Chapter 6. Chains as proper enrichment for intensively-farmed pigs?

Marc B.M. Bracke
Wageningen UR Livestock Research
marc.bracke@wur.nl

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Abbreviations used: AMI = animal-material interactions, IND = intelligent natural design

Abstract

This chapter primarily compiles work in which the author (Marc Bracke) has been involved with providing science-based decision support on the question of what is proper enrichment material for intensively-farmed pigs as required by EC Directive 2001/93/EC. Proper manipulable material should primarily provide occupation (i.e. reduce boredom), and preferably reduce tail biting.
The RICHPIG model was built expressing enrichment value as a score on a scale from 0 to 10. Metal objects like short metal chains had the lowest score. Subsequently, the Dutch government banned the use of metal chains, and most Dutch pig farmers attached a hard plastic ball or pipe to the prevalent, short metal chain. Unfortunately, our on-farm observations repeatedly suggested that this 'enrichment' may have reduced pig welfare, rather than improving it as intended by the Directive.
So-called AMI (animal-material interaction) sensors can be used to (semi-)automatically record object manipulation by attaching a motion sensor to hanging objects. Exploratory data are presented to, directly and indirectly, record enrichment value. AMI-sensors may provide objective, flexible and feasible registration tools of enrichment value, but their application is still rather demanding.
That the enrichment value of short metal chains can be improved upon, e.g. by providing branched chains. Essentially, this entails making chains longer, preferably reaching until the floor, and making them more readily available in a pig pen. To facilitate the process towards proper enrichment the principle of intelligent natural design (IND) is proposed. IND entails organising a repeated selection process of the (currently) best-available enrichment material so as to gradually reduce pig boredom and enhance the opportunities for the rearing of pigs with intact tails. IND should start with basically all pig farmers implementing promising enrichment like the branched-chain design on their farms as soon as possible, followed by conducting small-scale on-farm experiments to compare and improve enrichment through sharing of available knowledge. Suggestions are given as to how and why this novel approach can be implemented to solve persistent animal-welfare problems like providing proper enrichment for intensively-farmed pigs.

Keywords: Growing-fattening pigs, weaners, enrichment, animal welfare, chains, toys, policy making, decision support, intensive farming

6.1 EC Directive

Directive 2001/93/EC states that:

Pigs must have permanent access to a sufficient quantity of material to enable proper investigation and manipulation activities, such as straw, hay, wood, sawdust, mushroom compost, peat or a mixture of such, which does not compromise the health of the animals (Article 4 of the Annex, EC (2001)).

This may sound like a clear requirement, but in fact it is not. This is because the Directive's formulation contains words like 'proper' and 'such as'. To implement the Directive, therefore, it is necessary to answer the question of what are proper enrichment materials for pigs. This has proven to be a difficult question (CIWF, 2008; 2014). It is still largely unresolved despite the fact that the Directive should have been implemented in all EU member states as of January 2003. More recently, the European Commission also drafted new guidelines, both in 2014 (EC, 2014) and in 2016 (EC, 2016), trying to clarify the matter. The new guidelines are ambitious, but not obligatory and lacking detailed specifications. Hence their effective implementation may generate considerable challenges. Science-based decision support to improve pig enrichment, therefore, is urgently needed.

This chapter aims to address the question what is proper enrichment for intensively-farmed pigs as implied by the Directive. It focuses on enrichment materials that aim to provide 'proper investigation and manipulation activities'. Such manipulable materials are primarily intended to provide occupation and reduce boredom. Boredom results from the fact that pigs, which have evolved to spend a considerable proportion of their time exploring and foraging (typically by rooting) have little else to do in barren pens in intensive farming systems except for eating (briefly) and sleeping. This frustration of the behavioural needs of exploration and foraging leads to abnormal, harmful social behaviours especially in the form of tail biting in growing/fattening pigs (SVC, 1997) as well as to stereotypies such as bar-biting of sows in stalls. In accordance with this all materials listed in the Directive (straw, hay, wood , etc.), except sawdust, have been shown to be able to provide occupation and/or reduce abnormal biting behaviour (SVC, 1997; Bracke et al., 2006). It is worthwhile noting here that tail biting is a multifactorial problem (see Chapter 5), with a rather unpredictable and variable occurrence. This makes it difficult to study (EFSA, 2007b) such that it is virtually impossible to use a reduction in tail biting as the main criterion of whether a (new) material is to be regarded as proper enrichment. Hence, the primary objective of proper enrichment material is to provide occupation, also called 'animal-material interactions' (AMI). The secondary objective is to prevent abnormal/psycho-pathological biting behaviours like ear, flank and tail biting, and such that in particular the mutilation of routine tail docking, which has also been banned in the Directive, is no longer needed. Two additional requirements for what may be considered proper in accordance with the Directive are that manipulable materials must be (a) permanently available and (b) not compromise pig health.

In this chapter I address the issue of what is proper enrichment material for intensively-farmed pigs from my perspective through the various projects I have been involved with. Based on that experience I will formulate practical recommendations for the short-term implementation of the so-called branched chain design and the longer-term application of what I have labelled 'Intelligent Natural Design' (IND).

6.2 RICHPIG

In order to help the Dutch ministry decide what may be regarded as proper enrichment, we reviewed the scientific literature (Bracke et al., 2006), consulted experts (Bracke, 2006) and developed the RICHPIG model (Bracke et al., 2007a; 2007b; Bracke, 2008). The model contains 130 enrichment materials and 30 weighted assessment criteria to determine overall enrichment value (Bracke, 2008).

Figure 6.1 shows the conceptual framework underlying RICHPIG.

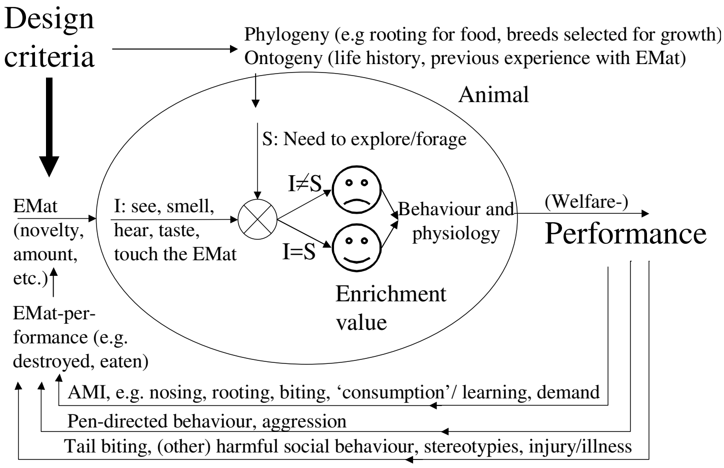


Figure 6.1 Schematic representation of the conceptual framework for assessing environmental enrichment for pigs. EMat: Enrichment material; AMI: animal-material interactions; I: Istwert, the environment as perceived by the animal; S: Sollwert, setpoint or norm (modified homeostatic model after Wiepkema (1987) and (Anonymous, 2001)). (Figure from Bracke (2008), permission granted by UFAW).

Progressive feedback loops in the framework indicate that the animal's welfare is good when proper enrichment satisfies the pigs' need to explore and forage. When the enrichment is deficient, the animals will redirect their attention and show pen- and pen-mate directed behaviour. Note that this may imply a mechanism resembling the principle of communicating vessels (connected containers filled with liquid; see Wikipedia (2016c)). In accordance with this principle pigs may distribute their (motivation for) exploratory behaviour (the liquid) depending on the quality of the manipulable 'materials' available to them (cf Bracke et al. (2012)). Eventually, an outbreak of tail biting may occur, potentially evoking a positive feedback loop (an escalating outbreak) leading to cannibalism when no 'proper enrichment' is provided buffering and/or eliminating the (primary) cause/stressor.

The conceptual framework emphasises that the pigs' need for enrichment is affected by their evolutionary and life history. Pigs have evolved to root in forest soil using their rooting disks, mainly involving downward, floor-directed behaviour. In other words, pigs are not built to reach up to straw racks or twist their heads to bite vertical wooden logs. Similarly life history, e.g. rearing on straw, may enhance the pig's need for exploration and put the animal at risk when access to straw is subsequently denied (Munsterhjelm et al., 2009). In addition, the experience of tail biting may further enhance the need for exploration (of tails and enrichment) as indicated by the tendency of tail-biting outbreaks to escalate (Fraser, 1987a).

The conceptual framework also provides the ordering principle for RICHPIG's assessment criteria. In total RICHPIG has 30 assessment criteria, classified as object-design criteria (e.g. novelty and accessibility), behavioural elements (e.g. nose, root, chew), biological functions/needs (explore and forage), manipulations (i.e. object- and penmate-directed behaviours), other (non-manipulative) consequences (e.g. aggression and stress) and object-performance criteria (e.g. destructibility and hygiene) (Bracke, 2008). Assessment criteria that generated the highest weightings included (known effects on) tail and ear biting, animal–material interactions (AMI) and rooting (Bracke et al., 2007b). In the final model weighting factors ranged from 12.5 for (being able to reduce) 'Tail and ear biting' to 1.2 for 'Movability' (Bracke et al., 2007b; Bracke, 2008) (see also Van de Weerd et al. (2003)).

A subset of 64 materials was evaluated by 9 international pig-welfare experts (Bracke et al., 2007a). Materials generating the lowest scores (on a scale from 0, low, to 10, high) included a mirror, a concrete block, a rubber mat, a minimal amount of straw (!), a mineral block, a heavy plastic ball, a chain (with or without hard wood attached to it), a rubber-hose cross, a free toy (sow neck tether), a hanging car tyre, a bucket, an additional operant feeder, a fixed wood block, bite rite (i.e. a plastic cone with 'tail-like' projections), and a knotted rope (all median expert scores < 2.5). Materials that generated high scores included forest soil, roughage, fodder beet, maize silage, grass (silage), whole straw with chopped beet roots, with maize silage or with additional feed, a bale of straw, long straw with fir branches and straw with forest bark and branches (all median expert scores >= 7.0). The experts suggested a score of 5.0 as the minimum score they considered acceptable enrichment, and this included materials such as compost from a dispenser, straw pellets (loose or from a plastic dispenser) and straw in a metal basket (cited from Spoolder et al. (2011)).
Based on the RICHPIG study and a follow-up study initiated by the pig sector (Ten Have-Mellema and Van Gemert, 2006) also looking at economic consequences (Zonderland, 2007) the Dutch Ministry decided that a most minimal welfare improvement would be acceptable. As of July 2007 the Ministry no longer accepted the prevalent short metal chain, but it would allow such chain if it had some indestructible synthetic/plastic material attached to it (Verburg, 2007). Only car tyres were excluded because they may contain metal parts that can be ingested (LNV, 2007). In the years after 2007 Dutch intensive pig farmers, i.e. those not involved in the Better Life welfare scheme, gradually attached indestructible materials, esp. hockey-type balls and polyethylene pipe, to the end of the chain.

6.3 Communication

Our next project focussed on reducing tail docking, now involving the issue of 'proper enrichment' as one of many measures to prevent and treat tail biting, and (eventually) to keep the pigs' tails intact (Table 6.1).

Table 6.1 Overview of communication time points concerning pig enrichment (including legislation drafting and implementation, and timing of research projects).

Date	Event
1994	Dutch legislation on pig enrichment (Barren pen no longer allowed; short chain is ok; Anonymous,1994)
Aug. 2001	EC Directive issued on proper pig enrichment (EC, 2001)
Jan. 2003	EC Directive ought to have been implemented (EC, 2001)
2003	NGO calls on Dutch Ministry of agriculture to enforce 1994 legislation to provide a chain (Bleijenberg, 2003)
Aug. 2003	Start of RICHPIG project (3yr; Verburg, 2007)
May 2006	Alarm letter of pig sector to ministry about enrichment (Ten Have-Mellema and van Gemert, 2006)
2006	End of RICHPIG project
2007	Project initiated by pig sector to weigh in other values (esp. economics; Zonderland, 2007)
July 2007	Dutch guidelines specified (Short chain is no longer sufficient; chain with ball or pipe is ok; LNV, 2007).
2008-2011	Project 'Ending tail docking'/'Responsible tail management'
2008	Farmer survey (De Lauwere et al., 2009)
2010-2011	Information and tool box for farmers to deal with tail biting; prize contest (www.hokverrijking.nl)
Sept. 2010	Dutch pig sector was informed about welfare deficit of ball/pipe and promising alternative (branched chain; Bracke, 2010a)
2011	Farmers optimistic about pig enrichment (Questionnaire Livestock Fair) in relation to Better Life RICHPIG calculations balls/pipe implementation in NL implied saving about 71 million euros at a loss of 376 million enrichment-value life-points compared to softwood over the period 2003-2011.
2013-2016	FareWellDock project (www.farewelldock.eu)
2015	Enrichment (chain+ball/pipe) mostly implemented in NL (NVWA, 2015a, 2015b)
March 2016	New EC guidelines/recommendations on enrichment and tail docking (EC, 2016, 2016b)
2016	Pig expert questionnaire confirms value of branched chain design (Bracke, Submitted)

In 2008 we conducted a telephone interview among 487 conventional and 33 organic pig farmers in the Netherlands (De Lauwere et al., 2009; Bracke et al., 2013). We found that conventional farmers mainly used metal chains (52–63 % of the farms) and hanging rubber or plastic balls (22–30 %). Other reported materials were a ball or jerrycan loose in the pen: 15-19%; chain with plastic hose around it: 15-20% ; other plastic or rubber toys: 8-12%. Non-synthetic materials (wood, rope, straw, sawdust, woodshavings, roughage) were only used marginally (all <<10%).

We also made information about enrichment and tail biting available on the website called www.hokverrijking.nl (Dutch for 'pen enrichment'), and we developed a tool box for farmers to deal with tail biting. The website was also used in a separate project where the objective was to provide more proper enrichment in the outdoor run of organic pigs. Since the outdoor runs in organic farming are often rather barren enclosures with a slatted floor, the design challenge for providing proper enrichment in organic pens was found to be remarkably comparable to the challenges encountered in conventional pens.

