Institution: University of Glasgow

Unit of Assessment: Unit 6, Agriculture, Veterinary and Food Science

Title of case study: Improvements in egg quality and hen welfare have enhanced productivity in the egg industry

1. Summary of the impact

Key findings of two University of Glasgow research programmes have transformed the UK egg-laying industry, driving substantial improvements in productivity and bird welfare. First, two of the largest international poultry-breeding companies adopted an innovative new tool for assessing eggshell quality that was validated by University of Glasgow researchers. This tool has improved eggshell quality through selective breeding, with increased numbers of undamaged saleable eggs (saving approximately £10 million annually in the UK alone), as well as enhancing the hatchability of breeding stock eggs. Second, University of Glasgow research on the long-term health and welfare implications of infrared beak trimming influenced UK policy debate, preventing a ban on beak trimming (due to be enacted in 2011) that would have exposed 35 million laying hens to potential pecking injury or death, as well as costing the industry an estimated £4.82–£12.3 million annually.

2. Underpinning research

The Institute of Biodiversity, Animal Health and Comparative Medicine at the University of Glasgow is one of the few UK institutes that contribute specialist research in poultry science directly to the poultry industry. This research is directed by Dr Maureen Bain (Lecturer, 1990–2006; Senior Lecturer, 2007–present) and Dr Dorothy McKeegan (Senior Lecturer, 2005–present).

Validation of a novel measure of eggshell quality

Cracked and damaged eggs account for 8–10% of total global egg production, which was 64 million metric tons (over 1000 trillion eggs) in 2012, resulting in substantial economic loss. For the UK alone, this could amount to a yearly loss of £53.6 million. Cracked eggs also pose a risk to food safety, and may adversely affect hatching, thus reducing chick output. For decades, poultry-breeding companies used laboratory-based measurements, such as shell-breaking strength and non-destructive deformation, in their selective breeding programmes to improve eggshell quality. Although such traits are heritable, none has been proven to influence the rate of egg breakage that occurs during routine handling.

During the late 1990s, a test was developed at Leuven University, Belgium, to detect both cracked eggs and those at risk of cracking. This test evaluates the acoustic vibration response of an egg when subjected to a non-destructive impact generated by a lightweight hammer making contact as the egg rotates around its long axis, providing a measure of the ability of an egg to dampen vibration ('dynamic stiffness' or K_{dyn}). However, for this text to be useful to the poultry industry, the heritability of K_{dyn} and its value for predicting egg breakage during routine handling first required demonstration. Between 2001 and 2004, as part of the European Union (EU) project 'Egg Defence', Bain and her team collaborated with Dr Ian Dunn (Roslin Institute, UK), researchers at Leuven University and Lohmann Tierzucht GmBH (a primary breeder of egg-laying hens). Two studies investigating K_{dyn} were proposed and led by Bain and Dunn.

The first study, conducted between 2002 and 2003, showed that K_{dyn} has a moderately high heritability (i.e. the trait will respond directly to genetic selection) and correlates positively with other eggshell quality measures, such as breaking strength and thickness (which can only be determined by destroying the egg).[1] Bain measured the eggshell quality data of 3,000 eggs from a pedigree population provided by Lohmann Tierzucht, comprising 1,500 offspring derived from mating 32 sire with 240 dams. Dunn conducted the statistical modelling and calculated the heritability and genetic correlation for K_{dyn} from Bain's data and values provided by Lohmann Tierzucht.

The follow-up study (March 2004) established that K_{dyn} can identify 'risky' eggs.[2] A field study was set up by Bain in collaboration with Scottish egg producer Glenrath Farms Ltd., who provided full

access to their production unit and grading equipment. The statistical analysis was performed by the team at Roslin. Of 1,660 eggs measured before and after passing through the collection and grading equipment, those with higher K_{dyn} values were significantly less likely to be cracked. Therefore, University of Glasgow research played a key part in validating K_{dyn} as a useful tool for selecting hens with superior eggshell characteristics, and in demonstrating that this measure reflects susceptibility to cracking during routine handling.

