



# An overview of Irish pig production, research and knowledge transfer since 1960

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## Abstract

*Pig production in Ireland has gone through enormous changes during the past 60 yr, from pigs being primarily produced as a sideline on dairy farms, to an industry with one of the highest average herd sizes in Europe. This happened in part due to external pressure on the industry, whereby economies of scale were needed to compete with pigs produced in other countries, but largely due to the instigation of national programmes to support the pig industry through research, education and knowledge transfer. These efforts helped producers to take advantage of genetic improvements and monitor their own performance over time, as well as allowing for benchmarking of the national herd against other countries. The research programme initiated in the 1960s continues to grow and expand, providing the pig industry with internationally renowned data and knowledge in the areas of nutrition, animal welfare, the environment and energy use. Recent initiatives such as the establishment of the Teagasc and Irish Farmers Association Pig Joint Programme, and a Pig Health Check section in Animal Health Ireland, will help to promote further cross-collaboration between stakeholders in the pig industry, and enable it to rise to the challenges of the years ahead.*

## Keywords

Environment • health • legislation • management • nutrition • performance

## Introduction

Pig production is a major sector of the agricultural economy of Ireland. It ranks third in gross agricultural output (8%) after milk and beef, and the value of pig meat exports in 2020 was almost €1 billion. Traditionally, pigs were produced alongside the dairy sector, as historical by-products of dairy production (whey and skim milk) provided an excellent and cheap source of feed for pigs. However, the structure of the pig sector in Ireland transformed during the past 60 yr. In 1960, there were 111,000 pig famers with an average herd size of eight pigs, and a national output of ≤1 million pigs. Today Ireland has 280 commercial pig farms comprising ~200 sow breeding/integrated farms with an average herd size of ~700 sows and ~80 specialised finishing farms, and a national output of 3.8 million pigs (Teagasc, 2021 personal communication).

Up to the 1960s, most farms comprised of small breeders with a few sows producing pigs for finishing on their own farms, or for sale to specialised finisher farms. An initiative undertaken

in the 1960s by the Department of Agriculture (Department of Agriculture, Food and the Marine [DAFM] today) was the development of pig cooperatives where small breeders could sell their weaned pigs at 25–30 kg live weight for finishing in a central farm. This allowed small breeders a share in the profit from finishing pigs to slaughter. However, it soon emerged that mixing of pigs from several farms resulted in disease incidence, which led to this system ceasing. Thus, over time, the production model in Ireland evolved from small breeding and specialised finisher farms, to the “integrated pig farm” which breeds, rears and finishes pigs all produced on the same farm.

### **The Teagasc Pig Development Department**

One of the most significant developments for the Irish pig sector occurred in 1959, when Dr Jim O'Grady was appointed to the Moorepark Research Centre (part of the new agricultural research institute to become known as An Foras Talúntais,

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AFT). Because of the close linkages between pigs and milk production at farm level at the time, it was decided that pig research should be located at the same campus as the dairy research centre. Jim was tasked with developing the facilities and programme that would provide the vital technology for what was to become an internationally competitive pig production sector. His initial team included technicians Tom Gardiner and Sean Scanlon, who oversaw the construction of an 80-sow farm with farrowing pens and dry sow accommodation on straw, with individual feeders. Indeed, in 1968 Moorepark was one of the first farms in Ireland to fit individual stalls for pregnant sows to allow tailored feeding for individual animals. A strategic programme was developed aimed at providing the technologies for housing, feeding and fertility that would revolutionise the Irish pig industry over the following decades.

Early experiments focused on feeding sows during pregnancy and lactation. Subsequently, the first major experiment compared the Jordan (an uninsulated concrete structure originally used in Northern Ireland, later to become known as the “sweat box”), the Solari (a hayshed-type structure with kennels, under which the pigs slept with straw stored on top) and the Danish house (the most expensive of the three, it had a single feeding passage through the centre and small pens on each side, with a feed trough parallel to the passage).

In the late 1960s, the research team was further strengthened with the recruitment of two new scientists, Tom Hanrahan and Brendan Lynch. This led to a massive expansion in the research programme, especially in the area of feeding and nutrition, and subsequent dramatic improvements in the efficiency of pig production at farm level. The late 1960s saw the development of the “Moorepark Diet”, a barley-soya bean meal diet, which became the standard diet for finisher pigs and, with subsequent improvements over the years, it remains the benchmark diet to date in Ireland. Moorepark also developed blueprints on housing and hygiene, which enabled the further development of large farms.

### **Knowledge transfer**

Dissemination of research from Moorepark and further afield came about via nationally funded advisory services, operated over the years by the Department of Agriculture, the County Committees of Agriculture, the national advisory and training body (ACOT) and currently, by Teagasc. In 1970, two young agricultural graduates, Pat Tuite and Michael Martin, were appointed Specialist Pig Advisors by the Department of Agriculture. As the pig sector developed, it became clear that specialisation was needed and Pat and Michael put together a national team of eight Specialist Pig Advisors in the early 1980s. In the mid-1990s, the pig research and advisory departments were amalgamated into the Pig Development Department (PDD).

### **Education**

Skilled staff, motivated to deliver a high level of technical performance, are essential in pig production. Education and training for staff to supply the pig sector was initially provided at Mellows College, Athenry where the Certificate in Pig Husbandry trained managers and skilled stock persons for the industry from 1969 to 2003. Numbers in the first year of the course peaked at 32. However, a greater range of training options outside agriculture and the fall from favour of narrow agriculture-only courses in general contributed to the demise of the course. The final intake of six was in 2000 and of these, four graduated in 2003. This created a dearth of skilled labour, which in the short term was part-filled by foreign-born labour, particularly from Eastern Europe. However, in 2009 the PDD initiated a level-5 certificate in Agriculture (Pig Production; National Framework of Qualifications Level 5) which has since trained 140 students. A level 6, advanced certificate in agriculture (Pig Management), followed in 2018.

