represents the scientific evaluation of the described best practices for the challenge "Applying Precision Production to increase gilt and sow performance (farrowing rate, litter size, piglet survival, weaning to estrus interval, etc.)" and is the background material for production and the end user material described on the website for the project "EU-PIG".

2. Background to the challenge

Worldwide, pig-producing structures managing large sow herds and growing pigs from weaning to slaughter rely on a sustainable and efficient production process to maximize their economic return (Solà-Oriol and Gasa, 2017). Swine production is clearly divided in different stages or phases, according to the type of animal (reproductive sows or growing-fattening pigs), the age of the animals or their physiological state. Within this context, sow productivity is essential to sustain a constant production flow of pigs to slaughter.

Number of piglets weaned per sow per year is arguably the most used parameter to measure sow productivity. Although influenced by the genetic line used, nowadays the average productivity of EU commercial sow herds is reaching 30 pigs weaned per sow per year. Nonetheless, there is variation in the number of pigs weaned per sow per year between and within the different EU pig producing regions (AHDB, 2016). Maximization of litter size and reduction of the farrowing interval are the main aspects behind the achievement of sow productivity targets (Muns et al., 2016). Despite the fact that high litter size observed in current breeds has been achieved by genetic selection for highly prolific sows (Marandis et al., 2013), the influence of nutritional and feeding management of sows (Solà-Oriol and Gasa, 2017) as well as the effect of gilt conditioning and sow body weight, body condition and fat deposition levels (Farmer, 2015) on litter size and piglets' birth weight has been extensively documented.

The production cycle of sows is approximately 20 to 22 weeks long, depending on the lactation length. The farrowing interval is a major concern for sow productivity due to its direct relation to the number of non-productive days of female pigs (days in which a sow is neither gestating nor in lactation) and its impact on the production cycle (Koketsu and Sasaki, 2009).

In addition, sow longevity is an important factor for economic efficiency of the herd. It is estimated that around 50% of the sows are culled before their initial replacement costs can be met (third or fourth parity) (Farmer, 2015).

Throughout the whole production cycle, from the conditioning of the gilt and the insemination program to the management of both sows and piglets during lactation, producers have the capacity and potential to improve sow productivity by implementing a wide variety of management and nutritional practices oriented to improve the farrowing rate and reduce the number of non-productive days, to maximize litter size, reduce viability of piglets at birth, and to enhance the weight and number of piglets weaned and sow weaning condition. Despite most practices are implemented locally based on each farm's structure and idiosyncrasy, some of the best practices might contribute to improve sow productivity to a different range of sow herds within the EU and globally.

3. Addressing the Challenge

The challenge for the present section of the Technical report was "Applying Precision Production to increase gilt and sow performance (farrowing rate, litter size, piglet survival, weaning to estrus interval, etc.)". This area is of high focus in all EU countries and has significant impact on the revenue for the individual farmer. In the consortium of the EU PIG project was collected a total of 28 good practices addressing the challenge of reducing emissions or odour. Good practices are farmers own examples addressing the challenge. From these 29 good practises was selected the top 5 denominated "Best Practice".

4. EU PiG Best Practice

In order to identify the top five best practices by applying precision production on water management with the aim to increase feed efficiency across all the EU PiG regions a series of criteria aiming at measuring the effectiveness of the collected practices to match the specific challenge were defined.

The following set of criteria have been scored for each practice.

- **Excellence/Technical Quality**
  - Clarity of the practice being proposed;
  - Soundness of the concept;
  - Knowledge exchange potential from the proposed practice;
  - Scientific and/or technical evidence supporting the proposed practice.