In addition, a small questionnaire (n=34 pig farmers) was conducted on the hockey-type ball that had been implemented rather widely on pig farms in the Netherlands (Bracke, 2011d). It showed that pig farmers did not consider the investment in the balls acceptable, and they significantly lowered their appreciation of the welfare-benefits of the ball when they had such a ball in their own barn (compared to when they didn't). This suggests that the hockey-type balls raised higher expectations than were actually realised, both in terms of economy and pig welfare.

Furthermore, a compact questionnaire was also distributed at a livestock fair in the Netherlands in October 2011. As many as 72% of all respondents (n=1687) regarded enrichment as an opportunity for livestock husbandry, and they expressed a very high (up to 95%) level of optimism regarding environmental enrichment. This was probably related to the recent introduction of the Better Life (Beter Leven) welfare scheme of the Dutch Society for the Protection of Animals. This provided conventional livestock farmers with an opportunity for some additional economic benefit. For pigs it entailed providing some extra space (1.0 instead of 0.8m^2/pig), enrichment materials (e.g. a straw briquette), minimum tail length (>2.5 cm at docking) and the rearing of intact boars. The types of enrichment provided in the Better Life scheme, however, could be optimised. In particular the straw briquette was introduced, made up of a cylinder of pressed, short-chopped straw held in a PVC holding pipe. Like the hockey ball, the briquette enrichment probably looked, in my opinion, nicer than it really was. Apparently, farmers seemed to be providing a minimal amount of straw by restricting the pigs' access to the straw briquette (e.g. by making it protrude minimally from the PVC holding pipe (Van den Berg, 2016; Weber, 2016)) and sometimes failing to de-block or refill containers timely. As indicated by the RICHPIG model and consulted experts a minimal amount of straw has very limited welfare benefits to the pigs (average expert score <2.5 where 5.0 would have been acceptable). It may even reduce welfare due to inducing frustration and competition.

Hence, when considering the issue of what is proper enrichment, it is important to be aware of preconceived ideas, potential bias and anthropomorphism. The term enrichment suggests a welfare improvement, or even a welfare bonus, but that may at times be little more than a human expectation or perception. Furthermore, the term enrichment (or 'better life') can be a euphemism. When a material improves welfare, it may formally be correct to label it as enrichment, but when the pigs are otherwise still kept under most barren conditions at a very low level of overall welfare, it would be more appropriate to use the term 'de-barrenment' instead of enrichment. Some researchers also prefer to avoid the term enrichment altogether, because the term is too general and because, rather than providing something 'extra', pig enrichment deals primarily with manipulable materials which the pigs can use as a minimum fulfilment of their need to root and explore (A. Valros, pers. comm.).

Another example of human perception of pig enrichment, in which I have been involved, is the computer-game for pigs, called Pig Chase (HKU, 2011; Van Peer, 2012; Anonymous, 2012b). Its primary objective was to trigger ethical thinking about pig farming. In addition, what I found interesting about the idea of a computer game for pigs is that it could challenge the pig's cognitive abilities, in my view a much neglected aspect of pig enrichment. Pig Chase shows pigs interacting with a gamer via an iPad. When the pig follows a red dot controlled by the gamer, it is 'rewarded' by fireworks. This is not proper enrichment for pigs. Fireworks are nice for people. Similarly, balls are nice for people (esp. because they are associated with sports), and chains are not perceived as nice. In the perception of the general public metal chains are more likely to be associated, perhaps unconsciously, with prisons and slavery, and, for those who are a bit more knowledgeable, with the stereotyped chain-chewing seen in tethered sows (Schouten and Wiegant, 1996). Since these underlying emotions and associations may have contributed to the general appreciation of balls and lack of appreciation of chains as pig enrichment, it is important to be aware of the distinction between our human perceptions and what is important for the pigs themselves.

6.4 On-farm observations

In on-farm work, often with the help of students, the poor state of enrichment in conventional pig farming, as already indicated by the RICHPIG work, was confirmed. I had seen farms, some of them suffering from high levels of tail biting, where the hockey-type balls were dry and collecting dust, and where pigs were frustrated when they tried to grab the ball (see also Figure 6.3b later in this chapter). Also bigger balls provided loose on the floor can often be seen lying in the dunging area without any persistent enrichment value to the pigs.

Our more systematic (scientific) observations in pregnant sows, weaned piglets and growing/fattening pigs kept in different housing systems repeatedly indicated that the pigs were interacting less (!) with the chain when relatively hard, indestructible balls or plastic/synthetic tubes had been attached to the end of the chain (Ettema, 2010a; 2010b). Perhaps chain manipulation reduces stress, as has been shown for the early phases of chain chewing in tethered sows (Schouten and Wiegant, 1996). Hence, and as farmers sometimes suggest, perhaps interacting with the end of a metal chain is comparable to chewing gum or playing with a pencil in human adolescents. When the chain is on the floor, it allows some form of rooting on the chain, and the interaction may be comparable to stone chewing which is prevalent in outdoor sows (Horrell et al., 2001). Most farmers opted for rather indestructible (and hence cost-efficient) materials (balls and pipe), e.g. by hanging them a bit higher when they had to be replaced so they are less easily destroyed. Thus the ‘add-ons’ were found to be mostly inferior compared to the flexible end of a freely available metal chain. Plastic materials are probably better when they are more destructible (e.g. as indicated by Courboulay (2006; 2011). However, destructible plastic materials (tylene, alkathene, pvc, etc.) need replacement and they pose an environmental risk as they are ingested or they are degraded by the pigs and end up in the slurry pit (Spoolder et al., 2011).

Figure 6.2 Branched chain i.e. a chain reaching till floor level where the chain may be ‘rooted’ or manipulated while lying down, and to which two short pieces of chain have been added such that ends of a chain are available at nose height to pigs of different sizes or age groups for manipulation while standing. (Note, however, that this is a c-chain, not a stainless steel anchor chain, which is recommended).

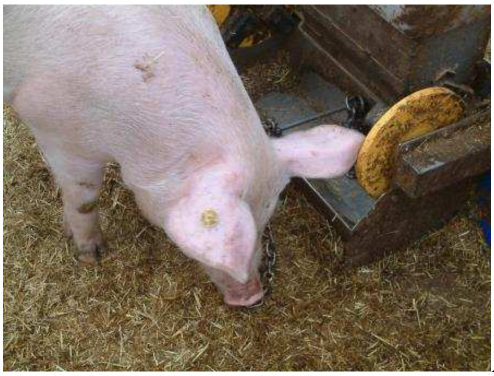
We also found that pigs interacted more and for a longer period of time with a branched chain (Figure 6.2) compared to various other enrichment devices such as a chain with hard, hockey-type plastic ball attached to it, a loose ball on the floor, a large wood block, a short chain hanging from the ceiling, and a short chain attached close to the floor (Wind, 2012). With branched chains pigs have access to the ends of a chain both at floor level and at nose height. This gives pigs the opportunity to choose, and we found that pigs interact more than twice as often with the chain end lying on the floor than as with the pieces of chain ending at nose height (Wind, 2012). In other words, pigs seem to prefer to ‘root’ on the chain that is lying on the floor, and they can manipulate such a chain while the pigs themselves are lying on the floor (which is not possible with the conventional, short chain ending at nose height).
Even organic pigs with access to straw bedding have been observed to interact extensively with branched chains and similar designs (e.g. a round chain with rings for ‘rooting’ (which they didn’t use) and branches (which they did)). This implies branched chains may have enrichment value even when straw is provided, despite the fact that straw has been shown to be used much more extensively (Scott et al., 2007) and is known to reduce tail biting (Zonderland et al., 2008). It is not expected that branched chains will substantially reduce tail biting. This remains to be shown, however, and longer chains have been shown to substantially reduce ear biting under compromised conditions of limited access to a water nipple (De Grau et al., 2005)). However, branched chains do provide substantially enhanced

(longer and supplemented quality) occupation (AMI) for the pigs compared to the conventional, short metal chain. This makes them suitable candidates for what may be regarded as proper enrichment material for intensively-farmed pigs. The indestructible materials I have encountered are not better, most often worse, than the short metal chain, thus worse than a branched chain. By contrast, compared to alternative, more destructible materials (like ropes, jute, soft wood, substrates), branched chains are probably, but not always, used less (Bracke, 2007b; Ettema, 2010a). However, branched chains are much more feasible (lower cost, less labour for maintenance, less risk of blocking of the manure system), more hygienic (reduced health/biosecurity risk), probably better for the environment, and they provide a much better guarantee of being permanently available as required by the EC Directive, and (hence) they also much better allow for verification of actual compliance. Furthermore, branched chains can be specified much more accurately and uniformly than any of the destructible alternatives (and such detailed specifications are given below). This is because destructibility is difficult to measure objectively, and because many qualities co-determine the suitability of destructible materials (e.g. wood, straw and rope come in many different types, sizes and processing stages/freshness). In other words, branched chains are much more suitable candidates for being used as a standard or benchmark (reference point) against which other materials can be compared. Note, however, that such a benchmark for proper pig enrichment, doesn't entail it must be proper, i.e. provide a sufficient level of occupation, in and of itself. Expert opinion strongly suggests branched chains should be regarded as providing almost proper enrichment (Bracke, Submitted). These chains, therefore, provide a most suitable starting point for further enrichment, also because other objects can be attached to the branched chains. Furthermore, even when branched chains are supplemented by substrates on the floor, such as roughage or straw, the pigs have been found to remain interested in the branched chain, providing a background enrichment that will remain permanently available, even when the substrates or other destructible materials are not (Figure 6.3).

Several important conclusions can be drawn from our modelling work and on-farm observations:
1. A short metal chain without attachment consistently elicited more manipulation and investigation activities by the pigs than the same chain at the end of which a rather indestructible hockey-type ball or pipe had been attached. Since pigs clearly prefer to manipulate the end of a chain over a ball and pipe, such materials are not proper enrichment materials for pigs (see also (EFSA, 2007a; 2007b; Spoolder et al., 2011)). Such 'enrichment' is more properly referred to as impoverishment.
2. The short chain can be improved upon, esp. using a branched-chain design reaching in part down to floor level (see also Parmentier (2007)).
3. The RICHPIG model was designed to support decision making to implement the EC Directive in the Netherlands. By the end of 2010 it became clear that welfare had more likely been reduced and that branched chains provided a possible solution (Bracke, 2010b). In 2011 I quantified pig welfare in the Netherlands using the RICHPIG model together with available data about the numbers of pigs raised in the Netherlands (CBS, 2011) and economic data about enrichment materials (Zonderland, 2007). I calculated the economic investment and welfare discrepancy between chains with/without balls and pipe on the one hand and a soft-wood beam on the other between 2003 and 2011 (when I did the calculations (Bracke, 2011d)). The soft-wood was taken as an example of a more proper (though not fully proper) enrichment material than the plastic objects (Bracke et al., 2007a; Bracke, 2008; EC, 2016). My calculation over the period 2003-2010 resulted in a total of 70 million years of pig life experiencing a welfare discrepancy of 376 million enrichment-value life-points. This is

equivalent to roughly 140 million pigs experiencing a reduction of 2.7 enrichment/welfare RICHPIG points for the balls/pipes compared to the soft-wood beam provided in their 6-month life span each. In addition, I found that the Dutch pig sector had invested about 4.7 million euros in the balls and pipes, whereas the soft-wood beam was estimated at 76 million Euros (Bracke, 2011d). This illustrates how welfare models based on semantic modelling like the RICHPIG model and/or expert opinion scores can not only be used to support future decision making, but also to calculate welfare effects (here, a lifetime 2.7 RICHPIG points improvement for a cost of 0.5 euro per pig) related to decisions that have been made in the past, as well as welfare benefits that may be obtained by pursuing suggested welfare solutions.

These findings also strongly emphasise the need for empirical observations to underpin claims about enrichment. New materials should preferably be tested properly before they are released onto the market. This led us to examine feasible and flexible tools, so-called AMI-sensors, to assess enrichment value more objectively.


A

B

Figure 6.3a Pig manipulating an anchor-type chain on the floor covered with straw. The feeder (actually a rooting bin) in the picture was permanently empty and not used for feeding or rewarding the pigs. Note that the chain is a stainless steel anchor-chain, which has more rounded links than the cheaper and apparently less preferred c-chain (Photo by Herman Vermeer).
Figure 6.3b Balls dry and collecting dust near a short chain and a chain reaching until the floor. Note how the short chain is rusty (hanging too high) and that the metal slats are shining indicating intensive use of the chain on the floor.

6.5 AMI sensors

6.5.1 Introduction

The term AMI-sensor was coined by Johan Zonderland. AMI stands for animal-material-interactions. AMI-sensors may record object use in various ways. Zonderland et al. (2001) used an electrical circuit to detect AMI in different hanging materials that were changed weekly. They found renewed interest immediately after introduction, indicating that novelty is important for pig enrichment. Earlier, Grandin had used mechanical counters to record levels of toy use (Grandin, 1989). I also used mechanical counters, e.g. to show that repellents, such as Dippel's oil and Stockholm tar, can reduce the pigs' interest in a novel rope (Bracke, 2009). Similarly, soiling with faeces reduced rope manipulation, while making the rope more destructible enhanced rope manipulation (Bracke, 2007b). As of 2013 the FareWellDock project enabled further work on AMI-sensors. To validate their use we explored whether we could determine enrichment value either directly or indirectly. Direct measurements record movement of the enrichment materials to which the AMI sensors have been attached. Indirect measurements are intended to detect an effect of one enrichment (e.g. substrate) by recording AMI of another material (e.g. a rope). Based on the principle of communicating vessels, indirect AMI measurements assume that if the enrichment material of interest (e.g. substrate) has a higher enrichment value, it should reduce the interest in the recorded material (e.g. rope). In the next four subsections, examples are given of the use of AMI sensors in experiments that investigated the effects variables such as feed restriction, tail and flank biting, streptococcus infection, and maize silage provision on the use of enrichment materials.