### **The joint programme**

The PDD has always worked closely with pig farmers, and in 2012 Teagasc and the Irish Farmers Association agreed on a “Pig Joint Programme”, which facilitated the recruitment of additional researchers, advisors and technical support for the research and advisory programme. This led to a significant increase in the capability of the PDD. On the research side, the PDD currently hosts ~12 postgraduate students and 4 postdoctoral researchers at any one time, compared to ~4 and 2, respectively, prior to the joint programme’s establishment. Along with this, in 2016 a newly built Teagasc Pig Research Facility, which could accommodate 200 sows and their offspring, opened in Moorepark. This facility contains state-of-the-art feeding systems (both wet and dry), a “baby-feed” system for pre-weaned and immediately weaned pigs, as well as specialised facilities and equipment to measure individual pig intake, detailed animal behaviour testing and measures of physical condition (e.g. blood sampling, hoof scoring, etc.). With regard to knowledge transfer activities, this greater critical mass allowed the PDD to establish multiple outreach activities which were previously not possible, through a dedicated communication officer. These activities include a monthly newsletter, a bi-monthly podcast “The Pig Edge”, a dedicated Twitter account, an annual research dissemination day, facilitated pig farmer discussion groups across all regions of the country, a regularly updated suite of infographics and posters for use on pig farms, and a YouTube “skills series”. In addition, the Pig Research Facility releases a video diary every month, so that stakeholders can stay up to date with research and performance indicators. The success of the joint programme is evidenced in the results of an external peer review across all the livestock sectors in Teagasc, carried out in 2017. Not only did the PDD rank highest within Teagasc,

but the Peer Assessment Panel described the PDD as “one of the largest and arguably best applied pig research/extension programmes operating globally today”.

### Improvements in performance

Key performance indicators (KPIs) are important in the management of any business, as they enable business owners to make decisions using data, and monitor those decisions. Teagasc Pig Advisors have worked with pig producers over the years to develop a number of industry-relevant KPIs. These were initially collated from the mid-1990s using the Teagasc PigSys recording system, and in 2014 the system was switched to the Teagasc eProfit Monitor (ePM) recording system. Participating pig farmers submit their data to their Teagasc Advisor on a quarterly basis, and the data from all participating farms are compiled and published by Teagasc as the “National Pig Herd Performance Report” each year. Although not available since 1960 (when the average litter size was 11.4 piglets, sows produced 15 pigs/yr and feed conversion efficiency from weaning to sale was 4.0), annual data are compiled since 2000.

Data were collected from 141 farms in 2000 (average of 400 sows/herd), 98 farms in 2010 (average of 654 sows/herd) and 88 farms in 2020 (average of 799 sows/herd). The database currently represents over 55% of the Irish sow herd.

#### KPIs over the years

Table 1 provides an overview of the main KPIs used in the Irish pig industry and provides values for 2000, 2010 and 2020. Numbers born alive (BA) per litter have risen steadily with a 30% increase between 2000 and 2020. Although the number of litters per sow per year is stable, this meant an increase of 28% in pigs produced (sold) per sow per year in 2020 relative to 2000. Between 2000 and 2020, there was an increase in live sale weight of 25.2 kg, and an increase in deadweight (carcass weight) of 20.1 kg. Indeed, average daily gain (ADG) from weaning to sale has improved by 150 g per day over the same period. The increase in pigs produced/sow per year and carcass weight of each pig has contributed to more pig meat sold/sow per year (an increase of 66% between 2000 and 2020). The amount of feed required to produce each kilogram of carcass is also decreasing over time, and can be seen in the drop from 3.66 to 3.50 kg of feed to produce a kilogram of pig meat.

### The market for pig meat

In 1960, Ireland recorded an annual pig throughput of just under 1 million pigs (3.8 m today) equating to 71,586 t of pig meat valued at almost IRE160 m. Slaughter pigs were

**Table 1:** Key performance indicator values from the Irish pig industry in 2000, 2010 and 2020

	2000	2010	2020
<b>Measures of sow performance</b>			
Litters/sow per year	2.29	2.32	2.31
Born alive/litter	10.85	12.01	14.26
Piglet mortality %	9.0	9.9	11.1
Weaner mortality %	2.6	2.4	2.8
Finisher mortality %	2.3	2.5	2.7
Pigs produced/sow per year	21.5	23.9	27.5
<b>Performance weaning to sale</b>			
Liveweight at sale (kg)	90.1	103.6	115.3
Deadweight at sale (kg)	68.1	78.9	88.2
ADG (g)	585	668	735
Feed conversion efficiency	2.34	2.47	2.40
<b>Pigmeat produced</b>			
Carcass weight sold/sow per year (kg)*	1471	1886	2426
Total feed/sow (kg)	5385	6966	8488
kg feed/kg of carcass	3.66	3.69	3.50

(Source: Teagasc PigSys herd recording system, 2000, 2010, replaced by Teagasc eProfit Monitor, 2020).

\*This is the pigs produced/sow/year multiplied by the average deadweight at sale.

ADG = average daily gain.

processed in 38 factories or “curers” operating at the time at various locations throughout the country. The organisation of the pig meat market throughout the 1960s remained under the control of the Pigs and Bacon Act (PBA) first introduced in 1935. The PBA and subsequent amendments were a set of national measures aimed at stabilising the market, which was subject to large fluctuations, to ensure orderly and reasonably profitable pig production on the island. Established in 1939 under the PBA, the Pigs and Bacon Commission regulated the production and marketing of pig meat and was responsible for managing Irish pig meat exports via a quota arrangement with individual curers.

The shift to modern pig management systems from the mid-1980s brought about major rationalisation and investment in the sector, which helped Ireland to develop an internationally competitive export-orientated pig meat industry (see Table 2). The impact of EU membership, government policy, technological developments and market forces influenced the type of pig products exported in the intervening years. Ireland is over 200% self-sufficient in pig meat and in recent years has shown exceptional growth in exports. In 2020, the Irish product was exported to over 50 different countries throughout

**Table 2:** Details of the pig meat sector at 10-year intervals from 1970 to 2020

	Gross output		Exports	
	Output <sup>1</sup>	Volume <sup>2</sup>	Volume <sup>2</sup>	Value <sup>3</sup>
1970	1.93	128.7	45	68
1980	2.38	154.3	54	87
1990	2.37	156.9	54	n/a
2000	3.15	230.4	121	270
2010	2.66	214.3	134	317
2020	3.54	320.0	317	586

Source: the Central Statistics Office.

<sup>1</sup>Million head.

<sup>2</sup>Thousand tonnes.

<sup>3</sup>Million €.

the world. The UK has remained a principal market for Irish pig meat exports dominating supplies since the 1960s. The outbreak of African swine fever (ASF) in 2018, particularly in China, dramatically reshaped the global meat market and its trade patterns. Shipments of Irish pig meat to the Asian market now account for 47% of the total volume and 41% of the total value of exports, with China being the leading destination for Irish product in 2020. Asian markets have now overtaken the UK market in terms of both volume and value for Irish pig meat exports. The UK market as our closest neighbours, however, will still remain a key market in the future for Irish pig meat accounting for 30% of the total value and 23% of the total volume of exports in 2020 (Bord Bia, 2021).