- **Impact**
  - The extent to which the practice addressed the challenges pointed out by the RPIGs;

- Clear/obvious benefits/relevance to the industry;
- Impact on cost of production on farm and/or provide added value to the farming business or economy;
- The extent to which the proposed practice would result in enhanced technical expertise within the industry e.g. commercial exploitation, generation of new skills and/or attracting new entrants in to the industry;

- **Exploitation/Probability of Success**
    - The relevance of the practice to each MS or pig producing region/system;
    - Timeframes for uptake and realisation of benefits from implementation of the proposed practice are reasonable;
    - Level of innovation according to the Technology Readiness Level (TRL)
    - The extent to which there are clear opportunities for the industry to implement the practice/innovation;
    - Degree of development/adaptation of the practice to production systems of more than one Member State

Scores had to be in the range of 0-5 (to the nearest full number). When an evaluator identified significant shortcomings, this was reflected by a lower score for the criterion concerned. The guidelines for scoring is shown below (no half scores could be used).

0	The practice cannot be assessed due to missing or incomplete information.
1 – Poor	The practice is inadequately described, or there are serious inherent weaknesses.
2 – Fair	The practice broadly addresses the criterion, but there are significant weaknesses.
3 – Good	The practice addresses the criterion well, but a number of shortcomings are present.
4 – Very Good	The practice addresses the criterion very well, but a small number of shortcomings are present.
5 – Excellent	The practice successfully addresses all relevant aspects of the criterion. Any shortcomings are minor.

The selection of the top five practices followed a procedure in six steps:

1. All members of the TG had the opportunity to send their scoring sheets to the TG leader
2. The TG members provided brief comments to the first 10 practices they have chosen as best practices, as these comments facilitated the discussion about the first five

3. The TG leader standardized all individual scores by calculating Z-scores
4. The first 10 practices have been ranked according to the average Z-scores of all participants of the TG. All other lower ranked practices have been excluded.
5. The TG leader collected all the comments of the individual members of the TG for each of these 10 practices and sent them around to the TG.
6. In a dedicated meeting, the TG discussed the results and finally decided on the top five best practices for each challenge based on the comments provided by the group.

4.1. Validation of the top five best practices

Nedap Electronic Sow Feeding Station (The Netherlands)

The best practice consists in the implementation of an electronic feeding station (Nedap electronic sow feeders) for gestating sows in group housing. The system allows for a customized feeding program of the sows. At each visit to the feeder, each sow in the group gets the exact amount of feed according to their customized individual feeding curve. In addition, the system notifies when a sow does not eat its daily meal by weighing the left over feed and it automatically identifies, marks and separates sows that are due to be moved to the farrowing room. The Nedap feeding station is designed to feed sows to achieve the optimum body condition at farrowing with reduced labour cost/time and considering the inherent variability in sows' requirements within a group due to parity and gestation stage.

Ideally, after weaning and during gestation sows recover from the loss in body condition suffered during lactation. At the end of gestation, they should reach an optimum body condition that allows them to face the high energy demands of milk production but, at the same time, avoiding over-fattening, which could cause problems during farrowing and reduce feed intake during lactation (Farmer, 2015; Solà-Oriol and Gasa, 2017). In addition, good body condition and back fat deposition protect sows against lesions such as shoulder ulcers (Nystén et al., 2018). Feeding curves for post-weaning and gestating sows requires accurate management to properly adjust the feeding level to the gestational stage of the sows. It has been suggested to increase feed allowance ("flushing") during the days before service to increase ovulation rate and litter size. During the first 3 to 5 days after service limited feed intake is recommended to avoid an early interruption of pregnancy. After one week of mating up to day 30-35 of gestation an increase in feed allowance (to match the desired growth curve or body recovery from the previous lactation) is suggested to promote embryo survival. Finally, especially in hyper-prolific sows, extra feeding during the last weeks of gestation has a positive effect on piglet birth weights (Martineau and Badouard, 2014). The system allows to automatically set the change in feed allowance according to the individual gestating day, even in dynamic groups. The fact that the feeding system also allows to customize different feeding curves should allow the producer to differentiate between young (first and second parity sows) and older sows -with the former having higher energy requirements- and/or to differentiate between individual sows (Solà-Oriol and Gasa, 2017). Finally, the system alerts when a sow does not eat in any given day which is important to detect health problems in an early stage and to avoid off-feed incidents or a sustained low intake, both factors that might trigger pregnancy failure and embryo losses, especially during early gestation (Farmer, 2015). Nonetheless, this practice requires the producer to be precise on setting the feeding curves and identifying the different requirements of sows varying in their body condition and age at weaning. Installation cost of the feeding system and herd size could also be a handicap for its implementation.