6.5.2 Food restriction prior to anaesthesia

We used Icetag loggers to record AMI directly by attaching the loggers to a jute sack (reaching until the floor) and a bare metal chain ending at nose height. Both materials were simultaneously present in a pen with 2 pigs. The pigs were also subjected to a brief (12-24h) period of food deprivation prior to propofol anaesthesia. Three such incidences were logged. In accordance with expectations (Feddes and Fraser, 1994l; Ursinus et al., 2014b), the pigs interacted much more with the destructible jute sack than with the indestructible chain (Figure 6.4). In addition, on the day after anaesthesia AMI values seemed depressed. In contrast to expectation, the 3 periods of feed deprivation prior to anaesthesia did not show clear signs of enhanced AMI. Perhaps habituation was incomplete, or the pigs may have been (re-)directing exploratory behaviour towards the (limited amount of) sawdust that was provided on the floor. These exploratory data may well be among the first minute-by-minute recording of enrichment AMI in pigs.

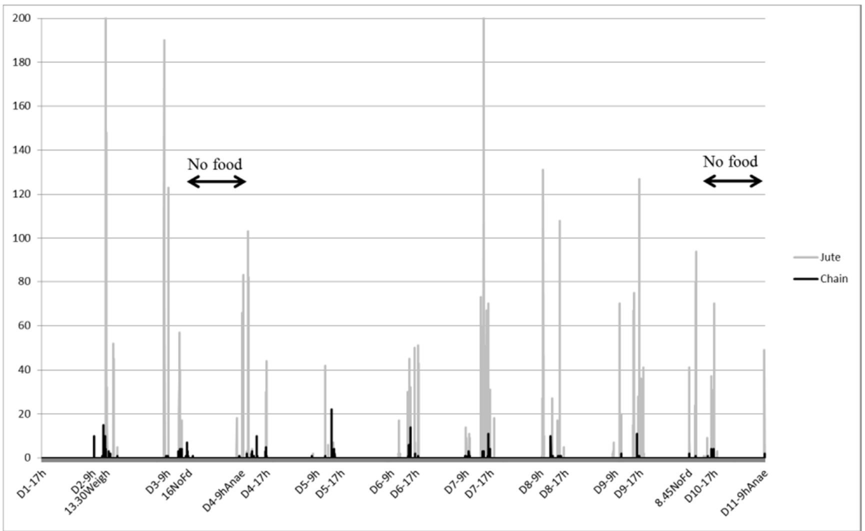


Figure 6.4 Icetag Motion Index, expressed as a value ranging from 0 to 280 and from 0 to 22 for jute sack and chain respectively, on a minute by minute basis over 11 days in a pen with 2 pigs. D: day number – time (h: hour); NoFd: no food (also indicated by arrows), e.g. 16NoFd = Fd taken away at 16h, to be available only in the afternoon of the next day (after anaesthesia); Anae: Animals under anaesthesia that day (D4 and D11); D11: anaesthesia followed by euthanasia.

6.5.3 Flank and tail biting

On one farm we did a matched control study on all pens with flank and tail biting (Bracke and Ettema, 2014). Mechanical counters were used to test the pigs' propensity to interact with a novel rope in biter and control pens. On the farm 20% of the pens had pigs with biting wounds; 5.4% concerned tail biting and 14.3% showed flank biting. In accordance with earlier findings (Bracke, 2009), the pigs lost interest in the ropes over time. Most importantly, however, we showed that biter pens interacted significantly more with the ropes compared to controls. This may indicate an enhanced need for enrichment when biting wounds are present, thus perhaps complicating the principle of communicating vessels. In other words, what is proper enrichment under normal conditions (in control pens) may not be adequate enrichment once abnormal biting behaviour has resulted in tail, ear, leg or flank biting wounds.

6.5.4 Streptococcus infection

While abnormal biting seems to be associated with an increased need for enrichment, sickness, by contrast, may reduce it. To explore the effect of sickness on AMI we (the author in collaboration with de Greeff et al.) attached IceCubes (IceRobotics, UK) to a metal chain (n=6 pens with 5 pigs per pen) to record AMI before and after an experimental infection with Streptococcus (either S. suis or S. pneumoniae, high/low dose, intranasally/intravenously (de Greeff et al., 2016)).

AMI appeared to be reduced shortly after the infection (Figure 6.5). In other words a streptococcus infection may reduce the pigs' propensity to interact with a chain, perhaps reflecting the experience of feeling sick (Bracke, 2016b). This indicates that AMI-sensors could perhaps be(come) of value in an early warning system for disease, and thus help in early diagnostics and reduction of the use of antibiotics.

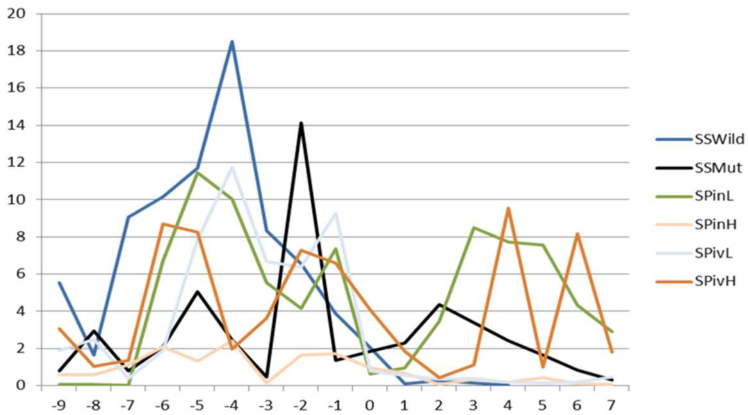


Figure 6.5 Average motion index values per day for the 6 treatments (1 pen per treatment). SS: S. suis; Wild: wild strain; Mut: Mutant strain; SP: S. pneumonia; iv: intravenous; in: intranasal; L: low dose; H: high dose. Day 0 is the day of infection.

6.5.5 Maize silage

Two related experiments by Aarnink et al. investigated the effects of maize silage in the so-called Starplus barn and the thermally-controlled so-called APF barn (Air Pathogen Free barn using overpressure) at the pig research station (Swine Innovation Centre, Sterksel). The main objective of the AMI recordings was to detect indirectly whether maize silage had enrichment value by logging AMI of ropes (Bracke et al., 2014; Bracke et al., 2015 (unpublished)). In addition, we looked at some variables like time of day, room temperature and gender, and directly compared AMI of ropes and hockey-type balls.

In the Starplus barn (Verdoes et al., 2014) pigs are provided with additional space, roughage and outdoor access to enhance pig welfare. We found that finishing pigs in the Starplus barn provided simultaneously with chopped straw and maize silage on the floor were interacting with this roughage more than pigs provided with chopped straw only. This effect lasted for about 30 minutes. Providing maize silage, however, had little or no effect on directly-observed behaviours (general and exploratory behaviours), nor did it have an overall effect on toy (esp. rope) manipulation as measured by the AMI-sensors. Furthermore, in both Starplus and APF barns, and in accordance with expectation, the AMI-sensors confirmed that pigs were more interested in the sisal rope than in a hard-plastic, hockey-size ball hanging on a metal chain. In the APF barn rope manipulation also appeared to be affected by maize-silage enrichment in that on some days AMI was reduced when maize silage was provided. Furthermore, other variables like gender, (time of) day and room temperature seemed to play a role, e.g. more reduction of rope manipulation due to maize silage at normal compared to low temperatures (Bracke et al., 2015 (unpublished)). Overall, while these moderate amounts of maize silage (0.17-0.25 kg/pig/day) seemed to have some beneficial effects on pig welfare, we only partially managed to detect this using indirect AMI-sensors on ropes, and background variables seemed to complicate the interpretation of AMI recordings. The number of pens per treatment was rather low, however, and perhaps the AMI sensors are not as sensitive as we would like, or the enrichment of maize silage is not substantial enough to be detected using indirect AMI recordings (however see Bracke and Spoolder (2007b)).

6.5.6 Straw

A semi-automated novel rope test also failed to show an effect of background enrichment (straw/no straw) or gender (boars/barrows) on AMI recorded indirectly as novel rope manipulation in the Comfort Class barn (de Greef et al., 2011; Vermeer et al., 2014). Again, the number of pens was rather low (n=6 per treatment) (Ettema, 2010a). In these pens (n=216 growing pigs in 12 pens; 1.67 m^2/pig) 3 types of enrichment materials (short chain, hockey-type ball on a short chain, wooden plank on the floor) were weekly rotated. Behavioural observations showed that the wood on the floor was used much more than the hanging chain. More interestingly, the chains without balls were used more than the same chains with balls (Ettema, 2010a). While there was no effect of background enrichment (straw vs no straw) on toy use, we did find an effect of the use of automated rooting bins (cf Figure 3, not containing any food reward, so functioning as a kind of AMI-sensors): Pigs in straw pens interacted less with the rooting bins. This suggests that AMI-sensors, i.e. rooting bins, can indirectly record enrichment value (of straw), perhaps by virtue of the principle of communicating vessels between the rooting bins and straw. In accordance with this principle, rooting bins were also used more by the end of the week in which a toy (wood, chain, ball) was present compared to shortly after object rotation, when the toys were novel and attracted more interest. So perhaps the rooting bins did not only function as an AMI-sensor, but also as permanently present enrichment material attracting a variable interest depending on background conditions (straw/no straw; novel/familiar toy). In this way the rooting bins themselves may even have acted as a kind of buffer, reducing the likelihood of picking up the background enrichment using the novel rope as an indirect AMI test. Using a subjective scale of biting intensity/severity, we also found that pigs without straw would bite the observer more severely than pigs kept on straw (and in another study we found that biter pigs in tail biting pens were biting the observer who was present in the pen the hardest). Furthermore, biting wounds (but not fighting wounds, i.e. deep scratches) were only observed in the pens without straw, and more tail wounds were found in pens without straw. These findings, again, seem to confirm the hypothesis of communicating vessels, indicating that enrichment value of an object (the level of AMI it attracts) may be affected by the enrichment quality of other types of enrichment provided in the pen. In other words, the more barren a pen becomes, the more important the enrichment value of an enrichment material like a metal chain (or another pig).

6.5.7 Short and (a bit) longer chains in poor and (really) rich rearing conditions

Finally, in an experiment by Van Dixhoorn et al. (2016) we did seem to be able to detect a difference between rich and poor pens (4 pens per treatment; see example pens in Figure 6.6a and 6.6b) using *indirect* AMI measurement of two chains hanging in each pen (Bracke, 2016a). Young pigs in poor pens were more interested in the chains than pigs in (very) rich pens. The poor pens were conventional farrowing and weaner pens. In the rich pens the pigs were provided with extra space, compound enrichment (straw, peat, woodshavings, jute and branches) and social rearing (2 farrowing pens were joined after 1 week). This indicates that AMI-sensors (IceCubes, IceRobotics, UK) may be able to detect a (substantial) contrast in background enrichment in accordance with the principle of communicating vessels. The contrast between chain AMI of rich and poor pens, however, was less pronounced in the weaner pens than in the farrowing pens.

Another noteworthy finding was that in poor pens short chains (ending at nose height) appeared to be manipulated less than 10-15cm longer chains. The longer chains seemed to be better, even without reaching the floor. This was esp. the case in the farrowing pens where the chains were hanging against the back wall and thus much less likely to be set in motion by the pigs' locomotor activity in relation to either enrichment level (more/less space) or chain length. This may indicate that the conventional short chain may even be improved upon by letting it reach a bit further down.

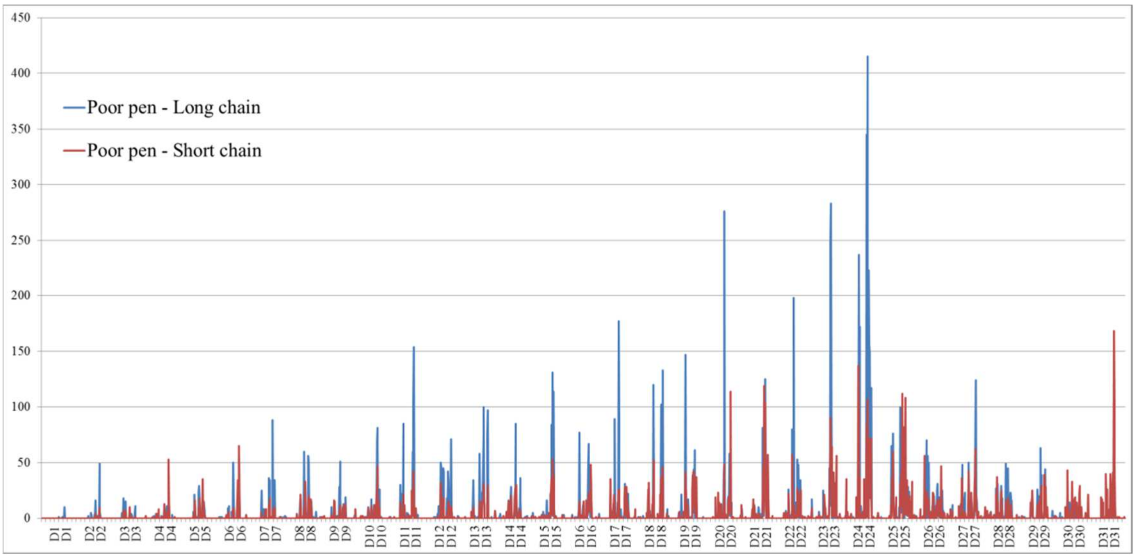


Figure 6.6a Motion Index values over 31 days in the farrowing pen for a short (red) and somewhat longer (blue) metal chain in a poor pen (conventional farrowing pen).