Contribution statement from B. De Ketelaere and J. De Baerdemaeker, Leuven University: "*Our group has performed quite extensive research into [K_{dyn}], and collaborated with Dr. Maureen Bain in order to gain more insight, not only into its relation to breakage in practice, but also with respect to its heritability. This research was published jointly with the group of Maureen [Bain] taking the lead. We believe that both aspects, for which credit goes to Maureen [Bain], have triggered the wide interest in the AET [Acoustic Egg Tester] by major poultry companies worldwide.*"

Determining the consequences of beak trimming

Injury caused by bird-on-bird pecking affects laying hens in both intensive (cage) and extensive (barn and free-range) systems, and is a major welfare and economic issue. Commercial egg producers use beak trimming to minimise such damage, which can result in the loss of breeding stock and egg production. However, beak trimming can potentially cause loss of normal beak function (reduced ability to feed, drink and preen), and short-term or chronic pain and debilitation.

Beak trimming was traditionally performed by hand, using a hot blade to simultaneously cut and cauterise the beak. In 2008, McKeegan characterised the physiological response of birds to infrared beak trimming. This procedure uses a high-intensity infrared energy source, which is localised, non-contact and can be automated. This research – jointly commissioned by the Department for Environment, Food and Rural Affairs (DEFRA) and the British Egg Industry Council (BEIC) – assessed the chronic sensory (i.e. welfare) consequences of infrared beak trimming.[3] Beak nerve function and anatomy were examined at a range of ages in both trimmed and non-trimmed birds by: (i) recording the responses of single sensory nerve fibres that provide sensation in the lower beak and (ii) by detailed microscopic and X-ray measurements of beaks. The results suggested that infrared trimming does not cause chronic pain or other adverse consequences for sensory function, such as neuromas (pain and abnormal sensations generated by bundles of nerves). The beaks of birds across all age groups tested had full sensation with no evidence of pain or numbness, even in regrown beak tips. Examination of beak healing showed nerve regeneration and the presence of specialised touch receptors by 10 weeks after infrared trimming.

This research provided evidence that infrared beak trimming represents a refinement compared with previous approaches and that the welfare cost of beak trimming (acute pain and some on-going loss of sensation) might be outweighed by the benefits (reducing suffering and mortality of injured laying hens; fewer hens injured or lost from bird-on-bird pecking).

3. References to the research

1. Dunn, I.C. *et al*. (2005) Heritability and genetic correlation of measurements derived from acoustic resonance frequency analysis; a novel method of determining eggshell quality in domestic hens. *Br Poult Sci*. 46, 280-286. doi: 10.1080/00071660500098574
2. Bain, M.M. *et al*. (2006) Probability of an egg cracking during packing can be predicted using a simple non-destructive acoustic test. *Br Poult Sci*. 47, 462–469. doi: 10.1080/00071660600829233.
3. McKeegan, D.E.F. and Philbey, A.W. (2012) Chronic neurophysiological and anatomical changes associated with infra-red beak treatment and their implications for laying hen welfare. *Anim Welfare*, 21, 207–217. doi: 10.7120/09627286.21.2.207.