The Gestal farrowing house feeder and two week batch system (United Kingdom)

The best practice consists on the capacity to programme six different feeding periods within a day in the farrowing house thanks to the installation of Gestal "Solo" feeders. The producer also determines a feeding curve according to sow's parity, body condition and/or litter size. The feeder has a "toggle switch" in the trough that allows the sow to call for feed (additional up to 120% of her total daily allowance). All feed events (e.g., feeding bouts, amount of feed dropped at each feeding bout, etc.) per sow are automatically logged at a computer and can be displayed in a computer printout. Sows that do not eat at the level of their assigned feeding curve are flagged both on the computer and on each feeder by using a LED light. In addition, the pig farmer works in a two-week batch system which allows him to wean piglets at 32-33 days of age, with subsequent higher weaning weights. The best practice is designed to maximize sows' feed intake during lactation, therefore maximizing milk yield and minimizing body condition and body weight loss during lactation. The automation of lactating sows feeding also allows for the relocation of labour towards other tasks (e.g., farrowing monitoring, new-born piglet assistance, cross-fostering, etc.). In addition, the implementation of a two week batch system aims to wean heavier more develop piglets with reduced risk of suffering from post-weaning growth check.

Lactation is the most demanding period in the sow's reproductive cycle. The energy demand for milk production usually exceeds the energy intake of sows, especially in highly-prolific breeds, leading to body reserves mobilization and extra risk for milk diseases (Mosnier et al. 2010; Hansen, 2012). Reaching the maximum intake potential of each sow is a challenging endeavour, especially in large herds. From a management point of view, one of the biggest difficulties in the farrowing house is to properly identify whether a sow is able and willing to eat more or not. Maximizing feed intake of sows during lactation, preferably using a step-up strategy, reduces body weight loss during lactation and improves milk yield and litter weight at weaning (Hansen, 2012). It also has a positive effect on sows' reproductive performance in the subsequent cycles (Wientjes et al., 2012). However, there are evidences that offering feed to sows above their intake capacity might end up reducing their total feed intake (Koketsu et al., 1996). In addition, it has been observed that when sows are allowed to choose when to eat and how much to eat they show increased appetite. The solutions provided by this practice are valid for different herd sizes and breed types, since it does not require for more labour (e.g., more time checking the feeders, looking for feed refusals, assessing body condition and litter size, etc.) and the final decision to increase feed allowance falls to the sow. This practice also allows to program up to six feeding periods and feeding curves within the farrowing house, hence adapting feeding to factors such as parity, body condition and/or litter size. Nonetheless, this practice requires the producer to be precise on setting the feeding curves and identifying the different sow requirements within each batch. In addition, to obtain the maximum benefit of the system the sows should be monitored for body condition and/or performance output and contrasting them to the system settings. Installation cost of the feeding system could be a handicap for its implementation.

Finally, the production of heavy and well developed pigs at weaning is another key aspect in modern pig production. Increased body weight of piglets at weaning is one of the most influential factors minimizing the negative impacts of weaning and is also correlated with their growth after weaning (Klindt, 2003), contributing to the total kg of pork meat produced per sow per year. With a prolonged lactation length, the best practice not only improves weaning weight of piglets but their maturity, making them more resilient to the weaning stress. However, implementation of a longer lactation period through a two week batch systems might be limited by management and farrowing house capacity in farms.