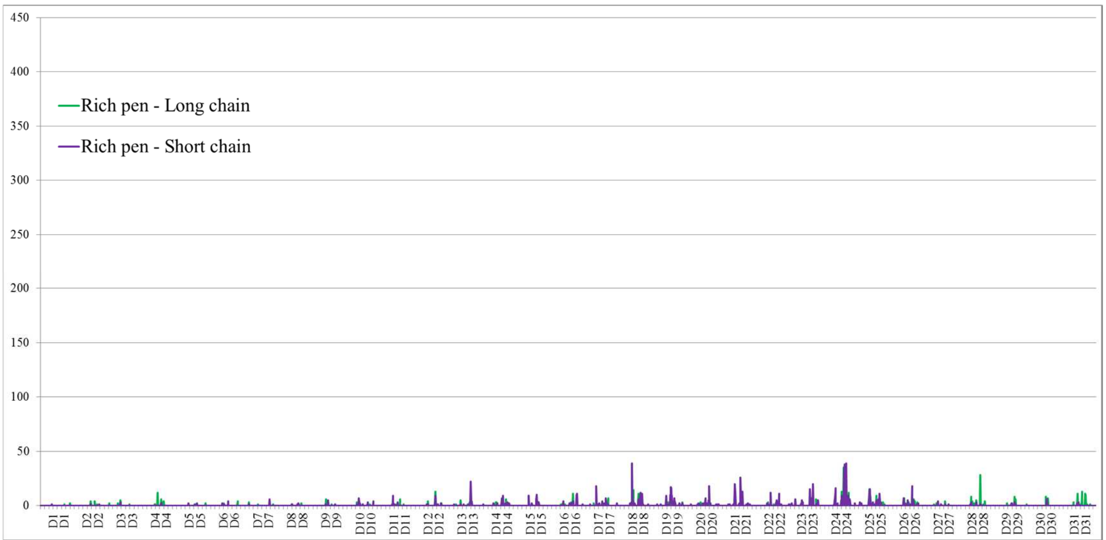


Figure 6.6b Motion Index values over 31 days in the farrowing pen for a short (purple) and somewhat longer (green) metal chain in a rich pen.

6.5.8 Conclusion about AMI sensors

Data obtained from AMI-sensors (motion sensors) attached to hanging enrichment materials may provide valuable supplements to other ways of assessing enrichment value, i.e. expert opinion, RICHPIG assessment, direct (casual/expert) observation and experimental study. AMI-sensors are flexible, can be used on commercial farms, and they are much less expensive and labour intensive than doing a behavioural study. Compared to behavioural observations, AMI data are also more objective (i.e. more related to physics than to the interpretation of an observer). And most importantly, AMI-sensors are able to provide a more comprehensive, minute-by-minute and day-and-night, record of animal-material interactions. Disadvantages include that AMI-sensors may have a limited sensitivity (e.g. may require a larger number of pens to obtain statistically significant results). AMI sensors can only be attached to certain, esp. hanging, materials, out of reach of the pigs. The sensors need to resist a potentially hostile environment (e.g. moisture, biting, pulling, hitting, ammonia and dust). Furthermore, AMI sensors do not readily allow recording the behavioural elements as is conventional in behavioural studies, and special care must be taken to deal with potentially confounding factors such as different types of object interaction (e.g. manipulation versus touching the object accidentally e.g. during locomotion or pen cleaning). Specific algorithms may be developed to make more fine-grained behavioural distinctions. Also the enrichment materials themselves may affect AMI–sensor data. For example, the sensors themselves may elicit attention from the pigs (esp. when novel) and objects with different physical properties may show different responses to (the same type of) manipulation by the pigs. Hence, the application of AMI-sensors is not as straightforward as it may appear, and further validation is needed before it can be implemented in practice to support the recording of enrichment value. Our AMI-sensor findings, however, seem to confirm existing knowledge (e.g. that a jute sack is used more than a chain; that a chain with ball is used less than a rope). We also found some confirmation of the ability of AMI-sensors to (indirectly) detect contrast in background enrichment (esp. when the contrast is evident). This seems to be in accordance with the hypothesis of communicating vessels. This hypothesis was originally brought to my attention by Johan Zonderland, who also initiated the work on AMI-sensors at Wageningen Livestock Research. Further research is needed to establish in more detail the role of a number of factors (like nutritional status, health, thermal conditions, breed, etc.) on AMI. In this respect, health status may be of particular relevance as AMI-sensors may be useful in early warning of disease and thus help reduce the use of antibiotics. Most importantly, however, given the history of providing inadequate enrichment materials (hockey-type balls, pipe, straw briquette), AMI-sensors may become a valuable supplement to the behavioural observations which are evidently needed to verify RICHPIG-type assessments and other, esp. commercial, claims about enrichment value.

6.6 What is proper enrichment for intensively farmed pigs in the short term?

According to the EC Directive, as of 2003 proper investigation and manipulation materials should have been provided to all pigs at all times in all member states. Most European countries have not implemented this in accordance with the scientific communis opinio (Bracke et al., 2007a; Bracke, Submitted). Here I will formulate a proposal meeting this requirement, that is feasible under current commercial conditions and can be implemented widely in the short term. The proposal is based on my own research (RICHPIG, AMI-sensor data), personal observations supplemented with input from colleagues, experts (Bracke, Submitted) and farmers. It is specified in more detail in a supplement, which will be made available online via http://farewelldock.eu and http://hokverrijking.nl.

Our research indicated that the enrichment value of the short chain can be improved with little extra cost, essentially by making the chain longer, and by adding short pieces of chain, resulting in a branched chain with chain ends both resting on the floor and hanging slightly below nose height of the pigs in any stage of their development. When provided in sufficient quantity, such a branched-chain design is what I recommend as the most suitable starting point (base-line) as well as benchmark (negative control) for (developing) proper enrichment for intensively-farmed pigs. This is especially true when the ratio of enrichment value per invested euro is taken into account. The branched-chain design implies the following conglomerate of specifications in terms of object-design, material, availability and placement:

1: **Object-design**: *A branched chain consists of a vertically-positioned long chain with its end resting on the solid floor over a distance of 20 cm. Two or three additional chain ends (branches) end at or slightly below the nose height of the smallest and middle-sized pigs reared in the pen.*
This should allow pigs of all sizes to interact relatively readily with the chain ends. It also allows two or three pigs to play with the chain in the same location, thus supporting social facilitation and synchronisation. Pigs will interact with the chain in both a standing, sitting and lying position, and, most importantly, pigs can stand with their head down manipulating the end of the chain that is lying on the floor with their nose. This resembles (some rudimentary) rooting behaviour.
2: **Material:** *The chains are stainless-steel anchor chains (for at least the last 5-10 links of each chain end). Recommended dimensions are 7mm for growing-fattening pigs, 5-6 mm for weaners, 4-5 mm for piglets and 8 mm for sows.*
Anchor chains have links which are more round and heavier than the cheaper, more oval-shaped c-chains. The links of an anchor chain appear to be more pleasant for the pigs to be held in their mouths, but this is a subjective impression that remains to be confirmed. The size of the links should fit the size of the pigs' oral cavity. Note that the indicated sizes refer to the diameter of the metal, not the diameter of the links. For example, a 7 mm anchor chain for finishers has links measuring 36x23 mm. For rearing pens (containing growing-finishing pigs ranging in body size from about 25 to 120 kg) various chain sizes should be provided in the pen, such that the most preferred types are available for all sizes of pig. Stainless-steel anchor chains are more expensive than c-chains. However, they also last much longer. According to the farmer who recommended the chain link sizes, the stainless-steel anchor chains themselves will last 'forever'. Only the last 5 or so links need to be replaced every 5 - 10 years. This implies that the overall costs of the stainless-steel anchor chains remain very low, esp. when second-hand chains are used. Note that the branched chain is itself equivalent to several chains hanging side by side, except that the shorter 'branches' require less material, and thus costs, to produce chain ends valued by the pigs.
3: **Availability and placement:** *One branched chain is provided for every 5 pigs.The chains are spaced apart as much as possible, preferably with at least one pig length between 2 branched chains in a pig pen. The branched chains are attached at the top end of the pen wall, over the solid floor, and not in the dunging area.*
Chains should have some action radius and be accessible to the pigs, even when one chain accidentally gets blocked by a dominant or resting conspecific. So, chains in corners should be avoided, unless they are provided in surplus. Also, when the chains are getting out of reach (e.g. thrown out of the pen), alternative attachment, such as hanging them away from the pen wall, may be required. Chains hanging on the pen wall away from the corner are generally readily accessible without inducing frustration, i.e. the pigs voluntarily approach to interact with them.

6.6.1 Are branched chains really proper enrichment?

No, they are not. But they seem to be *almost* proper, and they are a major step forward, also according to an international group of pig welfare experts (Bracke, Submitted). Furthermore, farmers should be able to make the last step towards proper enrichment by themselves (Table 6.2). It may only be a small step. For example, perhaps an indestructible object (which is already present in many pig pens, e.g. a ball, pipe or wood) can be added to one of the branched chains. This may well be sufficient to surpass the threshold of both scientific and current legal acceptability. However, it will probably not be enough to reduce the need for tail docking (which is also required by EU law). For this, destructible materials are probably needed. To my knowledge, however, no such materials can be recommended for widespread implementation in intensive pig farming in the short term, unless they are enforced. They are (perceived as too) costly even though they may cost as little as 6-13 eurocents per kg of pig meat (carcass weight) (Zonderland, 2007; Zonderland et al., 2008). Furthermore, the materials may block the manure system and keeping up maintenance is a real challenge. As a consequence, the use of destructible materials on commercial farms tends to be mitigated by practical considerations, often leading to compromised pig welfare benefits. Therefore, it is highly recommended that their enrichment value is verified, e.g. using the branched-chain design in a sufficient number of pens (e.g. 10 pens) as a benchmark.

Table 6.2 Tentative scoring of enrichment materials for intensively farmed pigs in relation to observations reported in the text.

Score	Enrichment material
10	Ideal enrichment
>=7.0	Destructible materials provided properly, e.g. Forest soil, roughage, fodder beet, maize silage, grass (silage), whole straw with chopped beet roots, with maize silage or with additional feed, a bale of straw, long straw with fir branches and straw with forest bark and branches (all median expert scores >= 7.0)
	Plenty of long straw on the floor, regularly renewed
	Compost from a dispenser, straw pellets (loose or from a plastic dispenser) and straw in a metal basket; ropes, jute, soft wood, substrates
	Branched chain + indestructible objects
5.5	Cut-off of what is minimally acceptable or 'proper enrichment' (above this line)
	Branched chain design
	Short chain
	Destructible materials provided improperly (e.g. limited access/not destructible/soiled), e.g. Straw briquette; narrow hay rack; forced grass silage consumption; large, swinging softwood; loose logs, rope-and-rubber, wooden plank
	Short chain with indestructible ball/pipe
<2.5	A mirror, a concrete block, a rubber mat, a minimal amount of straw (!), a mineral block, a heavy plastic ball (on the floor), a chain (with or without hard wood attached to it), a rubber-hose cross, a free toy (sow neck tether), a hanging car tyre, a bucket, an additional operant feeder, a fixed wood block, bite rite (i.e. a plastic cone with ‘tail-like’ projections), and a knotted rope (all median expert scores < 2.5)

0	No enrichment (barren pen)

In my view branched chains provide by far the most feasible solution for short-term pig enrichment. Many aspects of their design as well as prospects for further improvement still remain to be verified and falsified in further research. However, in answering the question ‘what is proper pig enrichment in the short term’, it is better to avoid suggesting that more research is needed, at least in the classical sense of scientists working in research laboratories/research stations. Because further research could (again) lead to delays in implementation of the knowledge which is available at present.

Before the EC Directive was implemented in the Netherlands, a metal chain was considered proper enrichment. This was often a short chain, reaching not further than nose height. Such a chain would seem highly feasible, involving low cost and hardly any labour, totalling 0.25 euro per pig per year (Zonderland, 2007). Nevertheless, farmers were reluctant to provide it as almost 10 years after prior legislation coming into force in 1994 (Anonymous, 1994), the government was still urged to enforce it (Bleijenberg, 2003). Currently, providing the legally required enrichment (i.e. adding an indestructible piece of pipe or ball to the metal chain) has been an issue until recently in the Netherlands (NVWA, 2015a; 2015b) as well as in most other European countries (CIWF, 2013; 2014). In non-European countries, like the US, Canada and New Zealand, most pig farmers don’t provide any enrichment, apparently because it is not (considered to be) cost-effective (Bracke, Submitted).

However, from a legal perspective, there is increasing pressure to improve pig enrichment. Recent EC guidelines (EC, 2016; 2016b) recommend that destructible materials should be provided. However, the new guidelines are neither legally binding, nor specified in much detail. Chains are classified as ‘materials of marginal interest’, which cannot be provided alone. Other marginal materials include “rubber, soft plastic pipes, hard plastic, hard wood, ball, salt lick” (EC, 2016). The new minimum recommendation appears to be to provide either a marginal material like a chain together with a so-called ‘suboptimal material’, or two suboptimal materials. Suboptimal materials include straw, hay, or silage in a rack/dispenser, soft wood, natural rope and hessian sack, but also natural soft rubber, sawdust, sawdust briquette, compressed straw in a cylinder (i.e. straw briquette), pellet dispenser and ‘sand and stones’. The guidelines have open standards on various materials, e.g. what classifies as soft wood, how accessible the straw provided in straw racks or straw briquettes must be, and what dimensions of wood would be acceptable (as e.g. large logs of softwood can be indestructible and thus ineffective for the pigs). Also, rubber is classified in the guidelines as marginal, but natural rubber is suboptimal. Natural rubber is frequently used in materials like car tyres, and the guidelines do not specify how soft ‘soft natural rubber’ must be. Because the guidelines have open (i.e. unspecified) standards, implementation will be difficult and the overall effect on pig welfare will differ between farmers. When pig farmers try to (or are forced to) reduce costs, they may (try to) provide a stone and a chain, for example, or a straw briquette as described in the Directive and practiced in some welfare schemes in a suboptimal way (as described earlier in this chapter). Such ‘enrichments’ may have a very limited actual welfare benefit, especially when compared to providing the full branched-chain design (see the supplement for more details).