## Genetics and breeding

One of the major reasons for the improvements in the aforementioned KPIs is a change in pig genetics. In the early 1960s in Ireland, the pig industry was composed of many small individual pig breeders, each specialising in one or two pig breeds. These breeders competed in national shows (e.g. the Irish Spring Show), for the prize of National Champion Boar for each individual breed. Indeed this national competition lasted until the mid-1980s. However, by that stage there was a significantly reduced number of Irish pig breeders, and along with an increased awareness of disease transmission/biosecurity and consequently a reluctance to risk bringing pigs to public shows/events, the competitions were no longer sustainable.

The development of larger pig farms from the 1960s, and the shift into modern pig production, coincided with the introduction of the Landrace and Large White breeds and their establishment as the predominant breeds. A government breeding programme in the mid-1960s, supported by the

importation of high-quality breeding stock, brought about initial rapid improvements in carcass leanness. In more recent years, the pig breeding industry developed independently from government programmes, and since the 1990s a new model emerged. The number of Irish pig breeders declined until only Hermitage Pigs remained as the last of the original pedigree pig breeders in the Irish Pig Herd Book, and currently only four genetic sources supply the Irish market. This followed an international pattern, whereby since the 1990s the global pig genetic companies amalgamated. The large-scale uptake of artificial insemination (AI) in the commercial pig production sector means that today pig breeding is almost 100% by AI. The dominant breeds remain the Landrace and Large Whites, with the Duroc breed also gaining in popularity in recent years.

### Rate of genetic change

Adoption of AI in Ireland during the late 1980s means that at each service a high genetic merit boar can now inseminate 20 sows instead of one. National, and eventually international, AI delivery increased access to high genetic merit boars, contributing to the emergence of global pig genetic companies. These larger companies, along with the greater use of BLUP (Best Linear Unbiased Prediction) computing and genomic selection, allowed for increased accuracy and acceleration in genetic improvement for key performance/economic traits during the last 20 yr. Indeed, pigs were initially considered “dual purpose” (i.e. equally suited for breeding and finishing) but since the 1980s are separated into separate breeding goals for sire and dam lines.

The focus on dam-line fertility largely concentrated on 1) reduction of the weaning-to-service interval (WSI) and 2) increasing the number of piglets BA. Advances in fertility were initially made by individual breeders with small “nucleus” herds, and therefore genetic progression was slow, but this increased rapidly after the consolidation of the industry. This is evidenced by the increases in BA in Ireland (Table 1). Unfortunately, the strive for higher BA over this period was negatively correlated with birth weight, and positively correlated with within-litter variation in birth weight and increased pre-weaning mortality. Wientjes *et al.* (2012) estimated that the average birth weight fell by 40 g for every extra piglet born; therefore, over the last 20 yr an increased BA of 4 pigs/litter equates to an estimated average reduction in birth weight of 160 g/piglet. As such, in recent years the industry introduced a “survivability by day 3/5” into their dam-line selection traits.

The split into separate breeding goals for sire-line and dam-line allowed for a significant increase in sire-line growth rates and feed efficiency (FE), and by extension, reduced back-fat and increased lean meat percentage. Indeed, these traits improved even though sale weight has increased steadily over the last 21 yr (Table 1); the average growth rate from weaning

to sale increased by 150 g/day (585 g to 735 g) even though birth weight decreased by ~160 g/pig over the same period.

### **The challenge of rearing large litters**

As a result of recent increases in litter size, sows are often not capable of rearing all of their own piglets to weaning, because the number of piglets increasingly exceeds the number of teats. Additionally, larger litters are associated with a decrease and variation in piglet birth weight, meaning piglets are increasingly susceptible to injury and death (Calderón Díaz *et al.*, 2017). Thus, the genetic changes listed earlier have resulted in concurrent changes to sow and piglet management.

Cross-fostering (CF) is the practice whereby piglets are moved between sows to match piglet and teat numbers, and to even up piglet sizes within litters, when sows are all within the same farrowing batch. It often occurs throughout lactation, although usually during the first week. Results from a recent survey conducted on 79 Irish pig farms show that in 51.9% of farms CF takes place 4 d after farrowing and in 46% of farms, only late CF is practiced (unpublished data). However, movement is stressful for piglets (they need to repeatedly attempt to establish their own teat on the udder), and ultimately results in lighter carcass weights, greater risk of mortality and greater risk of pericarditis and heart condemnations (Calderón Díaz *et al.*, 2017, 2018). Average daily gain was reduced by 21 g/d for CF piglets, resulting in them being ~550 g lighter than non-fostered piglets at weaning. Moreover, the heavier the piglet was at birth, the more detrimental the effect of CF (i.e. greater the differences in weaning weight between piglets that were or were not CF; O'Driscoll *et al.*, manuscript in preparation). A piglet may end up being moved several times if care is not taken to monitor piglet movement, and as such Teagasc recommend tagging all CF piglets.

Nurse sow strategies are an alternative, highly structured, version of CF, used when multiple sows in a batch have more piglets born than teats available. The nurse sow is a sow later into lactation. If her piglets are at least 21 d old, they are weaned, and if not, they are moved to another sow, who has had her own piglets moved off of her (again, weaned or moved to another sow). Newly born piglets from multiple large litters are then moved to the nurse sow at between 12 and 24 h after birth, once they consume colostrum from the mother. Thus a new litter of very young piglets is formed, rather than piglets entering an already established one.

Teagasc research found that when nurse sows were left without piglets for 3 h, all accepted their new litter (Schmitt *et al.*, 2019a). There was intense fighting between piglets at nursing during the first few days, which was associated with piglets completely missing nursing bouts, until the teat order was formed about 1 wk later (Schmitt *et al.*, 2019b). Interestingly, this research also found that when piglets were moved as a litter to a new sow, there was an increase

in piglets switching teats during nursing. This suggests that the teat order was disturbed just by the transfer onto a new sow, and highlights again that movement of piglets should be minimised (Schmitt *et al.*, 2019b). In this research, the heavier piglets were moved from their mothers to form the nurse sow litters, which had the consequence of all litters being a similar weight at weaning; this has benefits for pig management later on in the production cycle. In addition, there was no evidence of compromised welfare associated with nurse sow strategies (Schmitt *et al.*, 2019a).

Other options for management of large litters is provision of supplementary milk in the pen, or indeed a complete artificial rearing strategy. Pilot work in the Moorepark unit, which is being expanded upon in the coming years due to installation of a milk-feeding system in the farrowing and weaner rooms, indicates that a supplementary energy supply has benefits for weaning weight (O'Driscoll & Schmitt, 2016). However, removing 7-day-old piglets from their mother, and artificially rearing them in a plastic enclosure with a milk-feeding system (Rescue Deck®) until 28 d of age, was not beneficial for growth. These piglets also had more harmful behaviours and were dirtier than sow-reared piglets (Schmitt *et al.*, 2019c). Thus, artificial rearing is not a suitable strategy to rear piglets.