Improving young sow retention (United Kingdom)

The best practice consists on the implementation of a monitoring system for gilts at strategic/key points during their first cycle to maximize their performance in the subsequent cycle(s) and ultimately improve sow retention and longevity in the herd. Using a back fat meter the farmer measures gilts' back fat thickness on the P2 spot at service, when entering the farrowing room, 18 days into lactation, and at weaning. With the help of weight scales, the producer also records gilts' body weight at service and at weaning. The producer uses the recorded information to recalibrate and adjust the feeding to optimize gilts' body condition at different production points (e.g., avoid over-fattening at farrowing and/or under conditioned at weaning).

Proper conditioning of the gilt is a key factor for maximal lifetime reproductive performance and economic efficiency. Assessment of gilts body mass or body composition is required to determine the animal's body condition. The best practice measures two parameters, body weight and back fat, that are directly related to body mass and composition and uses them to subsequently adjust the feeding level. Although growth rate of gilts seems to be the most accurate predictor of their development, body weight at first service is usually considered as the reference breeding target for gilts since it includes all body tissues and it is easier to obtain. To measure gilts' body weight at service can be a good strategy, evidence shows that lighter weight gilts (< 130 kg) could result in lower performance at second parity, while very heavy gilts (> 170 kg) have more risk to experience lameness before parity two (Amaral Filha et al., 2009; Lyvers-Peffer et al., 2003; Williams et al., 2009). On the contrary, recording back fat thickness at first service might be less relevant by itself as a predictor for subsequent reproductive performance although it is recognized that either too little or too much body fat in gilts at first service will increase the risk of poor reproduction performance and culling (Bussières, 2013).

Similarly to sows, gilts need to arrive at farrowing with a good body condition to face the high energy demands of milk production but avoiding over-fattening, which could cause problems during farrowing and reduce feed intake during lactation (Farmer, 2015; Solà-Oriol and Gasa, 2017). Measuring back fat thickness of gilts before farrowing can contribute to identify any potential risks, plan a specific peri-partum management or post-farrowing feeding regime based on their back fat thickness. Around day 19 of lactation sows reach their peak of milk production (14 to 28 days. Hansen, 2012) after which the persistency of milk production is highly related to body condition and back fat level (Hansen et al., 2012). Therefore, measuring back fat thickness at day 18 is a good measure to evaluate gilts capacity to sustain lactation and/or to foresee the risk of excessive body energy mobilisation. Back fat level at day 18 compared to the value obtained before farrowing will allow the producer to adjust feed allowance/intake of the gilt accordingly and/or to evaluate the need for providing supplemental milk or extra creep feed to the litter. Finally, sows need to recover body protein and fat after weaning to attain again an optimum body condition before the subsequent farrowing. Measuring back fat and body weight at weaning will allow the producer to set different feeding curves for the gilts according to their body weight and back fat loss during lactation. In addition, it will allow to identify sows that suffered from extreme body energy mobilization during lactation, a factor that will compromise their second parity performance (Schenkel et al., 2010).

The best practice provides the producer with information useful to take management and feeding decisions at a gilt level and also at a herd level. The purchase and installation of the weight scale for weighing sows can be costly and is important to place it in a convenient/strategic location to minimize labour time, unnecessary sow handling and movement. Measuring back fat and weight of gilts regularly can be worthwhile for all farms (and even extended to multiparous sows) if they are willing to invest time in the monitoring task (which might be higher for bigger farms).

Automatic milk cups (Denmark)

The best practice consists in the installation of milk cups in the farrowing pens (either conventional or loose farrowing pens) to deal with large litters as an alternative to the use of nurse sows. The system consists of one or more tanks for mixing milk powder with hot water from which the milk is pumped through pipes to each farrowing pen where the piglets have ad libitum access to the milk through cups or troughs. The producer gradually transitioned from the implementation of nurse sows towards the installation of the milk cups in the farrowing rooms. Such change allowed to reduce the amount of time and resources intended on managing nursing sows (e.g., selecting and mixing piglets, moving sows, sufficient number of farrowing pens available, etc.) while maintaining piglet production from hyper prolific sows.