Our on-farm observations also point in this direction. Conventional pigs provided with limited access to a hay rack or a soft-wood beam showed signs of frustration, enhanced aggression and skin lesions, as (conversely) did organic pigs that were fed substantial amounts of grass silage (Bikker and Binnendijk, 2012; Wind et al., 2012). Furthermore, weaners provided simultaneously with a bundle of chains hanging till floor level, a (rather big but soft) wooden plank, a rope and a flexible rubber toy (piece of hanging rubber mat), interacted about three times more with the chains than with the other materials. Also, fattening pigs simultaneously provided with a short chain and a rope with a flexible rubber flap interacted more often with the chain than with the rope-and-rubber. The rope-and-rubber was virtually indestructible, whereas the chain was a ‘proper’ stainless steel anchor chain reaching about 20 cm closer to the floor than the rope-and-rubber (52 and 33 cm respectively) (Ettema, 2010a). In these examples, the suggestion in the new guidelines that chains are inferior to the other materials, i.e. wood-rope and rope-rubber combinations, appears to be false. If so, allowing the combination of materials while rejecting the chains, seems to be suboptimal as regards pig welfare as well as suboptimal as regards the economic interests of farmers and consumers. Economic considerations alone may justify the use of branched chains, as no alternative material seems to provide as much welfare improvement for every Euro invested in enrichment. Furthermore, indirect economic benefits may include improving pig health by reducing stress and the use of antibiotics, or perhaps by reducing the cost of tail biting (which occurs in intensive pig farming despite tail docking, Zonderland et al. (2011)). But such indirect economic benefits, however, remain to be shown.

Non-economic considerations also need to be taken into account. This includes pig welfare in intensive pig farming systems, with proper enrichment being a notable item for pig welfare. The branched-chain design provides a unique opportunity for the pig sector. It can lead to proper pig enrichment and intact tails, two increasingly recognised requirements necessary to maintain a societal licence to produce. Within animal welfare, pig enrichment is special, because of its association with positive welfare, rather than with reducing suffering (as in the case of reducing tail docking, for example). Enrichment materials are very much visible to visitors and provide an opportunity to explain about pig welfare and how the pig sector is responding to societal concerns. In this way, enrichment may become the pig sector’s flagship of the transition towards a better future, a future also where former enemies perhaps may become allies (see supplement). The final section explains how this may happen.

6.7 Intelligent Natural Design

Intelligent Natural Design (IND) holds the promise of resolving persistent welfare problems by organising an evolutionary process resembling natural selection, e.g. by providing economic incentives to promote desirable outcomes. IND is a term coined to solve complex pig-welfare problems, like proper enrichment and intact tails, through human-made evolution (Bracke, 2010; Bracke et al., 2011). The concept derives from a so-called TED talk entitled ‘Trial, error and the God complex’ (Harford, 2011). Harford explains how Unilever physicists failed to design a properly-functioning nozzle to make washing powder. The problem was finally solved by an evolutionary biologist, Steve Jones, who subjected the problem to a process of human-made evolution. Jones built 10 different nozzles as a first ‘generation’, selected the best ones, and repeated this trial-and-error selection process for 45 ‘generations’. It resulted in a nozzle that performed much better than the solutions scientists had been able to come up with. Harford suggests this approach can solve just about any problem. I propose it can solve the problem of providing proper pig enrichment as well. Yet, I also think the method needs refinement, because a fully ‘blind’ trial and error process applied to pig welfare could lead to poor welfare, putting it at risk of being unethical. Also, being a welfare scientist myself, I believe available knowledge should be used intelligently. Hence, IND expresses the ambition of an ‘intelligent’ evolution. IND combines the phrases ‘intelligent design’ and ‘natural’. Natural is what happens in nature, i.e. evolution guided by natural selection. It has an impressive ability to find the most elegant solutions for very complex design problems through trial and error, i.e. without relying on scientific knowledge or intelligence. ‘Intelligent design’ normally refers to a religious form of creationism holding the view that certain features of the universe and of living things are best explained by an intelligent cause (Wikipedia, 2016). ‘Intelligent design’ in IND, however, refers to the idea that we may intelligently design the conditions needed to facilitate gradual, evolution-like improvements towards more desirable and sustainable livestock-production systems. For this scientific understanding of underlying mechanisms is desirable, but not absolutely necessary. We should use it, where possible.

According to the principle of IND, we may organise individual variation and persistent selection to deal with pig enrichment. For this, the main selection criterion is pig occupation, i.e. the time spent in voluntary, enrichment-directed behaviour or AMI. AMI duration and the type of AMI may be recorded using behavioural observations and using AMI-sensors. Pig tails provide a related selection criterion. Pig tails may be measured in terms of tail lesions and tail length. Using these criteria the selection process starts with comparing the most promising feasible enrichment materials. As a starting point, this should include the branched-chain design as described above. The enrichments are implemented in a limited number of pens ('individuals'). Enrichment materials, or combinations of materials, in pens are then compared, either as individuals or as a group of 'clones'/treatments, to see which is doing best in terms of providing pig occupation. The best, most 'fit', 'individuals'/enrichments are selected and used to 'generate', i.e. design and install, the next 'generation' in, say, a new batch of pigs. When repeated persistently, this process should inevitably lead to gradually improved enrichment. Ideally, the selection process should lead to considerably improved pig welfare. This requires the ample performance of positive, natural behaviours (Bracke and Hopster, 2006; Bracke and Spoolder, 2011b) and a minimised level of abnormal behaviours, mutilations and health problems.

Farmers should be responsible for the implementation of the branched chains on their farms, and for the IND selection process and innovation. This turns farmers into a kind of pioneers for doing participative science. It implies that farmers themselves, alone or with the help of others (e.g. vets, students, scientists), make science-based comparisons. As a result, supplementing a comparison of individual instances of enrichment materials as in the case of the nozzles for making washing powder, IND proposes comparing groups/repetitions/'clones' of enrichment treatments as much as possible in accordance with scientific standards (e.g. random allocation of enrichment treatments; standardised observations, statistical analysis, etc.). This makes sense, i.e. is smart, because pig enrichment is subject to considerable individual variation (Feddes and Fraser, 1994), as is the case in nature (and much less so in washing-powder nozzles). It is also smart because intensive pig farms typically have many repetitions of highly similar pig pens. This allows repetitions/'clones' of enrichment treatments to be compared at a group level, i.e. as average value and standard deviation, in addition to making a comparison at individual level. Not all farmers would have the time and skills required to do such science-based comparisons themselves. But, firstly, it is not necessary for IND to work, and, secondly, many farmers would have the skills to make it possible, e.g. through (scientifically-trained) extension and by allowing students and scientists do the work on their farm.

Main challenges include overcoming economic constraints, and re-directing farm management from its primary focus on maximised production efficiency to focussing on maximised efficiency of inclusive welfare. This includes both farmer welfare, of which economy is a most important component, and animal welfare. Seeking maximised overall welfare implies recognising that feasibility is a necessary condition. As such branched chains are feasible, and destructible materials generally are not (or not yet). It also implies that the impressive capacities of the pig sector to innovate for economic reasons can be redirected such that existing skills could innovate for improved animal welfare too. Innovating for personal financial gain often involves keeping knowledge private, because its leading principle is individual selection. By contrast, IND would promote altruism via group selection, thus suggesting that farmers share information, e.g. about which enrichments are promising and which are not. In this way the wheel doesn't have to be invented time and time again. Sharing also facilitates correction of potentially biased or misleading claims.

IND acknowledges that modern intensive pig production is itself the product of human-made selection, in particular of economic selection for maximised production efficiency. This implies that IND-based solutions for enrichment should work with, rather than oppose the underlying economic forces. Current economic forces are pulling towards completely barren pens, as is practiced in most countries outside the EU. Legislative measures and welfare schemes try to counteract this. For IND to succeed, it is important to start pushing towards welfare improvements. This implies providing incentives for doing well, and imposing a (relative) material or immaterial cost on doing less well. Several examples may illustrate how different stakeholders can implement IND by creating economic and other incentives to promote innovation towards more proper pig enrichment.

The first example is for regulatory bodies to use existing EU legislation to stimulate pig-welfare improvement. In particular, current EU legislation (EC, 2001) contains articles banning routine tail docking and teeth treatment at an older age. In particular, it also prescribes that 'plentiful straw' must be provided in cases of 'severe fighting' 'which goes beyond normal behaviour' (Article 3 of the Annex). Enforcing these requirements could promote better enrichment directly, e.g. by providing plenty of straw in case of tail biting (which was more commonly regarded as a form of abnormal fighting behaviour in the early days of drafting animal welfare legislation; and to some extent it may well be (e.g. when it originates at the feeder), even though ethologists now commonly agree that tail biting is not an agonistic behaviour as such). Enforcing existing legislation could also promote better enrichment indirectly, e.g. by requiring more serious efforts to stop tail docking.

A second example is more directed towards other chain actors and towards reward rather than punishment. Slaughterhouses could put a premium on pigs with longer and intact tails, at very little or no costs to themselves. The premium may be financed in various ways, e.g. through a general check-off payment by the farmers. This would imply a redistribution of (some) money from the worse to the better farmers. It may also be paid for by consumers, retailers and governments who feel this is important for sustainability. Also crowd-funding and prize-contests could be organised to generated incentives for farmers to implement the branched-chain design, and start directing innovation towards better animal welfare, proper enrichment and intact, curly pig tails in intensive pig farming (see also the supplement).

A welfare scheme is also conceivable where consumers can pay directly for improved enrichment, much in the way they can already pay for green energy and for climate-neutral holiday flights. In this way welfare revenue can go more directly (via the farmers) to the pigs rather than to the intermediate actors in the supply chain as tends to happen in most current welfare schemes. In fact, the top-end of enrichment, i.e. providing a sufficient amount of straw to stop routine tail docking and to raise pigs with intact curly tails on well-managed pig farms, may cost perhaps as little as about 5 (to perhaps 10) euro per pig, i.e. 6-13 eurocents per kg of pig meat (carcass weight) (Zonderland, 2007; Zonderland et al., 2008). If consumers would be willing to donate this kind of money to pig farmers, tail docking could soon come to an end. I even believe that the RICHPIG model (Bracke et al., 2007a; Bracke, 2008) and the more recent expert scores (Bracke, Submitted) provide a fairly sound basis for the suggestion that branched chains and the IND approach could be turned into one of the most cost-effective charitable objectives available at present to tangibly improve (any kind of) animal welfare (cf Effective Altruism, Wikipedia (2016b); (Singer, 2015)). (More ideas on IND and the development of proper pig enrichment are described in the supplement at http://www.farewelldock.eu/.)

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Supplement: Outline of a protocol to evolve proper enrichment, and intact curly tails, for intensively-farmed pigs by implementing branched chains on a global scale as soon as possible, and by using structured comparisons between alternative enrichments, repeatedly selecting the best materials, sharing information and by organising economic, social and legislative incentives to help farmers improve pig welfare

Marc Bracke
Wageningen Livestock Research

Introduction

The protocol presented here is an outline, a kind of first sketch, of how to make the world little bit a better place by suggesting that all intensively-farmed pigs, across the world, be provided with really proper enrichment. It describes a worldwide, collective effort to initiate an organised, concerted evolutionary development-process towards proper pig enrichment taking the branched chains as a benchmark and starting point.
Background details, supplementing the main outline, are presented below in smaller-font paragraphs. Note that this document is a supplement to a primary text (Bracke, 2017). As such this document is a ‘live/dynamic’ document, i.e. it may be updated with suggestions deemed relevant. As such, the document is rather poorly structured and may contain repetitions and even apparent contradictions.

This document's main **aim** is to provide background material to get the point of how Intelligent Natural Design (IND) can implemented in intensive pig farming so as to start providing proper enrichment (and stop tail docking) in the shortest possible time.
The proposal as a whole consists of various different **components**. I would like to ask the reader to judge each component on its own merits, and beware of the fallacy of rejecting the whole based on a rejection of a part. I hope that despite its chaotic structure and rather idealistic signature, this document provides inspiring contents for pig farmers and other stakeholders to improve animal welfare.
Branched chains are proposed as a **starting point and benchmark** enrichment. A starting point, because they can be implemented on virtually all pig farms almost immediately. And in virtue of providing near proper enrichment, the branched-chain design constitutes a benchmark, i.e. a standardised description that is suited to serve as a negative control enrichment in the process of developing more proper enrichment.
The branched chain is **described** in the primary text (Bracke, 2017). In brief:
Branched-chain design definition:

1. **Object-design**: A branched chain consists of a vertically-positioned long chain with its end resting on the solid floor over a distance of 20 cm. Two or three additional chain ends (branches) end at or slightly below the nose height of the smallest and middle-sized pigs reared in the pen.
2. **Material**: The chains are stainless-steel anchor chains (for the last 5-10 links of each chain end). Recommended dimensions are 7mm for growing-fattening pigs, 5-6 mm for weaners, 4-5 mm for piglets and 8 mm for sows.
3. **Availability and placement**: One branched chain is provided for every 5 pig. The chains are spaced apart as much as possible, preferably with at least one pig length between 2 branched chains in a pig pen. The branched chains are attached at the top end of the pen wall, over the solid floor, and not in the dunging area.