## **Pig nutrition**

As feed costs account for ~70% of pig production costs, improving FE is possibly the principal determinant of profitability in pig production. Since its inception, Teagasc conducted nutritional research on all phases of pig production, aiming to determine the most efficient feeding strategies, while optimising animal health and welfare.

### **The sow**

Inadequate nutrition of the gestating sow can negatively influence both the sow and her offspring, immediately, and in the longer term, and thus have a significant effect on farm profitability. Teagasc has performed both gilt and sow nutrition research, as they may respond differently to dietary adjustments. For instance, in the early 2010s, Teagasc research determined that back-fat for gilts should be targeted at ~19 mm by the time of first insemination. A daily feed allowance of ~2.5 kg of gestation diet (6.2 g/kg total lysine, 13.0 MJ digestible energy [DE]/kg) should be provided to gilts between day 25 and 90 of gestation, to maximise growth to slaughter in offspring (Amdi *et al.*, 2013, 2014).

A high proportion of Irish sows are liquid-fed. Frequently, producers inadvertently restrict the intake of liquid-fed sows during lactation by using feed curves (computerised plan of daily allocation of feed which increases during lactation) that do not provide sufficient feed to match the intake capacity of

sows. This results in excessive lactation weight loss, increased days to oestrus, reduced farrowing rate and reduced litter size at the subsequent farrowing. Indeed, increasing commonly used feed curves by 30% reduced the number of days between weaning and oestrus, reduced excessive sow weight loss and potentially increased litter size by two piglets. Thus, increasing lactation feeding levels holds promise to increase subsequent litter size and reduce the number of empty days (days not pregnant or suckling their litter) per sow (Lawlor *et al.*, 2007a; Ryan *et al.*, 2009).

Large litters mean that there is increased pressure on the sow to produce healthy, efficient piglets. L-carnitine is a water-soluble quaternary amine, and plays a role in the transport of fatty acids across the mitochondrial membrane. Thus, it is hypothesised to improve energy generation through fatty acid oxidation. Supplementation to hyper-prolific gestating gilts (~15 piglets born) not only increased the number of pigs weaned and litter weight at weaning, but also increased the carcass weight of offspring at slaughter (Rooney *et al.*, 2019, 2020b). Moreover, supplemented sows gave birth to heavier piglets, particularly for sows with >14 piglets born. Carnitine also improved piglet vitality at birth (Reid *et al.*, 2016). Thus, carnitine holds promise as an option to increase piglet survivability and growth where litters are large.

Energy intake depends both on the quantity of the diet consumed and on its energy density. Sufficient lactation energy intake is critical to maximise milk yield, minimise mobilisation of body reserves and maximise subsequent reproductive performance. Increasing the energy density of the lactating sow diet in increments from 13.8 to 15.9 MJ DE/kg did not depress sow-voluntary feed intake, and feeding a high-energy dense diet (>14.5 MJ DE/kg) improved only some indicators of piglet vitality. As no other measures were affected, the study concluded that energy intake of hyper-prolific sows is used with greater efficiency for piglet growth when sows are fed a low- versus a high-energy density lactation diet (Rooney *et al.*, 2020a).

The effect of supplementing sow diets with enzymes between day 109 of gestation and the following service was investigated as an alternative method to improve energy intake. Indeed, supplementation with a non-starch polysaccharide-hydrolysing enzyme increased energy intake during lactation for both gilts and sows. For gilts, the loss of body reserves (back-fat) at weaning was reduced (Walsh *et al.*, 2012a), and in multiparous sows, the extra energy was reallocated to increasing litter weight gain, resulting in an increase in piglet weight at weaning (Cozannet *et al.*, 2018). Finally, one of the practical limitations to applying accurate nutritional recommendations for sows on commercial farms is that accurate sow weights are not always available. A simple equation using easily obtained morphometric measurements to estimate sow weight was developed; sow girth was the

single most accurate estimator of body weight ( $R^2 = 0.81$ ), and, including back-fat thickness, parity number and day of gestation in the model improved the estimate further ( $R^2 = 0.89$ ; O'Connell *et al.*, 2007).

### **The newly weaned pig**

When planning routine management and nutrition programmes for weaned pigs, the influence of weaning age on post-weaning intake and growth is critical. A 1-kg increase in weaning weight results in a 1.7-kg increase in weight at 28 d post weaning, and increasing weaning age by 1 d is associated with a 500-g increase in weight at that time (Lawlor *et al.*, 2003a). In addition, each weekly increase in weaning age between 3 and 5 wk increased feed intake (week 3 to 4: 13%, week 4 to 5: 69%) and ADG of pigs between weaning and 10 wk of age (week 3 to 4: 11%, week 4 to 5: 67%; Leliveld *et al.*, 2013). Thus, Teagasc recommends that pigs are weaned at a minimum of 4 wk of age. From this age, pigs can better digest and absorb dietary nutrients. Therefore, they have increased growth and less post-weaning diarrhoea, both of which are increasingly important in light of the impending ban on pharmacological levels of zinc oxide in post-weaning diets, which, to date, has been used as prophylaxis against post-weaning diarrhoea.

Pigs that are heavier at birth outperform their lighter littermates post weaning, and reach slaughter weight sooner (Lawlor *et al.*, 2002a, 2005a). However, Teagasc studies found no clear relationship between increasing global nutrition of the sow (increased feed intake rather than an increase in specific nutrients) or energy supply at critical nutritional windows on piglet birth weight (Lawlor *et al.*, 2007b; Markham *et al.*, 2009; McNamara *et al.*, 2011). Although weaning weight is increased by supplementing piglets with creep feed in the farrowing pen, this advantage can be lost by 14 d post weaning (Lawlor *et al.*, 2002a), most likely dependent on the proportion of pigs within the post-weaning group that have consumed creep feed and so classified as "eaters". Thus, to minimise the weaning "growth lag", in late 2020 Teagasc commenced a 4-yr research programme aimed at increasing energy and nutrient intake, and stimulating earlier enzyme secretory capacity, in suckling piglets from large litters, by feeding liquid milk replacer and starter diets prior to weaning.