With the implementation of highly-prolific sows there has been an increase in the number of low birth weight piglets and in within-litter weight variability (Baxter et al., 2013; Rutherford et al., 2013). In addition, sow milk yield is becoming limiting for growth rate of lactating piglets (Farmer, 2015). To maximize sow output at weaning (e.g., reduce piglet mortality, maximize piglet's growth) the provision of supplemental milk (also referred as artificial milk, milk formula or milk replacement) for piglets in the farrowing pen has been suggested as a management strategy (Muns et al., 2016). Some experiences in the 90s and early 00s already pointed that early growth of piglets could be enhanced by providing supplemental milk starting as early as day 3 after farrowing (Dunshea et al., 1999; Wolter et al., 2002). The provision of supplemental milk during lactation has also been observed to increase not only piglets' pre-weaning growth but also to preserve sow body reserves at weaning in marked heat conditions (Spencer et al., 2003), when sow feed intake might be reduced. However, supplemental milk has little or no effect on reducing mortality of low birth weight piglets mainly because mortality mostly occur during the first 3 days post-farrowing, when voluntary supplemental milk intake is minimal or not started yet (De Vos et al., 2014). Supplemental milk also offers the possibility to add supplements and/or bioactive compounds to help the development of the piglets and it can be combined with other pre-weaning management practices such as the provision of creep feed. Therefore, the installation of automatic milk cups might contribute to enhance sow output by increasing piglets' weight at weaning. In addition, in production systems with a lactation length of 28 days or longer the supplemental milk has more potential to contribute to preserve sows reserves for in such systems milk production during the last week is limiting piglets' growth potential (Solà-Oriol and Gasa, 2017). The automation of the best practice reduces the work load of having to provide fresh supplemental milk daily manually. Compared to other strategies to automatically offer supplemental milk to piglets (e.g., split weaning) the present one requires no mixing nor changing of the environment for the piglets. However, the installation can be costly for producers and it requires a proper maintenance and hygiene of the system (mixing tank and distribution pipes). The benefits of installing such system might be influenced, among others, for factors such as climate of the region, prolificacy of the breed used, lactation length and for situations in which feed intake of sows might be impaired.

Unifeeder – precision creep feeding (United Kingdom)

The best practice consists on improving piglets' creep feed intake and reduce creep feed wastage in the farrowing pen by installing UniFeeders (Houston Hog innovation UniFeeder automatic piglet creep feeder). The UniFeeder, with a capacity for 2 kg of creep feed, is mounted on the side of the farrowing pen and it automatically dispenses creep feed to the piglets (on the floor or in a trough if placed underneath). Each feeder can be adjusted to different feeding curves and number of days according to litter size and/or litter weight.

Offering creep feed diets to piglets during lactation might not have a direct impact on maximizing sows output at weaning but it is a common practice oriented to promote feed intake after weaning and to help piglets cope with the weaning process, therefore, it contributes to maximize long-term sow output by enhancing piglets' post-weaning performance. During the last week of lactation (in 28 day lactation length or more) milk production decreases while piglets' requirements keep increasing (Solà-Oriol and Gasa, 2017). Such situation demands for additional sources of energy/nutrients for piglet's growth. Supplemental milk would probably be the most efficient and obvious strategy to supply the extra energy/nutrients needed for the piglets, however, it does little to prepare piglets for post-weaning conditions. Weaning is a stressful event for piglets resulting in anorexia, growth impairment, health problems, or impairment of gut structure (Pluske et al., 1995; Kim et al., 2012); a situation that is known to influence growth performance to slaughter (Magowan et al., 2011). One of the main factors contributing to the weaning stress is the sudden change from a milk based diet to solid feed. Despite only a low proportion of piglets consume feed during lactation (Sulabo et al., 2010b), piglets that consume creep feed during lactation show a shortened onset of feed consumption after weaning (Bruininx et al., 2002) and an increased feed intake and weight gain during the first days after weaning (Bruininx et al., 2004; Sulabo et al., 2010a; van den Brand et al., 2014). In addition, creep feed is especially beneficial for piglets in large litters and lactations longer than 21 days, which is the most common situation in EU pig systems using highly-prolific breeds.