All pig farmers may support this initiative. The more farmers participate the more effective the selection process, and the more quick proper enrichment will become reality. This implies a participation that is in principle world-wide, and across sectors, i.e. involving not only (though mainly) conventional, intensive pig farmers, but also farmers involved in welfare schemes and organic farmers. Even backyard farmers are invited to join in. Different (types of) farmers may focus on different aspects of the selection process.
Participation can take various forms, but essentially it involves installing (a series of) branched chains in (your) pig pens. In principle, every farmer should install **10-20 pens** (depending on farm size) with branched chains as specified above (esp. 1 branched chain per 5 pigs). In addition, if some kind of enrichment is already present, 10 pig pens for every type of enrichment are kept without branched chains (serving as 'negative controls' (assuming that the branched chains will perform better, else these are 'positive controls'). The rest of the pig pens are to be installed ideally with at least 1 branched chain supplementing previously present enrichment (even when e.g. straw is already present in the pen). This is the **starting point** for developing better enrichment.
Note that this outline is focussing primarily on all intensive farmers in the Western world. Farmers in **developing countries** may participate in proportion to their interests and economic capacities. Other Western farmers, e.g. **organic farmers** and other farmers providing straw or other clearly destructible materials (e.g. '**backyard farmers' and hobbyists**), are also welcome to participate. In organic farming in Europe, for example, straw is used indoors, but often partly or fully-slatted, barren outdoor runs are used without any enrichment. Branched chains provide an ideal starting point and benchmark for improved outdoor enrichment of such organic weaned and growing/fattening pigs, and the design challenge to improve further is largely similar to the conditions in intensive farming. Such farmers, however, may start with adding only 1 branched chain per pen, instead of 1 branched chain per 5 pigs, and they may be installing these chains in a lower number of pens, e.g. 6 to 12 pig pens, esp. when they don't have so many pens available.

The installation of the chains should, as far as I am concerned, be done **without delay**, i.e. within the shortest possible period of time (which could be a matter of weeks, rather than months).

Note: when there is no immediate financial gain to be expected, farmers **tend to wait** and see what other farmers will be doing. Though economically smart, I see no moral justification for undue delay (Bracke, Submitted). To counteract this tendency, I propose to support early-adopters. The same applies to innovators and farmers identifying major short-comings (i.e. falsification) (see below).

Objective

Really proper enrichment will not only provide proper investigation and manipulation activities to the pigs, such that they are no long bored, but it also supports a transition towards raising pigs with intact, curly tails. This is because proper enrichment is a very important element in an effective strategy to prevent tail biting, (thereby) reduce the need for tail docking, as well as effectively treat/curtail outbreaks of tail biting (and other forms of harmful social behaviours like ear, flank and leg biting).

However, tail biting is a multifactorial problem, where other aspects may be relevant besides enrichment. If, for example, an underlying disease, climate or nutritional problem is causing tail biting, then enrichment materials may provide mitigation of the problem, rather than solve it. So, evolving solutions for tail biting and tail docking is more complex. These conditions are also more likely to lead to poor welfare. This probably requires more specialised external coaching. In addition, learning how IND works to improve pig enrichment will lead to a certain level of experience that will later benefit evolving more complex solutions for tail biting and tail docking.

Various **main objectives** in developing proper enrichment can be distinguished:

(1) Optimising the branched chain design (in terms of AMI)

(2) Finding other forms of enrichment that are better for pig welfare than the (optimised) branched chains

(3) Developing enrichment materials that are effective in preventing tail biting

(4) Developing enrichment materials that are effective in counteracting an outbreak of tail, ear, flank or leg biting (and cannibalism).

A **first objective** within the optimisation of the branched chains is to make sure that they meet the **basic requirements for operation** on the farm. In all pens containing branched chains farmers can soon identify potentially major bottlenecks (e.g. pen soiling, chains being thrown out of the pen, competition). Though unlikely, these should be solved first (preferably by exchanging ideas and possible solutions, see below).

Another bottleneck may be current **legal** requirements, or requirements related to the welfare scheme a farmer is are involved in (Bracke, Submitted). In the Netherlands and Germany, for example, a branched chain alone is not legal, because it doesn't have some other material attached to it. Of course, it is not difficult to add a ball or pipe to a branched chain (but preferably not at the end of a chain), so as to meet the legal requirement. In the UK a similar solution is possible within the welfare scheme requiring (hard) wood in strawless systems. In Belgium, where the chain must be hanging away from the pen wall, one branched chain may be provided as a replacement of the free-hanging short chain, and/or (the remaining) branched chain(s) may be provided hanging from the pen wall. This would enable an interesting comparison to confirm the added value of free-hanging suspension in practice. Also other variations in suspension (e.g. high (ceiling), medium (pen wall) and low (near floor) suspension points) may provide interesting comparisons for further optimisations

In addition, from the start, a **comparison** can be made between the various types of enrichment present on the farm, both between pens and within pens. To this end, the various types of enrichment (full branched-chain design (1 per 5 pigs), original enrichment, original enrichment + 1 branched chain) should be presented in blocks of pens (where each block contains each of the enrichment types once in a different pen; and using randomised assignment of treatment (i.e. enrichment type)). Within pens the original enrichment(s) and

the branched chains can be compared esp. when their relative location can be randomised (or varied qua location in alternating order).
This suggestion implies an attempt to do **on-farm science**. I have done several experiments on farm (Bracke, 2007b; Bracke and Spoolder, 2007b; Bracke, 2009; Bracke and Ettema, 2014). This has made me well aware of the fact that doing scientific research on farms, even on research stations, can be a most challenging activity. As judged from what is needed for proper science, many things can, and often do, go wrong on farms. It is for this reason that it is important to build in **checks and balances** so as to compensate for and correct deficiencies.
The next step, once the branched chains have overcome potentially major bottlenecks, further implementation of branched-chain designs is required, provided branched chains have indicated being used substantially by the pigs and more so than the original enrichment. This implies **scaling up** to installation of full branched-chain designs (1 branched chain for up to 5 pigs) in (nearly) all pens (except those pens needed as negative controls for comparison purposes and further development). This should be done as soon as possible, preferably within 0.5-1 year after the first branched chains have been installed.
Should it turn out to be impossible to solve major immediate or longer-term bottlenecks (which is unlikely, given the innovative capabilities of the pig sector as a whole), the branched chains can be dismantled (to the extent necessary to counteract the bottleneck, e.g. made a bit shorter to reduce floor abrasion), and used as (somewhat) shorter chains to provide many years of a most basic form of pig enrichment (as a moderately long chain). So the **investment in the branched chains will never be negative**.
When stainless steel anchor chains cannot be purchased in the short term (e.g. not available second-hand), or when the costs of stainless steel are considered too high (e.g. for farmers that do poorly financially), it would be possible to start with cheaper c-chains and/or to start with a branched-chain design 'skeleton'. In this case a cheaper branched chain is installed missing the 5-10 stainless steel links that are to be added later.
Optimising the branched-chain design involves comparing various aspects of these chains that may be verified (or falsified) and adding details in the specification that lead to enhanced object use. This includes aspects like the best location in the pen (relative to dunging area, feeder and resting area, relative to solid and slatted floor, relative to other enrichments, type of pig, etc.), modes of suspension (e.g. against the wall, or free hanging), solving smaller bottle necks (e.g. how to best provide a branched chain on the floor on slatted flooring; how best deal with pen soiling and floor abrasion if it occurs) and checking specification details (e.g. what is the preferred link size for different types of pig, and what number of pigs per branched chain is best overall for the pigs). Under optimisation many ideas can be tested, esp. adding indestructible objects, like balls, pipe or hardwood, and destructible objects like rope, jute and softwood. For example, it could be interesting to find out if tying a small piece (20cm) of sisal rope into the branched chain at one point, enhances the subsequent use of the chains (i.e. even after the sisal rope has been destroyed or removed). This could be especially interesting for pens that show low levels of chain manipulation. If so, it may also be interesting to examine if such treatment may have an effect on the subsequent likelihood of developing tail biting.
Note: When the installation of (only) branched chains is **illegal** in your country (as it is in the Netherlands and several other NW-European countries) or in your welfare scheme (as it is in the UK), you cannot use pens with only branched chains. However, you can add branched chains to see if they are used a lot (more), and thus compare the enrichment value of different materials and the branched chains within pens, and you can compare pens with original enrichment and those were one or more branched chains have been added.
When branched chains have been installed and compared to other materials or other versions of the branched chains, they are de facto used as a starting point for evolution. The branched chains prescription provided in the primary text (Bracke, 2017) provide only near proper enrichment, thus failing to be sufficient (Bracke, 2017; Bracke, Submitted). In addition, the branched-chain design is also proposed as a **benchmark**, i.e. a reference point, for further development. This involves especially comparing alternative enrichment materials against the

branched chains to see which materials are better and how much. Branched chains thus first serve as a positive, and hopefully soon also as a negative control in a scientific experiment.

Evolution

The **evolutionary process** follows the principles of **Intelligent Natural Design** (IND, see the prime text (Bracke, 2017)).

In this evolutionary process every instance of an enrichment material, e.g. a branched chain, may be perceived as an '**individual**' that can be subjected to selection (Harford, 2011). For the main outline described here it is more proper (i.e. more functional for developing better enrichment, i.e. more effective) to define the 'individual' enrichment at '**group** level' by all the distinct, individual materials present in a pig pen. In this case the 'group' (of enrichment materials) is the 'selection unit'. Another important integration step for optimised selection of better enrichment is to perform selection at '**group** level' rather than at individual level. With this is meant that mostly/preferably we won't be comparing one enriched pen with another (slightly different) pen, because individual variation will make selection a rather seemingly arbitrary process (though in fact it won't have to be). Instead we prefer to compare groups of '**clones'** using principles borrowed from science to make (more) valid comparisons at group level. In this set-up the comparison is between one type of enrichment installed/'cloned' in about 10 randomly-selected pens with another type of enrichment installed/'cloned' randomly in 10 other pens (where all pens are as much as possible (treated) identical to each other, except for the difference in enrichment).

Note: This is a very nice thing about intensive pig farming: most farms have several buildings with several units in each building and a **series of pens in each unit**. Pens within units are highly similar, e.g. because of all-in-all-out principle all pigs are approximately the same age and size. Often pigs are also genetically related and many pens resemble each other. When many pens are present, but just not many similar ones (e.g. when buildings differ in layout/design, and in case pigs are kept in large groups), then it is smart to use a **matched-pair** design, i.e. a set-up comparing different enrichment in pairs of pens that are similar as much as possible in all other respects. Such a matched pair design can be most convenient for on-farm application, also because it may **simplify the selection** process, i.e. it only requires a relative judgement within each pair (in terms of better, worse, or same) in order to be able to make a scientific/statistical selection. Note: statistical significance is very interesting to know, but not necessary for selection: a higher average value suffices.

When there are not enough identical pens present on a (**small) farm**, it is possible to reduce the number of pens needed, e.g. by comparing different materials within pens (with the 'experimental design' being balanced for relative location in the pen). In fact, if the farm/pig owner has only **1 pig in 1 pen**, it is still possible to follow this outline and contribute to the development of better enrichment, namely by comparing different materials within one pen and comparing enrichments across shortened generation intervals of e.g. 3 weeks each (using a so-called Latin Square design applied sequentially).

The selection unit (individual material, collection of materials in a pig pen) is **described** in detail by its components and by the relationships to each other and other elements in the environment (i.e. the pig pen). **Documentation** also includes taking pictures and video images, and care is taken to avoid focussing on longer-term object-use (i.e. after at least several days of habituation).

Selection involves comparing each selection unit to its 'contemporaries' (i.e. other instances of enrichment materials) and using the best materials to start a new 'generation'. In principle, every new batch of pigs is a new **generation** that builds on the best enrichment found in the previous generation.

Note: The outline describes the main principle. Deviations from the outline are possible: (1) It is possible to reduce the generation interval to a minimum length of about 2-3 weeks. (2) It is possible to select enrichment across generations. (3) While the main objective is to select between pens, it is possible to select different materials within pens. Conversely, for certain variables it is not possible to select at pen level, but selection must take place at unit level (e.g. comparing climatic conditions), building (pen-layout effects), farm (farmer effects) or even regional level (outdoor climate effects).

The 'generation interval' lasts for several weeks in weaned pigs and several months in growing/fattening pigs. The prime **selection criterion** is the duration of object use (**AMI**) by the pigs.

Note: **Secondary behavioural** selection criteria include the type of object use (rooting, biting, pulling, chewing, swallowing), the demand/willingness to work for AMI/the enrichment material/perform the behaviour, and effects on other behaviours, e.g. competitions/aggression, frustration, disturbance of resting, penmate-directed behaviour and harmful social

behaviours. Other secondary criteria for better enrichment (but prime in their own right) relate to **health** status, esp. wounds, esp. tail biting, ear biting and flank biting wounds, and e.g. tail length (related to the need for tail docking).
Note: **Feasibility** is also an important prerequisite. Ideally, the aim should be to evolve towards the best enrichment for the least amount of money, i.e. reaching the level minimally required to provide substantial occupation to the pigs at the lowest possible cost in terms of finance, labour and other risks).

The more **objectively** it can be shown that one material is superior to another, the better it is. Thus, there is a hierarchy in possible '**instruments**' to record AMI.

Farmers may use their **personal judgement** (impression) about the (relative) quality of different enrichments which are to be compared. They may also **consult** other farmers and ask visitors to compare materials. Farmers may also employ students, or even highly-motivated animal welfare activists, using some kind of **protocol** (ethogram) to record behaviour, or use a devise to record AMI more (semi-)automatically (AMI-sensor, data logger).

Animal activists are highly motivated to improve farm animal welfare, and they are often frustrated because there so little they can do about it. Conversely, farmers are frustrated because they feel threatened by animal activists. This leads to considerable aversion on both sides. Among the group of animal activists some are extreme, aiming only for the complete abolition of intensive farming. Others, however, are much more moderate. These animal-welfare minded citizens are motivated to see even small improvements in animal welfare. The IND approach offers an opportunity for pig farmers to reach out to this more moderate majority of animal-minded people and invite them to come and work on the farm to help improve pig enrichment and welfare. Thus, IND of enrichment offers an opportunity for old **enemies becoming allies**.