The post-weaning growth lag, normally experienced by pigs, is due not only to the change in feed consistency and reduced feed intake, but also to a limited digestive and absorptive capacity, resulting from insufficient production of gastric hydrochloric acid and pancreatic enzymes. Feeding organic acids or reducing the acid-binding capacity of post-weaning diets helped increase intake and growth with the benefit being greatest when diets contained low levels of milk products. These strategies are beneficial because they supplement the newly weaned pig's limited capacity to produce gastric

hydrochloric acid (Lawlor *et al.*, 2005a, 2005b, 2006). These strategies are now widely used in the commercial production of post-weaning pig diets, and the work is receiving renewed attention due to the previously mentioned changes to the regulations with regard to veterinary medicinal products.

#### *Ingredients and feed delivery*

Although post-weaning growth rate is increased by feeding high levels of milk powder in diets immediately after weaning, and time taken to reach slaughter weight is reduced, feeding excessive levels of these expensive diets post weaning was not cost-effective (Lawlor *et al.*, 2002a, 2003b, 2005a). Thus, Teagasc recommend that a target of 2 kg/pig of starter diet and 5 kg/pig of link diet (a diet intermediate in composition between that of a starter and a weaner diet) should be fed post weaning. Alternatively, a starter diet should be fed for 7–10 d post weaning followed by a link diet for another 12–14 d. Heat-treated (steam-flaked, micronised, expanded, extruded, etc.) cereals were also once common in post-weaning diets, but are expensive, and Teagasc research demonstrated that although starch was effectively gelatinised by the process, the heat processing did not significantly improve animal growth or FE (Lawlor *et al.*, 2003a, 2003b). Therefore, it is no longer recommended to include heat-processed maize and wheat in post-weaning pig diets.

In the early 2000s, it was thought that liquid feeding could be a panacea for successful feeding of newly weaned pigs, so a series of trials in which pigs were liquid-fed (fresh, fermented and acidified) for 28 d post weaning were performed in Teagasc. Contrary to popular opinion at the time, the practice was found to be quite wasteful of feed depending on the design of the feeding trough; in one trial, liquid feeding actually caused a reduction in growth rate (Lawlor *et al.*, 2002b). As a result, very few liquid feed systems for weaned pigs were installed on Irish pig units, resulting in savings related to FE through reduced feed waste.

#### **Growing pigs**

##### *Feed enzymes*

There is now a move towards the use of novel ingredients and co-products in the pig industry in order to reduce feed costs. Although pig diets are primarily composed of ingredients of vegetable origin, pigs lack the enzymes needed to break down fibre and therefore cannot efficiently digest fibrous ingredients. However, supplementing the diet with enzymes could potentially improve nutrient availability and FE.

Two meta-analyses of data from the literature confirmed that dietary supplementation of multi-enzyme complexes appears to be the most consistent strategy to improve FE in both weaner and finisher pigs (Torres-Pitarch *et al.*, 2017, 2019). Results were most consistent when maize-based diets were

supplemented with mannanase, barley-based diets with protease and when the diets were low in nutrient and energy density. Experimental work confirmed that supplementing carbohydrases and phytase as a multi-enzyme complex to low-nutrient-density diets returned the growth and FE of the pigs, as well as metacarpal and foot areal bone mineral density, to the levels reached by pigs fed diets meeting nutrient recommendations (Lawlor *et al.*, 2019).

Nevertheless, the results from other Teagasc studies were less consistent. Growth and FE of grower-finisher pigs fed a wheat-dried distillers grain with solubles and rape seed meal-based diet did not improve when supplemented with an enzyme complex containing phytase, carbohydrases and protease (Torres-Pitarch *et al.*, 2018). Supplementation of xylanase and beta-glucanase to liquid diets increased nutrient digestibility in two liquid-feeding studies but improved FE in only one (Torres-Pitarch *et al.*, 2020a, 2020b). Interestingly, when FE was improved due to enzyme supplementation, bacterial taxa in the gastrointestinal tract (GIT) that were correlated with increased pig growth increased in abundance, whereas in the experiment where FE was not improved, they did not. This may help to explain the inconsistency often observed between enzyme supplementation studies.

##### *Liquid feeding – growing finishing pigs*

Computerised liquid-feeding systems reduce on-farm labour because they can mix feed ingredients and automatically deliver complete diets to troughs. These systems feed more than 70% of Irish pigs, and were often installed when significant volumes of liquid co-products (e.g. liquid whey and skim milk) were readily available in Ireland. However, these co-products are no longer easily and cheaply sourced, and the systems require a high degree of skill to operate optimally. Indeed, there is clear evidence of uncontrolled spontaneous fermentation of liquid feed leading to amino acid degradation and a reduction in energy, on Irish pig farms (O'Meara *et al.*, 2021). O'Meara *et al.* (2020a) found that wet/dry feeding a pelleted diet was the optimum method (out of six options) of feeding grow-finisher pigs as it maximised carcass growth and optimised FE; liquid feeding also maximised growth rate, but resulted in poorer FE. The question then was how to improve FE when liquid feeding. O'Meara *et al.* (2020b) found that a water-to-feed ratio of less than 3.5:1 on a DM basis optimised FE, and could be lowered to 2.4:1 to reduce the manure volume. Benzoic acid in liquid feed did not improve growth or FE (O'Meara *et al.*, 2020c), but an acid blend containing formic acid (SALMO-NIL® Dry LC; Nutri-Ad International NV, Turnhout, Belgium) did. Controlled cereal or whole diet fermentation did not improve FE (O'Meara *et al.*, 2020d). Work on optimising feeding management and hygiene routines with liquid-feeding systems is continuing with the objective of improving FE.

### Phase feeding

The nutrient requirements of pigs change from birth to slaughter. Adjusting the nutritional composition of diets to these requirements (phase feeding) is important to minimise costs and reduce environmental impact. Feeding programmes for growing finishing pigs should include at least two to three diets, with a progressive reduction in nutrients, mainly protein. However, many Irish farms work with only one diet from 30–40 kg to slaughter (Teagasc eProfit Monitor, 2020), as they often only have one feeding line. However, moving to diets with lower protein levels, especially around 80 kg to slaughter, results in important financial savings and reduces N excretion significantly (Goodband *et al.*, 2017). This will be more important in the coming years as DAFM target an average crude protein level in pig diets of <16%.