Grant funding

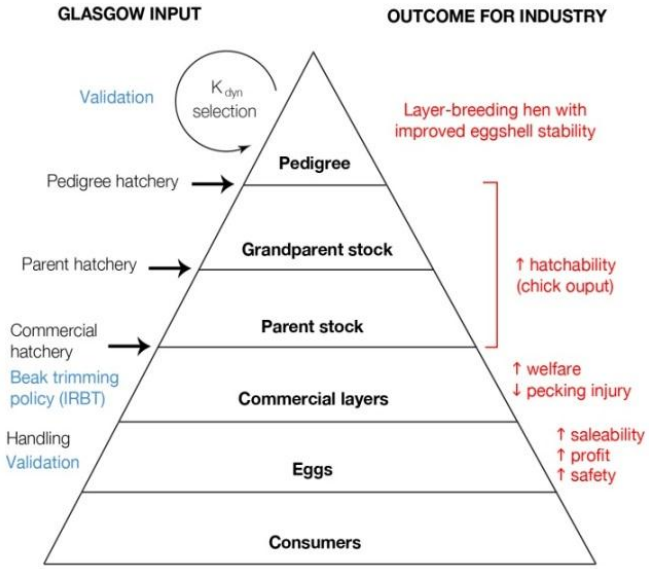
i. 'Egg defence' (2001–2004) EU 6th Framework Programme Priority 5: QLRT-2000-01606. Partner Work package 1, 6, 7 and 9 (£94,875); total value of project €2.6 million.

ii. Chronic neurophysiological and anatomical changes associated with infra-red beak treatment (2008–2009) DEFRA - Science Directorate and British Egg Industry Council (£39,167)

4. Details of the impact

There are approximately 35 million laying hens in the UK, which produced 9.3 billion eggs in 2012 with an estimated retail value of £957 million. The industry operates a pyramid distribution (Figure 1) with the upper levels being the 'layer-breeders', whose eggs are fertilised and hatched. These include pedigree birds selected for desirable characteristics, such as egg dynamic stiffness (i.e. the K_{dyn} metric tested by Bain). From these birds, the great-grandparents and grandparents are bred to create the parent stock, which are distributed around the world. It is the progeny of these birds, the commercial stock, that produce eggs for the table.

The combined research of Bain and McKeegan has contributed substantially at key levels within the layer industry (highlighted in Figure), to improvements in eggshell quality and hatchability and to positive legislative change that affects the welfare of UK commercial laying flocks. These contributions have led to substantial improvements in productivity, including better eggshell quality, higher chick output and decreased incidence of pecking injuries, as described below.



Improving eggshell quality

As a result of Bain's validation of a novel tool for assessing eggshell quality, several international specialist layer poultry-breeding companies are using the measurement of K_{dyn} in their breeding programmes. These include Lohmann Tierzucht GmBH,[a] a German-based breeder that holds a 30% share of the world laying market; and Hy-Line International,[b] a US-based breeder that holds 45% of the world market and 85% of the US market (the second largest egg-producing market in the world). Since 2008, both Lohmann Tierzucht and Hy-Line have tested all breeding selection candidates for K_{dyn} in all four of their pedigree lines for white and brown egg stocks,[a,b] with Lohmann using the technology on more than 20,000 pedigree birds annually. The process from selection of pedigree birds using K_{dyn} to commercial egg production takes approximately 3 years; thus, table eggs with improved stability have been available on the market since 2011.

To poultry companies such as Lohmann Tierzucht, the benefit of improved egg quality is not only relevant to commercial layers, but also benefits the breeding sector because eggs with better shell quality have improved 'hatchability', leading to a higher chick output.[a] Lohmann Tierzucht also claim that "*Eggs from birds with better DS [dynamic stiffness] achieve a better revenue through higher percentage of saleable eggs in relation to total eggs produced,*" citing 2% fewer egg seconds depending on the age of the flock.[a]

Both companies have UK subsidiaries supplying substantial shares of the UK market, with Lohmann GB (36%) and Hy-Line UK (30%) accounting for 66% of all day old chicks.[a,b] Both companies use a single hatchery, Millennium Hatchery in Warwickshire, owned by Hy-line UK. The hatchery produces infrared beak-trimmed/vaccinated day-old chicks that are transferred to rearing farms for 16 weeks, after which they go into commercial layer egg-production farms. Between them, Lohmann GB and Hy-Line UK are responsible for some 22.4 million of the 34 million laying hens in the UK, all of which will have been selected for improved eggshell quality on the basis of the K_{dyn} measure, and which are capable of producing in excess of 310 eggs per bird per annum with an annual packer-to-producer value of approximately £500 million. Therefore, the estimated 2% fewer egg seconds claimed by Lohmann incorporating K_{dyn} into their selection programs will have saved up to £10 million per annum to UK egg producers alone.