The more certain it becomes a material seems to be a real improvement, the more important it may be that this is **verified** independently and using **scientific** methodology (so as to minimize the risk of perception bias).

Observe how the pigs use the enrichment materials **after (at least several days of) habituation** as well as after prolonged exposure (weeks/months).

Note: the **immediate response** of pigs to enrichment materials is not relevant when materials are permanently provided. For **destructible** objects, where novelty is an inherent part of their presentation, short-term responses are to be included in deciding what their enrichment value is.

Observe **behaviour** (duration, frequency, types of interaction; also attend to e.g. vocalisation/sounds and possibly negative behaviours such as frustration (e.g. pigs trying to bite the material, but failing to do so) and aggression.

Preferably also observe **without disturbance** and at times when you are normally not in the barn (e.g. using a webcam or go-pro recorder).

Observe **how the materials respond** to being used by the pigs (making sounds when being used, wet/dry, wear and tear, damaged, collecting dust, etc.)

Note any effects on the pigs in terms of performance, biting wounds (e.g. on tails, ears, flanks), prospects for longer/intact tails.

When materials are sufficiently promising: **Test** the materials, i.e. try to get (more) quantitative information about object use (e.g. with the help of a student doing behavioural observations)

Preferably use a sufficient number of pens (e.g. 10 or 20 per treatment)

Try to use scientific methods (e.g. randomised allocation of treatments, etc.).

If possible measure AMI using an **AMI-sensor**. This is some kind of accelerometer/pedometer/cow-activity meter. AMI-sensors can generally only be used on hanging materials and away from pigs and walls (to avoid damage of the sensors. For non-hanging materials indirect measurement can be done (e.g. by attaching the AMI-sensor to an identical novel rope or branched chain hanging in both the treatment and control pen), but this may be less effective in detecting a difference in enrichment, so may require more pens and should preferably be supplemented with direct behavioural observations.

Farmers may also use **RICHPIG** to score enrichment value, and to **design** and evaluate new/alternative/improved materials before purchase/construction/introduction (Bracke et al., 2007a; 2007bl; Bracke, 2008).

Using RICHPIG, try to give an overall score by comparing the new material to the other materials that have already been scored.

Try to assess the 30 material properties in the model that make up enrichment value (e.g. novelty, destructibility, functionality (e.g. in obtaining food), does it allow various behaviours (e.g. rooting, biting, swallowing), accessibility (for all pigs at all times, i.e. meeting the requirement of permanent availability, etc.).
Make both an optimistic and pessimistic RICHPIG assessment of the new material.
Be critical of possibly biased judgement when using RICHPIG, esp. if you have an interest in some way (e.g. economically); Also be aware of anthropomorphic reasoning, e.g. thinking that balls are fun and chains must be bad (see text, Bracke (2017)).
Note: Also consider the potential impact on **other values**: Is the material synthetic or natural (and does it allow natural behaviours, esp. rooting)? Is the material in principle suited or functional for the process of 'evolving' more and more suitable pig enrichment? Does it 'feel' well, i.e. raise sympathy/aversion among farmers, scientists, NGO's and/or consumers? Why? Does it pose an environmental risk (e.g. when pigs consume destructible plastic toys that end up in the manure), a risk to the pigs (i.e. health risk, e.g. splinters from wood, iron parts in car tyres, wet wood or ropes that may transmit pathogens from one batch of pigs to the next), a risk to society (is it appealing/appalling to citizens and consumers, and if so, are they properly informed or misguided?), or is it a risk to the farmer (is it in accordance with (other) legal requirements? May it harm consumer confidence? Does it affect worker safety (e.g. raise dust levels), material costs, labour requirements or system failure (e.g. blockage of the slurry pit)?)?

Checks and balances

Install the new/promising materials in a few pens to get a first impression; but soon **scale up.**
When one farmer claims to have made an improvement, such improvements must be tested **independently** on other farms, so as to confirm and reduce the risk for error, perception bias (or worse). For this purpose, other actors are also important, e.g. vets, farm advisors and visitors.
For really promising materials, which are potentially suitable for more wide-spread, commercial application: Have the enrichment value of the material **certified** by a qualified and independent agency, e.g. a pig research unit, university (student project) or extension service. Include a comparison to the branched-chain design as a control (benchmark).
A possible risk requiring verification would be the situation of farmers promoting the use of a **most economically-feasible enrichment**. In this case, it is important to have some kind of check as to the suggested (or imagined) welfare benefits. For this, a scientific experiment would seem to be needed. However, NGO's or animal-welfare minded citizens (e.g. students) can play a role in doing a prior check as to whether the material indeed seems to be benefitting the pigs as much as claimed by the farmers.
To allow repetition and verification (and falsification) detailed **documentation** is important. The installed materials must be described in detail and supplemented with repeated recording of images (pictures, video), such that the **degradation** and use of the material over time is documented.
Every round/every couple of rounds the best materials are 'selected' based on AMI, and these are used to start a new 'generation'. This process is to be repeated time and time again (i.e. the **process of trial and error, variation and selection** is repeated time and time again).
Be aware that you are involved in a gradual design process, which requires **persistence**. But this does not imply that one shouldn't sometimes **try something radically/substantially different**. This may enhance motivation, and such radically different materials may be valued with a view of their potential to generate an entirely **new 'species'** of proper enrichment (instead of comparing the new material blindly with the performance of materials that have already gone through a long process of trial and error). Share information about such wild trials, also when they fail.
While the overall objective is to find suitable enrichment feasible for all intensive pig farmers, in some respects (aspects of) solutions may be **farm-specific**. This is more of a theoretical possibility, and should be treated with care in that claims to farm-specificity may not be used

to pretend that poor (and cheap) enrichments are working well on a particular farm. This needs to be shown first beyond reasonable doubt.
The selection process must be **reliable**. The role of human perception and risk for judgement bias must be minimised. This requires using objective (science-based) measures of AMI and tail status, as much as possible. It also implies knowing what may happen in practice and having the courage to be transparent. In particular, when the objective is to raise pigs with intact tails, the illegal practice of **teeth cutting** (or teeth breaking) should be acknowledged as a possibility (De Lauwere et al., 2009; Bracke et al., 2013). It should be monitored and effectively eliminated when detected, rather than being silenced. Failing this, the wrong kind of farmers may be selected to receive e.g. a premium for improved enrichment or even raising pigs with intact tails. Ignoring the practice of teeth cutting to curtail an on-going outbreak of tail biting also removes an important economic incentive for pig farmers to provide proper enrichment (Zonderland et al., 2011). The latter is a known problem that needs explicit attention as it may considerably disrupt the selection process due to a profound effect on the overall cost of tail biting (Zonderland et al., 2011). Hence, teeth treatment should be **monitored carefully** by inspecting the front teeth of pigs in biter pens, and effective counter-measures must be taken when it is observed.

Type of farmers

Intensive farmers in Europe should, in my opinion, make an extra effort, if they haven't done so to date, to improve pig enrichment by implementing **ample branched chains** as supplementary enrichment, and then taking the next step to also provide some kind of **destructible material** like rope, soft/fresh wood, jute, roughage and straw, renewed on a more or less daily (and for wood perhaps weekly) basis. That, to me, should be a decent short-term (within 1 year) objective for all intensive pig farmers in Europe, and in particular pig farmers in the Netherlands, so as to compensate the moral deficit.
Orderly farmers who have many similar pens and are able to make more or less exact copies of branched-chain designs (i.e. who are good at 'cloning') are best suited to compare various types or aspects of enrichment. Farmers who are least orderly, i.e. who have an inherent tendency to produce different 'individuals', rather than exact 'clones', are more suited to select at the level of the individual enrichment (as described in the text related to the TED talk by Hardford (2011)).
Farmers on **problem farms**, i.e. having problems with tail, ear or flank biting, should preferably focus on the use of branched chains and other, preferably destructible, enrichment materials to first prevent and then counteract these behaviours. Such farmers should take additional effort to compensate for reduced pig welfare, especially in biter pens. Two treatments for outbreaks can be compared by applying them in alternate order in each pen presented with an outbreak (Zonderland et al., 2008).
Note: Like using several enrichment materials in one pen as an 'individual' selection unit, so **various tail-biting measures** (even when applied sequentially) may be regarded as one selection unit. Enrichment may be only one element of various (multifactorial) measures taken to deal with (prevent and treat) tail biting (EFSA, 2007b; Spoolder et al., 2011). Since the main topic of this text is enrichment for occupation, rather than intact tails, I will not deal with this here in more detail.
Intensive farmers **without tail biting**, but who nevertheless dock their piglets' tails, should try to start raising pigs with intact (undocked) tails, preferably when they have good management skills. They should provide (at least some) destructible enrichment materials. This is best done starting with a limited number of pens and using partly docked pigs, i.e. where tails have been docked less short than previously practiced. When tail biting occurs, these farmers should follow the focus (testing treatment strategies) described in the previous paragraph for problem farms.
Note: This especially concerns **closed sow-farms** that also raise (part of their) piglets for fattening; and pairs of sow- and fattening farmers that cooperate well together. Superior management skills are a prerequisite.
EU law bans routine tail docking, so this seems to be in accordance with what EU law requires of such farmers.

Communication

Human-made evolution for proper pig enrichment must **use available knowledge and facilitate learning**. This requires transparency and open communication. The examples of the hockey-type ball and straw briquette are cases in point (Bracke, 2017). Making mistakes is not the problem. The problem arises when issues with being **honest and transparent** hamper learning. Since farmers who bought the ball didn't let other farmers know about their dissatisfaction, new farmers were not prevented from making the same mistake over and over again (Bracke, 2017). Modern information technology (the internet) provides **platforms** (e.g. Facebook) for widespread networking and information exchange in a user-friendly way.

Prior to and shortly after the installation of the branched chains, pig farmers should **communicate**. They should build networks to exchange ideas, tackle problems and get inspired.

The **objectives** of communication are to be much more efficient, to raise support and commitment, to 'be good and tell it', but also to 'do good and prove it'.

They may **start** with sharing their **experiences** about different enrichment materials they have tried in the past and about materials they are currently providing. They could exchange **tips** about how to provide materials in a way that is both beneficial to the pigs and economically feasible to the farmer. It also makes sense to exchange **expectations and worries** about using branched chains.

Exchange information concerns **both success and failures**. Making mistakes is necessary for progress. See mistakes as an opportunity to learn, rather than as something to be embarrassed about.

Communicate with other farmers and other chain actors (e.g. retailers), but also with scientists, NGOs and consumers. Show them what you are doing; share widely, e.g. using the internet (Facebook/Twitter).

In case of initial/apparent successful selections of improved materials: try to persuade several other farmers to adopt and test the candidate innovation too (rather than keeping it for yourself).

Inspire others and be inspired (e.g. schools may be most interested to have students do projects to design and test enrichment materials on a farm).

Try to raise money, e.g. through crowd-funding or donations (cf Effective Altruism).

Networks should not only be local, e.g. involving other farmers in the area, the local vet, farm advisors and other visitors. Networks should also be global, e.g. using social media, or (special) website fora for pig farmers.

Exchanging ideas implies that from the start existing knowledge can be used to the fullest possible extent.

Transparency is also important to avoid double work.

Note: Some repetition is good, even necessary, namely to confirm that something is or is not actually working. Too much repetition, however, is not efficient. The amount of repetition needed depends on the generalisability of the suggestion and on the quality of the observation (e.g. farmer's impression versus scientifically shown).

Sharing implies generating **involvement**, which may take various forms:

Involving **sector representatives** can help generate funds for organisation and logistics, e.g. through lobbying at the government, other chain actors like slaughterhouses, retailers, NGOs and the general public for support.

Involving the general **public** may restore trust in pig farming, and generate opportunities for crowd-funding, and other forms of support, e.g. (groups of) students doing observations or designing improved enrichments.

Involving local and regional **experts** with a university background like vets, farm advisors and biology teachers can help improve the experimental design and selection process.

Involving **pig breeding** companies would have major advantages in terms of their knowledge of dealing with selection processes and big datasets. They may also contribute (in the longer

term) by selecting for pigs that properly engage with feasible enrichment materials, and by selecting for pigs that have a reduced propensity to engage in harmful social behaviour (e.g. using group selection (Muir, 2003; Bijma et al., 2007a; Bijma et al., 2007b)).
Note that IND is aiming for group selection of farmers, by re-directing focus from (only) economy to (also) human and animal welfare, and by redirecting focus from self-interest to group-interest (e.g. by sharing of information and rewarding individual farmers who are doing well for the group).
Ideally, the collective effort of farmers should be coordinated or monitored from a central point, such that overlap is optimised and such that some kind of overall ranking/scoring of all kinds of tested materials can be made. The (adjusted/modified) RICHPIG model should in principle be suited to make this possible.
Involving **designers and builders of pig barns and equipment** can help design better enrichment materials, systems that are more suited to provide high-quality (destructible) enrichment (like straw) and/or tools to deal with bottlenecks (e.g. solutions to unplug a blocked slurry system from using some straw or roughage).
Global networks (the internet) can help find farmers having similar interests, similar buildings and similar management practices.
Note: **App designers** may be involved to help develop suitable AMI sensors for farmers. Nowadays every mobile phone as an accelerometer, and hence could be used as an AMI sensor. A modified 'running app' used in a clever way can be used to collect scientifically valid data to make statistical comparisons possible between enrichment materials. Apps could also be designed to help farmers and students conduct science-based comparisons of enrichment materials on-farm.
Networking implies **sharing**, and sharing implies that the wheel doesn't have to be invented repeatedly.
Networks are also important because the evolution of proper enrichment will require perseverance and dealing with **setbacks**.
Large-scale (world-wide) selection, maintained over a substantial period of time, requires the initiation of special **incentives**. These may take various forms:
Regional, national and global **competitions** may be organised (e.g. by farmers' organisations and NGOs) to present innovations and falsifications. Such competitions could provide rewards (prizes, honour) for early adopters, farmers who are more actively sharing information (about what does and what does not work on their farm), and innovators. Innovators could, for example, be rewarded by ascribing the innovator's name to each major innovation as is done in certain Olympic sports.
In competitions, businesses can be involved for **sponsoring**, and experts (pig farmers and farm advisors with a track record, NGOs, retailers, sector representatives and pig welfare scientists) can be involved as **judges** (cf prize contest at hokverrijking.nl, Bracke (2011c), supplementing a 'peer review' (by other pig farmers).
Inevitably mistakes will be made, and the importance of making mistakes is frequently overlooked. For this reason, **falsification**, i.e. showing that certain claims are false, should be regarded as in integral part of developing proper pig enrichment. Farmers should be rewarded for showing that some claims were false, e.g. suggested link sizes or numbers of pigs per branched chain, and that indestructible materials like branched chains cannot substantially reduce tail biting (perhaps they can after all). I wouldn't mind if I were shown to have been wrong about the branched chains, as long as this falsification is conducted in the process primarily aiming to improve pig enrichment.
Consumers may be persuaded to pay e.g. 0.10 euro for every 100gr of pig meat they have been consuming. If they would pay this directly to farmers actively involved in improving pig welfare, substantial progress could be made in a very short period of time. NGOs could play a role in verifying that the donations are well spent. In fact, donating money to provide proper chains in pig pens in intensive farming could probably be turned into one of the most cost-effective, tangible charities to tangibly improve animal welfare.
Slaughterhouses and retailers should support this process, e.g. by rewarding farmers for being actively involved and for making progress (which includes falsification). This both concerns improving enrichment and raising pigs with longer/intact tails.