### Gut microbiome and feed efficiency

The bacteria present in the GIT play a role in nutrient digestion and metabolism, as well as development and regulation of the host immune response. Teagasc studies were among the first to show that this gut microbiome is associated with FE in pigs (McCormack *et al.*, 2017, 2019a). However, many FE-associated bacterial taxa are present at low relative abundance, and few consistent reliable FE-associated bacteria were identified across different rearing environments (McCormack *et al.*, 2019a). Furthermore, faecal microbiota transplantation of inocula derived from highly feed efficient pigs, to pregnant sows, and/or their offspring, was not effective in improving FE or slaughter weight of their offspring (McCormack *et al.*, 2018), even if offspring were supplemented with the prebiotic inulin at weaning (McCormack *et al.*, 2019b). Nevertheless, the existence of a number of growth- and FE-associated bacterial taxa within the gut microbiome of pigs means that microbiota-targeted strategies offer real potential to improve productivity in pigs (Gardiner *et al.*, 2020). However, it is likely that the most appropriate strategy for the future is to select for production traits based on core functionality of the microbiome and to modulate overall functionality of the microbiome, rather than focusing on individual taxa *per se*.

## Carcass lesions

Meat inspection (MI) determines the health of animals both prior to death (ante-mortem) and after death (post-mortem) to ensure meat quality and safety. MI findings are currently underutilised (EFSA, 2011), and relaying this information back to pig farmers could contribute to reducing carcass losses and improving pig welfare on farm (Harley *et al.*, 2012a). In Ireland, carcass condemnation is a major source of financial loss in the pig industry (Harley *et al.*, 2014), with abscessation caused by tail biting being one of the main reasons (Harley

*et al.*, 2012b). Furthermore, given the scale of the problem of tail biting for pig welfare (Boyle *et al.*, 2021a), tail injuries are likely one of the most important carcass lesions to be recorded at MI (Harley *et al.*, 2012b).

Tail lesions (TL) are strongly associated with farm productivity parameters, and are less common on farms that avail of record keeping through the Teagasc advisory service (van Staaveren *et al.*, 2017a). They are also associated with lung pathologies at slaughter (Boyle *et al.*, 2021a); thus they appear to be negatively associated with better management in general (Teixeira *et al.*, 2016; van Staaveren *et al.*, 2016). Apart from severe TL in the finisher stage, carcass TL can also identify farms with problems with poor body condition in the first weaner stage, and bursitis in the second weaner stage (van Staaveren *et al.*, 2017b), and TL acquired both early and late in the production cycle are visible on the carcass (Carroll *et al.*, 2018). Indeed, TL are best detected after scalding and dehairing rather than at ante-mortem inspection (Carroll *et al.*, 2015). As mixing, transport, slaughter and carcass processing do not disrupt the visibility or presence of TL on the carcass (van Staaveren *et al.*, 2015), there is a strong case for including measures of the severity of carcass TL in the MI process.

However, consultations with stakeholders revealed a preference to focus on lesions related to health (such as lung lesions) in the MI process as a first priority (van Staaveren *et al.*, 2019). Thus, a programme of research to validate lung pathologies at MI against coughing on farm (Pessoa *et al.*, 2020) and to standardise methods of scoring was undertaken. Stakeholders also expressed positive attitudes towards the use of MI data to inform pig health and welfare if both standardisation of recording and feedback were improved, and if the MI system could provide real-time benchmarking possibilities (van Staaveren *et al.*, 2019). In 2021, DAFM rolled out a computerised ante-mortem recording system in Irish meat-processing plants, with a post-mortem system to follow in 2022. This will greatly improve feedback of information to producers, and will facilitate improvements to husbandry practices which are associated with lesions detectable on the carcass.

## Salmonella

*Salmonella* carriage in pigs is a significant food safety concern (EFSA, 2008). A number of Teagasc studies investigated the epidemiology of *Salmonella* on Irish pig farms. On high seroprevalence farms, second-stage weaners had the highest rate of *Salmonella* shedding, closely followed by finishers and gilts, with monophasic variants of *Salmonella* Typhimurium predominating (Burns, 2015). However, sows do not appear to pose a major risk in the maintenance and transmission of *Salmonella* to their progeny, but instead the contaminated pen environment is more significant in on-farm perpetuation



(Lynch *et al.*, 2018). Although feed was found to play a role in the transmission of *Salmonella* to pigs, *Salmonella* prevalence in pig feed and feed ingredients is low (Burns, 2015; Burns *et al.*, 2015). Interestingly, surveillance data highlighted feed form, biosecurity and disease control as significant factors associated with *Salmonella* infection on farrow-to-finish pig farms (Arguello *et al.*, 2018).

Much Teagasc research investigated low-cost practical solutions to control *Salmonella* in pig production. In finisher pigs, supplementation with fumaric acid or a seaweed extract reduced intestinal counts of bacterial species indicative of pathogens such as *Salmonella* (Campbell *et al.*, 2006; Gardiner *et al.*, 2008). Supplementation with coated sodium butyrate or a blend of formic and citric acids and essential oils was effective in reducing *Salmonella* shedding and seroprevalence, but only in the absence of secondary infections (Walia *et al.*, 2016, 2017a). In grower pigs, supplementation with these latter products also reduced *Salmonella* shedding and improved ADG (Lynch *et al.*, 2017a, 2017b). In weaned pigs, a novel combination of five probiotic strains selected for their anti-*Salmonella* activity (Gardiner *et al.*, 2004; Walsh *et al.*, 2008) reduced *Salmonella* shedding (Casey *et al.*, 2007). In addition, Arguello *et al.* (2019) revealed that gut microbiota composition and maturation (transition from a suckling to a post-weaning microbiota) appear to influence resistance to *Salmonella* infection in weaned pigs; thus, gut microbiota manipulation has potential to protect against infection.

Finally, *Salmonella* control strategies can also be effective when applied at the abattoir. Drying of lairage pens after cleaning with detergent and a chlorocresol-based disinfectant was the most effective hygiene routine to eliminate *Salmonella* contamination (Walia *et al.*, 2017b). Topical misting of pigs in the lairage with a peroxygen disinfectant was also beneficial as a *Salmonella* decontaminant prior to slaughter (Walia *et al.*, 2017c). These strategies should be adopted by the processing sector in an effort to reduce carcass contamination with *Salmonella* at the abattoir. The sanitisation strategies also have relevance in guiding on-farm hygiene routines.

In 2021, Animal Health Ireland (AHI) and Teagasc carried out a case-control study in Irish farms to identify management practices associated with a *Salmonella*-free status, which could be effective in reducing prevalence nationally. The outcome of this work will help further to implement the national *Salmonella* control programme.