The UniFeeders might make it easier for the producer to introduce creep feed earlier in the lactation. This can contribute to increase its total consumption and the proportion of piglets eating it (Muns and Tummaruk, 2016). Sows farrowing within batch systems are usually spread in 3 days. The capacity of programing by days and the delivery of feed intake makes the Unifeeder a good tool to ensure that creep feed is introduced at the same desired post-farrowing day to all litters without requiring extra effort. The capacity to program different feeding curves offers the producer an easy way of adapting the creep feed delivery to litters differing in their requirements (e.g., litters with higher weight variability and heavier litters might require higher amounts of creep feed). This refined delivery system is not only beneficial for the animals' performance but also contributes to reduce wastage of creep feed. This feature can be especially relevant considering that creep feed diets are high quality and energy rich diets formulated with highly palatable and digestible –usually expensive-ingredients. The system can be easily installed in a wide variety of farms and it can be combined with other pre-weaning management practices such as the provision of supplemental milk.

4.2. Cost and benefit analysis of the EU PiG Ambassador

Best practice 'Improving young sow retention' from United Kingdom was chosen as EU PiG ambassador 2018 for the challenge of increasing sow and gilts productivity. The best practice innovation basis on the implementation of a monitoring system for gilts at strategic points during their first cycle to maximize their performance in the subsequent cycle(s) and ultimately improve sow retention and longevity in the herd. The costs and benefits of this system have been analysed taken into account the changes in technical performance parameters before (2016) and after (2018) introduction of the system and necessary investments on the case study farm of David Goodier. Basing on the real farm data and calculations with the Interpig model the following parameters of the farm has been observed:

Benefits:

- number of pigs born alive per litter increased by 6.3% (from 12.7 to 13.5)
- number of pigs weaned per litter increased by 8.3% (from 10.8 to 11.7).
- number of litters/sow/year Increased by 5.4% (2.2 to 2.32).
- farrowing rate increased from 77.6 to 82.6%.

Costs:

- farmer reported an extra labour input of 8.5 hours per 3 weeks cycle (1.5 minutes as per weaned pig) which increased the time usage per sow per year by 5.2%.
- An initial investment cost related to back fat meter (measuring the backfat thickness) is £115 (ca €130) and Back Fat Scanner - £502 (ca €566). Investment in weight scale for weighing sows was not considered.

Based on these assumptions we compared situation on a farm *with monitoring system 2018* with the situation *before implementation* of the practice (2016). The variable production costs after implementation of best-practice decreased by **4.9%** as per piglet, mainly due to better breeding performance of the herd. The similar decrease was observed also case of fixed costs/per piglet, by **5%** (despite increased labour input and some investments, performance improvements allowed for decreasing the costs as per piglet). In result the total costs after implementing the best practice were **4.9**% lower per piglet than before.

4.3. Expert Analysis

Farm data provided by the selected Ambassador (used to elaborate the cost and benefit analysis) suggests improvements aligned with the expected benefits of implementing the best practice in a commercial setting.

Nonetheless, it would help to better understand the final impact of the best practice if details on how the farmer uses the information obtained from body weight and back fat measurements was provided. The potential benefits from the best practice might differ if the actions taken are, for example, limited to hold gilts for an extra oestrus cycle (either at first service or after weaning) when body weight or back fat levels are below their optimal values, or whether different feeding levels/regime are established during lactation and gestation according to sows' body weight and/or back fat dynamics.