Further points about chains

Several potential design problems of the branched chains may need attention. For example, Telkänranta et al. (2014a) reported some pen **soiling** when a branched chain was installed on the solid floor. As a result they (i.e. we) moved the chains to the dunging area. However, that imposes a risk of disturbed eliminative behaviour and the end of the chain could go through the slats thus reducing its availability to the pigs. Also, the pen soiling on the solid floor was only an incidental observation in a particular type of pen with a relatively large proportion of flat (i.e. not concave) solid floor as is common in the Netherlands. In these pens I don't think pen soiling is a serious concern. Nevertheless, it can easily be found out and solved, even when branched chains were provided on a large scale, as chains can easily be moved when pen soiling starts. Another, partly opposite, design problem came from farmers objecting that the branched chains may be used so much by the pigs that it could **damage the floor**. Again, this problem should be solvable. However, if the problem would be so big that no protective floor cover can be found and that even periodic movement of the chains would not adequately prevent floor damage, then I would be tempted to suggest that rooting and enrichment apparently are so important that continued deprivation is no option either. Such problems can be anticipated but they should be solvable.

In **very large groups** 1 branched chain per 5 pigs may be too much. This is again something that remains to be confirmed. If so, superfluous chains are best replaced by adding destructible materials like destructible ropes, softwood logs, jute sacks and edible substrates. In large groups such supplements should be much more feasible, and highly recommended. Of course, they would be most beneficial to pigs in smaller pens too, but for reasons stated above, I don't know how they can be provided in a feasible and reliable way.

In **fully-slatted** pens efforts should be made to provide chains on the floor, e.g. by closing part of the slats (e.g. using a small cover). When the chain end is hanging over the slatted floor, it will generally be inaccessible, or only with difficulty, and it may easily get out of reach of the pigs. When it is not possible to provide (some) solid flooring or when chains cannot rest on the floor (e.g. due to abrasion), measures may be needed to compensate for the loss of enrichment value, e.g. by supplying two extra chains for every 'lost' floor chain. This should ensure that the alternative is certainly not worse than the basic requirement. Perhaps it is possible to have the longest chain end resting on the slats for a couple of links. Alternatively, the chains may be altered such that they cannot drop or get stuck between the slats. For example, a bolt may be attached to the end of the chain, but care should be taken that the end of the chain remains interesting to the pigs. Alternatively, slats (esp. metal slats) can sometimes be used to attach a piece of chain that is allowed to slide up and down. Pigs can get fascinated by such provisions.

I think they are best **hung** at the (top of the) pen wall. I see no specific reason to always hang them away from the wall (as is prescribed by law in Belgium, for example (Varkensloket, 2014)), and I expect that the extra costs of such provision may better be invested in additional chains, providing better access and less disturbance of lying behaviour.

Observations on chains hanging from the ceiling seem to vary (De Grau et al., 2005; Wind, 2012). Pigs may bump into free hanging materials and I have seen pipes and wood hanging away from a pen wall inducing frustration, e.g. by obstructing visibility or movement between different functional areas like feeding, dunging and resting.

However, **movement** of the enrichment material itself is known to elicit the pigs' interest, and it will stimulate the pigs to interact with the chain when it is moving, e.g. by hanging a bit away from the pen wall or because the pigs in an adjacent pen are making the chain move.

Chains in the **dunging area** should be avoided as it may disturb eliminative behaviour and lead to pen soiling (Zonderland, 2007). Providing chains at or **near the feeder** or feed trough may benefit welfare as it may facilitate redirected behaviour when access to the feeder is blocked by a feeding pig or when food is anticipated but not available yet. However care should be taken to avoid chains interfering with feed intake, and vice versa, e.g. by blocking access to the feeder, or submissive pigs playing with a chain being chased away by a dominant pig on its way to the feeder (see also Parmentier (2007)). Hence, chains near the feeder need to be provided prudently and must be monitored carefully.
A circular chain (around a pen wall) with **large rings** did not lead to rooting movements (i.e. pushing the chain upwards by placing the nose in the rings), but it was used a lot because it also had multiple branches that could be used for manipulation.
An advantage of the branched chain over the provision of other 'rootable' objects, like stones provided loose on the floor, is that the chain on the solid floor won't get out of reach, and chains can't be swallowed with perhaps some risk of intestinal obstruction.
Much trial and error may be needed to find the best location and mode of suspension, and in part, optimised solutions may turn out to be **farm specific**.

The new EC guidelines

The branched-chains proposal formulated in the previous section translates into the following interpretation of Article 4 of the Annex of Directive 2001/93/EC:
All pigs must have permanent access to at least (i.e. at the very minimum) 1 branched chain with 3 anchor-chain ends (5-10 links, 7mm for growing-fattening pigs, 5-6 mm for weaners, 4-5 mm for piglets, 8 mm for sows) for every 5 pigs (a sufficient quantity) to enable, whenever a single pig prefers (i.e. at any time of day or night, and with chains spaced apart so as optimise accessibility, i.e. providing literally "permanent access"), at least some (though still suboptimal level of) biting and chewing in both the standing, sitting and lying positions as well as allowing at least some (though still suboptimal level of) floor-directed rooting on the end of the branched chain which is lying on a solid part of the floor (i.e. near proper investigation and manipulation activities). Since branched chains constitute only nearly proper enrichment according to international pig welfare experts (Bracke, Submitted) branched chains are to be allowed only in a limited number of pig pens, serving exclusively as a negative control for the purpose of developing better enrichment (and only until a better alternative standard has been found). All other pigs should have access to substantially better enrichment than the branched chain design, i.e. material that has been shown scientifically to be at least significantly better in terms of providing a longer duration of overall occupation and/or reducing pathological biting behaviours (tail, ear, flank, leg biting and cannibalism), such as has been shown (or is reasonable to expect) scientifically for materials such as long straw loose on the floor (e.g. at least 20gr/weaned pig/day), plenty of hay or other roughage, fresh, soft wood of easily biteable and destructible dimensions and presentation (such that it must be renewed at least every 1-2 weeks), a thick layer of non-dusty sawdust as bedding, mushroom compost, sufficiently moist peat or a mixture of such (SVC, 1997; Bracke et al., 2004a; Bracke et al., 2006; Bracke et al., 2007a; EFSA, 2007a; 2007b; Spoolder et al., 2011; EFSA, 2014), which does not compromise the health of the animals (after EC (2001)).

The EC Directive itself doesn't mention the metal chain. It specifies as proper enrichment "*straw, hay, wood, sawdust, mushroom compost, peat or a mixture of such*" (EC, 2001). When provided properly, as is generally done in scientific experiments, these materials are undoubtedly superior to the branched chains. However, farmers generally don't provide enrichments as optimally as scientists tend to do.

The Commission identifies suboptimal materials, which should be combined with other materials and may be provided when bedding is not possible. Examples include compost, peat, wood shavings, stones, straw rack, paper, pellet dispenser, soft wood, hessian sack, rope and straw briquette. Each of these materials may have problems. For example, I have tried providing stones loose on the floor. They didn't reduce tail biting and easily got out of reach of the pigs. Pellet dispensers easily get blocked, and farmers are not always keen on providing proper maintenance.

The Commission's guidelines, however, are a good initiative, but they should be specified further, legally binding and they should be enforced, so as to secure a level playing field in Europe. If a farmer, for example, uses finely chopped straw or presses the straw tightly in a straw rack, uses too narrow rack openings, or hangs the rack too high or otherwise difficult to reach (e.g. in a swinging basket), the benefits of straw may be offset by the frustration it induces. In pig pens I have observed hanging soft-wood logs being too large to be bitten, effectively resulting in bite attempts indicative of frustration rather than enrichment. This was also shown in our unpublished research where both wooden logs and straw briquettes seemed to result in very short interaction bouts indicative of frustration and competition. Another problem may arise when the optimal or suboptimal materials mentioned in the guidelines are provided in a more suitable way, i.e. as destructible and thus consumable form. For this implies frequent maintenance and regular or irregular renewal. It is also very difficult, if not impossible, to verify or enforce compliance. Materials like wood, rope, jute and straw may also have some biosecurity risk, e.g. when materials are used across batches, and wood may perhaps cause pain due to splintering. Without mindful implementation, careful monitoring and critical examination these risks may go undetected, thus compromising the objective of the guidelines to improve pig welfare in accordance with the Directive. Please note I am not at all opposed to the use of (most of) the destructible materials and substrates mentioned in the Directive, as long as they are used in a way that benefits the pigs.

For these reasons, I would personally recommend that the on-farm implementation of the EC Directive starts with the widespread provision of branched chains as specified above. In my view it is the most feasible thing that can be done. It is also the most certain measure that can be taken to substantially improve pig welfare across the entire sector. In fact, I personally believe it is the only morally right thing to do, thereby ending possible misperceptions among the general public about pig enrichment. In fact I propose that the branched chains are not to be regarded as an alternative to the guidelines, but as a supplement.

Furthermore, branched chains should be available as a benchmark of what is proper enrichment. In other words, branched chains should be installed in matched control pens in order to confirm that alternative materials, e.g. those suggested by the guidelines, are at least as effective in maintaining the pigs' interest and/or in reducing tail biting.

On-farm student observations have already confirmed the relevance of this proposition. Weaners provided simultaneously with a bundle of chains hanging till floor level, a (rather big) wooden plank, a rope and a flexible rubber toy (piece of hanging rubber mat), interacted about three times more with the chains than with the other materials. Also, fattening pigs simultaneously provided with a short chain and a rope with a flexible rubber flap interacted more often with the chain than with the rope-and-rubber. The rope-and-rubber was virtually indestructible, whereas the chain was a 'proper' stainless steel anchor chain reaching about 20 cm closer to the floor than the rope-and-rubber (52 and 33 cm respectively) (Ettema, 2010a). In these examples, the new guidelines may have approved of the wrong set of materials as in fact the chains were used more than the wood-rope and the rope-rubber combinations. Note that this problem may occur in welfare schemes as well, because of the premium it generates. Thus, branched chains provide a most useful benchmark and starting point for further implementation of the guidelines and welfare schemes on commercial farms in a way that will really benefit the pigs.

Down the road

Providing occupation as specified by the EC Directive is the primary purpose of the requirement to provided proper investigation and manipulation materials. In addition, the practice of routine tail docking must come to an end as soon as possible. Tail biting, as well as other forms of harmful social behaviour, must be prevented, and, when it does occur, it must be treated effectively. Since the effectiveness of branched chains to reduce tail biting is largely unknown and expected to be limited, the branched-chain proposal must at best be regarded as an absolute minimum level of enrichment. In addition, it is most useful both as a benchmark and starting point for further improvements.

With a view of reducing abnormal behaviour, research has been indicating that quite some straw may be needed to fully satisfy the pigs' need for exploration. Pedersen et al. (2014) reported that pigs required almost 400gr/pig/day to reduce penmate-directed behaviour. Permanent access to straw (>500 gr/pig/day) also reduced gastric ulceration (7 vs 33%) (Herskin et al., 2015). Similarly, Bodin et al. (2015) reported increased straw-directed behaviour with increasing amounts of straw up to 200 gr/pig per day, and decreased levels of pig-directed behaviour. In some cases, however, e.g. in high-health herds, much smaller amounts of straw may be sufficient. For example, Zonderland et al. (2008) reported that 20 gr/pig/day provided as long straw twice daily loose on the floor substantially reduced tail biting in undocked weaners kept at an SPF barn. A recent EC report mentions a Swedish farm providing about 30gr/pig/day to successfully keep pigs with intact tails (EC, 2016c) (see also similar Finnish experiences in EFSA (2014)). Noteworthy other, more feasible materials to reduce tail biting include (plenty of) fresh wood (Telkänranta et al., 2014a) and jute sacks (Ursinus et al., 2014b).

However, tail biting is a multifactorial problem, and merely providing proper enrichment is probably often not sufficient to keep tails intact. Other aspects of pig husbandry like climate control, feeding, social conditions, genetics and space will need attention too (EFSA, 2007b). This may not be easy.

Since intensive pig farmers have shown to be able to do what was previously considered impossible, namely to drastically reduce the use of antibiotics (EMA, 2016), they may be given a chance to solve this chronic welfare problem as well, provided this is evidenced by action and progress, rather than mere words and an expression of the best of intentions.