Influencing UK policy on welfare and productivity of commercial laying flocks

Between 40% and 80% of the 35 million laying birds in the UK are subject to injurious bird-on-bird pecking, which can escalate to cannibalism, causing up to 20% mortality.[c] To minimise this risk, every hen hatched by Lohmann GB and Hy-Line UK, and intended for the commercial production of eggs with improved eggshell quality, has its beak trimmed using infrared technology before leaving the hatchery. Carefully managed breeding programs and investment in improving eggshell quality is intrinsically dependent on the welfare, and therefore productivity, of layer hens. DEFRA has estimated the economic benefit to the egg industry of birds not being injured or killed (bird-on-bird) could be anywhere between £4.82 and £12.3 million per annum.[c]

However, an EU directive (1999/74/EC) outlining the minimum standards for keeping egg laying hens had also prohibited all mutilation, and the UK enactment of this legislation – including a ban on beak trimming by any means – was due to be implemented on 1st January 2011. In 2007, the Farm Animal Welfare Council advised the government of the implications of this ban, recognising the greater welfare issue of pecking injury and the lack current UK practice to prevent it if the ban went ahead.[d] McKeegan's research, commissioned by DEFRA and the BEIC in 2008, was instrumental in the UK Government's decision not to go ahead with the ban on beak trimming. The findings were presented to DEFRA in March 2009,[e] and considered by the Farm Animal Welfare Council.[f] The findings were then summarised in a wider consultation,[g] between January and April 2010, which was circulated to 79 poultry industry stakeholders, including industry representative bodies, animal welfare groups, veterinary associations, Government agencies, academic institutes, consumer groups and retailers.

The new draft regulations 'Mutilations (Permitted Procedures) (England) (Amendment) Regulations 2010' were presented to the Joint Committee for Statutory Instruments by DEFRA in November 2010, together with an explanatory memorandum explaining the evidence base, citing the Glasgow research.[h] On 7th December 2010, the amendment was debated by the First Delegated Legislation Committee. Mr Plaice (Minister of State for DEFRA) stated: "*the researchers believe infrared was the least painful method. I have said in my opening speech that we accept that it does cause pain. We do not believe that it causes chronic pain; the research at Glasgow demonstrated that even if neuromas are present, they are not functioning.*" The committee voted to extend the use of routine beak trimming of laying hens, but restricted the method used to the infrared technique only.[i]

The new amendment came into force on 23 December 2010, preventing the ban, which was due to be implemented on 1st January 2011. Thus, McKeegan's research has resulted not only in the maintenance of improved welfare standards for laying birds, but also the avoidance of what would have been substantial economic losses for the industry had the ban gone ahead.

5. Sources to corroborate the impact

a. Statements provided by Managing Director, Lohmann Tierzucht GmbH; available on request.
b. Statements provided by Director of Research, Hy-Line International Ltd; available on request.
c. DEFRA Impact Assessment of an amendment to Regulations to allow beak trimming of laying hens by infra-red technology, January 2010 (para 8.6).
d. Opinion on Beak Trimming of Laying Hens, Farm Animal Welfare Council, November 2007.
e. Commissioned research report to DEFRA: Chronic neurophysiological and anatomical changes associated with infra-red beak treatment, AW1139 (March 2009).
f. Farm Animal Welfare Council letter to the Minister for Farming and the Environment (p.2, point 5).
g. DEFRA consultation on an amendment to the Mutilations Regulations (permitted procedures) (England) 2007 (January 2010) Glasgow cited (Para 10.7.2).
h. Draft legislation laid before Parliament (Joint Committee on Statutory Instruments): House of Commons and House of Lords, both on 8 November 2010.
i. Debates and committee voting: House of Commons (Delegated Legislation Committee), 7 December 2010; House of Lords (Grand Committee), 8 December 2010.