## Feed safety

### Genetically modified (GM) feed

The Irish feed industry is highly reliant on imported GM protein sources, particularly soya and maize co-products. Teagasc research showed that both short- or long-term feeding of GM

Bt-maize, which expresses the truncated Cry1Ab toxin from *Bacillus thuringiensis* which confers resistance to certain insect pests of maize, to pigs is as safe as its conventional counterpart with respect to pig health and growth (Buzoianu *et al.*, 2012a, 2012b, 2012c; Walsh *et al.*, 2011, 2012b, 2012c). Neither was there any cause for concern regarding the safety of peas expressing  $\alpha$ -amylase inhibitor to provide protection against the pea weevil (Walsh *et al.*, in press). This work offers assurance to regulators, farmers and consumers alike as to the safety of GM feed ingredients in pigs of different ages, even when fed for extended periods or transgenerationally (Buzoianu *et al.*, 2012d, 2013a, 2013b; Walsh *et al.*, 2013). Given that pigs are an excellent model for humans (Bergen, 2022), this work also provides reassurance to consumers as to the safety of directly consuming these GM ingredients.

### Mycotoxins

Mycotoxins are secondary metabolites produced by fungi, mainly the moulds *Aspergillus*, *Penicillium* and *Fusarium*. They affect ~25% of the world's food crops, causing significant economic losses, as well as being a health concern in humans. A review conducted by Teagasc advised that if mycotoxin contamination is identified, the contaminated grain should be disposed of or, if safe to do so, diluted with clean grain and fed, along with a binder, to the least susceptible species and type of animal (Lawlor & Lynch, 2001a). Following removal of contaminated feed, the storage area should then be thoroughly cleaned and disinfected to prevent cross-contamination. A follow-on review highlighted that the clinical response in pigs to mycotoxins can vary; vomitoxin causes pigs to refuse feed, zearalenone affects the reproductive organs, ochratoxin causes kidney damage and aflatoxins increase susceptibility to disease through their action as immunosuppressants and can also cause haemorrhages and digestive disorders (Lawlor & Lynch, 2001b).

## Pig production and the environment

Although the overall density of pig production expressed as agricultural area used per sow in Ireland (26 ha/sow) is relatively low (e.g. Netherlands, 1.9 ha/sow; Denmark, 2.0 ha/sow), the pig industry generates large volumes of animal manure on a small area of land. This must be managed in order to comply with national and EU environmental legislation. Since September 1996, pig farms above a certain size were incorporated under the Environmental Protection Agency (EPA) Act (1992) as "intensive agriculture" and require an Industrial Emissions Licence. This licensing regime was introduced on a phased basis; currently, if a facility exceeds 750 sows and/or 2000 production pigs (pigs >30 kgLW), they must have an Industrial Emissions Licence, and 118 licences have been issued to date.

### Management of pig manure

Over the past 15–20 yr, provision of low protein diets and phytase enzyme has greatly reduced the levels of N and P excreted, respectively. This was driven by research work showing that performance on farms was not negatively impacted by these strategies (Campbell & Bedford, 1992; Hayes *et al.*, 2004; Humer *et al.*, 2015). The issue of managing slurry to ensure minimal impact on water resources was managed by a code of practice until 2005/2006 when the EU Good Agricultural Practice for Protection of Waters Regulations (the “nitrates” regulations) came into force. This requires all pig farms to have capacity for a 26-wk slurry storage. The regulations also encouraged better farmyard management by minimising the volumes of soiled water generated on farms.

There are a number of available technologies for using and treating pig manure (reviewed by Dennehy *et al.*, 2017a). Those investigated by Teagasc include anaerobic digestion (Xie *et al.*, 2011a, 2011b, 2012a, 2012b, 2017), composting (Nolan *et al.*, 2011; Troy *et al.*, 2012, 2013b) and pyrolysis (Troy *et al.*, 2013a, 2013b, 2014). Treatment of the liquid fraction of pig manure through integrated constructed wetlands (ICW; Harrington *et al.*, 2012), woodchip biofilters (Carney *et al.*, 2013, 2016) and intermittently aerated sequencing batch reactors (Zhang *et al.*, 2011, 2012) was also assessed. However, none of these technologies are currently cost-effective in Ireland, other than in limited scenarios (e.g. anaerobic digestion on integrated pig units with >2000 sows; Nolan *et al.*, 2012). Thus, land spreading remains the most cost-effective use for pig manure in Ireland.

Pathogen removal was also investigated to assess potential biosafety risks, as antibiotic-resistant *Salmonella*, for example, is common in pig manure (McCarthy *et al.*, 2013). Manure separation generated a solid fraction with lower faecal indicator counts than the manure (McCarthy *et al.*, 2013), and storage for 84–112 d reduced/eliminated *Salmonella*, including antibiotic-resistant strains, in manure and its solid and liquid fractions (McCarthy *et al.*, 2015b). Composting manure solids also reduced faecal indicators so that the compost complied with animal by-products regulations (McCarthy *et al.*, 2011a). Treatment of the liquid fraction of anaerobically digested (AD) pig manure in meso-scale (midway between bench and pilot-scale) ICWs reduced indicator bacteria (McCarthy *et al.*, 2011b). Furthermore, in on-farm ICWs treating agricultural wastewater, including the liquid fraction of AD pig manure, and woodchip biofilters treating the liquid fraction of manure, *Salmonella*, including antibiotic-resistant strains, was undetectable in the effluent (McCarthy *et al.*, 2011b, 2015a). Thus, management strategies can be successful in reducing pathogens, including antibiotic-resistant strains, in pig manure and its separated solid and liquid fractions.

A large body of Teagasc research was also performed on co-digestion of pig manure and food waste (FW).

At batch-scale, co-digestion had synergistic effects on specific methane yields and digestion kinetics (Dennehy *et al.*, 2016). However, varying the digester feedstock composition did not affect digestate biosafety or dewaterability (Dennehy *et al.*, 2018). Decreasing hydraulic retention time (HRT) from 41 to 21 d did not increase the counts of pathogenic indicator microorganisms (Dennehy *et al.*, 2018), but reducing HRT below 21 d had a negative effect on indicator reduction rates (Dennehy *et al.*, 2017a). Dennehy *et al.* (2018) also concluded that hydrogenotrophic methanogenesis may be a key methanogenic pathway at low HRTs (Dennehy *et al.*, 2018). Further research into dry co-digestion of pig manure and FW focused on methane production kinetics, inactivation of *Salmonella* and enteric indicator bacteria, system stability and the roles of, and interaction amongst, microbes (Jiang *et al.*, 2018a, 2018b, 2018c, 2019). Together with a review of the literature (Jiang *et al.*, 2020), the conclusion was that for successful anaerobic co-digestion of pig manure and bio waste, operating conditions need to be optimised in order to mutually benefit energy recovery, pathogen inactivation, economic feasibility and bio waste stabilisation.