As presented in *4.2 Cost and benefit analysis of the EU PiG Ambassador*, despite the initial investment required for the back fat meters and scanner, and the extra labour time associated with the best practice implementation; the analysis showed a potential production cost reduction up to 4.9% (in production cost per piglet).

According to literature, body weight and back fat around first service can be considered as indicators of bodily development of gilts. The measurement of body weight and back fat, contrasting them against ‘target’ values, and subsequently adapting feeding management to maximize the number of animals within a recommended range can be a good strategy against small litter sizes, increased non-productive days, second-parity production drop, or early culling (Farmer, 2015).

As with most of practices or protocols, there is potential to introduce refinements to the best practice in order to improve it and/or to simplify its implementation. For instance, growth rate of gilts has been suggested as a better indicator of future performance than body weight or back fat at first service (Bortolozzo et al., 2009). Therefore, recording growth rate of gilts at first service would be a better measurement for the current best practice. However, it would result into a more time demanding practice and its implementation in farms that purchase gilts could be difficult. Furthermore, it has been recognized that back fat thickness at first service is a poor predictor of reproductive performance (Aherne, 2005). Therefore, back fat thickness at first service could be omitted from the best practice without expecting any reduction of the potential benefit.

The reasoning behind the best practice and its implementation are valid for any producer across the different member states and probably abroad. The main differences that might be found among farms and/or regions are the ‘target’ reference/threshold values against to which compare the on-farm body weight and back fat measurements and the magnitude of the benefits obtained from the best practice. These differences will be mainly determined by the genetic breed line used in each farm, which will result in different body condition standards (e.g., target body weight at first service, body condition/back fat level at farrowing, etc.) and different performance targets (e.g., live born, piglets weaned per year, etc.). Therefore, ‘target’ values should be identified for each farm with the participation of farmers, production managers, veterinarians, geneticists and nutritionists.

4.4. Conclusions and advice to industry

Customizing different feeding curves for the different types of gilts and sows within a herd (differing in their requirements), either during gestation or lactation, will maximize their reproductive performance and milk yield.Maximizing lactating sows feed intake should be a priority in the farrowing house. Step-up strategies and systems/feeders that reduce the risk of feed refusals and allow sows to voluntarily reach their maximum intake are preferable.

Different criteria can be used –and combined- to decide how many feeding curves categories are needed during gestation or to establish the most suitable step-up feeding regime in the farrowing house: age of the sows (first and second parity versus older sows) and/or body condition (e.g., body weight, back fat) at different production points (i.e., service, end of gestation, mid-lactation or weaning, etc.).

Ensuring that gilts have reached a proper body condition at first service will reduce the risk of early culling and increase lifetime performance output per animal.

Offering creep feed to piglets is a very effective strategy to familiarize them with solid feed before weaning. Especially with highly prolific sows, creep feed should be combined with the provision of an energy supplement (e.g., supplemental milk) to enhance both piglets and sow performance.

5. The Future

Body condition targets (e.g., body weight, back fat, body condition score, growth rate, age, etc.) have been suggested in the past for conditioning of the gilt for optimal reproductive performance. However, as stated in Farmer (2015), it is not clear how the targets and their importance have changed during the last 10 years. There is a need to determine new recommendation values and to assess their predictive power in current commercial breeds.

Particularly, updated recommendations for gilt development obtained using current breeds should be developed to improve decision making in farms.

As implied above, research to update gilt development recommendations are needed. In addition, progress on reliable and easy to implement on-farm body protein measurements (i.e., *longissimus thoracis* muscle diameter or area) should be studied for their better prediction outcomes than body condition score or back fat.

During the last few years numerous research papers on gilt and sow nutritional requirements have been published and several projects across EU are studying the relationship between gilt and sow development and their lifetime performance. In the coming years it is expected that research-based information will be available to answer most of the current knowledge gaps.

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