The final part of this research involved development of an economic model to assess the financial viability of on-farm biogas plants in Ireland (Dennehy *et al.*, 2017b). Despite lower operational and capital expenditure than co-digestion, mono-digestion of pig manure was not financially viable. In terms of co-digestion, Monte Carlo simulation revealed that net revenues from a small farm were least sensitive to any future changes in FW availability, gate fees (fees charged by the anaerobic digester operator for disposal of the FW), digestate disposal costs and renewable energy feed-in tariff. Due to its potential to treat greater amounts of FW than a small farm, whilst requiring a lower amount of FW to remain profitable relative to a large farm, medium-sized farms had the highest revenue-generating potential under optimal market conditions (Dennehy *et al.*, 2017b).

### What does the future hold for the Irish pig sector?

The European pig sector currently faces challenges that could have significant long-term implications for the industry. These include ASF, volatility of feed prices and EU regulations in the areas of health (e.g. Regulation [EU] 2019/6 on veterinary medicines), welfare (e.g. Council Directive 2008/120/EC on minimum standards for the protection of pigs) and the environment. The Irish pig sector has an added challenge with Brexit due to the UK, along with China, taking a significant proportion of Irish pork exports. To face these challenges, it is essential that the industry as a whole improve standards of production. This includes not only investigating the potential to produce value-added products, but also optimising efficiency

and innovation to ensure maintenance of existing presence in the domestic, European and international markets.

### **Market opportunities**

In the short term, Irish pig exports will face a significant challenge when the Chinese pig herd recovers from the impact of ASF. The increased volume of global pig meat production will likely exceed demand, resulting in downward pressure on pig meat prices and margins. In the medium term, economic and population growth in developing countries will be the main drivers of meat consumption globally, which may provide new markets for Irish pig meat. Nonetheless, producers and processors face continuous challenges when competing in the international marketplace, ranging from high feed and energy costs to market access disruption, supply surges, currency fluctuations, etc.

Ireland currently has only a very small number of pig producers producing low volumes of potentially high-value products such as outdoor pigs and organic product. The vast majority (99%) of our pig meat output is not a high-margin product (Teagasc, 2019). One way that the Irish pig meat industry could differentiate itself on the international markets is to develop a “bespoke” high value-added pig meat product. To this end, Teagasc researchers recently commenced market research into consumer demand for high-welfare pork, which will include interviews with major buyers (e.g. supermarkets, etc.) and economic analysis to determine the return needed to remain profitable, upon conversion to a higher-welfare system.

### **Health and welfare**

A significant challenge for the pig industry across the EU is the growing emphasis on enforcement of Council Directive 2008/120/EC, which mandates that pigs should not be routinely tail docked to prevent tail biting, and provided with environmental enrichment that satisfies their behavioural needs. Moreover, the outcome of the recent European Citizen’s Initiative to “End the Cage Age” and the EU’s Farm to Fork Strategy will both see the enactment of additional pig welfare legislation in the coming decade. In addition, all EU countries must implement the Regulation (EU) 2019/6 on Veterinary Medicinal Products in 2022, effectively banning the routine use of in-feed antibiotics and zinc oxide. Such legislation will require significant changes in the way pigs are housed and managed. However, the risk factors for tail biting and poor health (and thus the need to use antibiotics/zinc) are similar (Boyle *et al.*, 2021b), and as such, efforts to comply with both sets of legislation will be complementary.

Another change to pig farming in Ireland is likely to be a shift towards increasing the time that the sow has freedom of movement. Several producers already manage free lactation systems, and Teagasc research demonstrated that pigs from these systems perform better than those from standard crates (Kinane *et al.*, 2021). Thus, “free” systems are likely to grow

in popularity, and there is potential for entirely free farrowing systems to be adopted; plans are in place for conversion of half of the farrowing rooms in the Moorepark research unit to free farrowing pens. Adoption of such systems could form part of a marketing plan to enhance the image of Irish pig production both at home and internationally.

Finally, in 2021 DAFM committed to fund the largest pig welfare project to date on the island of Ireland, drawing together a collaboration between Teagasc, University College Dublin, Queens University Belfast and the Agri-Food and Biosciences Institute in Northern Ireland. Apart from investigating commercially feasible alternatives to current systems (provision of outdoor access to growing pigs, and investigation of a range of alternative enrichment materials), the work will explore the feasibility of outdoor and agroforestry pig production. This will include a social, economic and environmental lifecycle assessment, as well as an analysis of the economy of changing land use to alternative systems of pig production.

### **Optimising system efficiency**

The Irish pig sector has fewer but bigger farms than many other countries, the management of which could benefit from specialisation and the establishment of superstructures for coordination and decision-making. In the long term, this could involve a shift from individual farms, the current norm, to vertical integration at a range of levels. However, in the immediate term, and on the basis of a 2-yr recently completed pilot study, Teagasc are co-ordinating a new project to bring LEAN methodologies (management practices to improve efficiencies by eliminating waste) to pig farms. The first aspect of the project will involve two pilot farms which will have their management and health systems evaluated, with the aim of shifting towards ceasing docking of pigs’ tails. Another project that is currently underway is a feasibility study investigating whether the Moorepark Pig Production Model (Calderón Díaz *et al.*, 2019) could be commercialised as a spin-out company. The aim would be that the model could be used as a consultancy tool to assist producers in improving biological and financial efficiency.

### **Increased collaboration across industry stakeholders**

During the past 4 yr, Teagasc, DAFM and AHI worked to establish schemes to collect data on different areas of pig production such as biosecurity, welfare, slaughterhouse findings, antimicrobial use and *Salmonella* status (AHI, 2021). The launch of the AHI Pig HealthCheck programme, and the hiring of a programme manager to co-ordinate activities in 2019, streamlined this process. Activities included upskilling private veterinary practitioners in the pig sector in how to audit farms with regard to biosecurity and animal welfare, establishment of a database for recording the output of such, and co-ordinating, running and management of both a pig

technical working group and a pig industry implementation group. Both of these groups include stakeholders from across the industry. These activities will enable robust benchmarking of current standards and help to improve efficiency of production and the quality of the pork produced in Ireland.

## Conclusion

The pig industry worldwide faces an enormous challenge in terms of meeting demands for protein from a growing world population, while simultaneously improving pig health and welfare, minimising damage to the environment and remaining economically sustainable. The Teagasc vision is to increase profitability in the pig sector by producing environmentally sustainable and welfare-friendly pig meat to the highest safety and quality standards. Teagasc has an integrated approach to pig production research, advisory and education supported by a vast network of international collaborators and close contact with all of the major industry stakeholders. This, and the legacy of its success in the past 60 yr, means that the Teagasc PDD is in a strong position to assist the Irish pig industry in adapting to become a more resilient and sustainable industry for the future.

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