Economic challenges facing a global breeding company

Santiago Avendaño and John Ralph

Aviagen Group.
11 Lochend Rd, Midlothian EH28 8SZ, Edinburgh, Scotland-UK.
savendano@aviagen.com *(Corresponding Author)*

Summary

The main objective of a poultry meat global breeder is to deliver genetic potential suited to the wide range of commercial production systems and environments worldwide. Poultry meat is expected to contribute to over 40% of the 48 million tons increase of meat production globally by 2025. Poultry breeders have a central role in contributing to the challenge of producing affordable animal protein to a growing population in a global scenario of limited agricultural resources, emerging trends and economic challenges. These have a direct impact on the definition and evolution of breeding goals and the gene flow from the breeding programme to the wider industry. Breeding goals including both environmental and animal welfare sustainability will keep expanding and becoming more complex to accommodate new market and societal requirements. This paper explores how a global poultry breeding company positions itself in the above scenario in terms of breeding goal setting, investment in Research and Development (R&D), product portfolio evolution and safeguarding the health status of high generation stock globally.

Keywords: Avendano S, Ralph J, poultry, breeding, economic, challenges

Introduction

The main objective of a poultry meat global breeder is to deliver genetic potential suited to the wide range of commercial production systems and environments worldwide. This is of special relevance given the predicted preponderance assigned to poultry meat in terms of both production and demand in the near future. OECD/FAO (2016) forecasts that by 2025 global meat production and consumption are to increase by 48 million tons, with poultry meat contributing to 44% to the total production growth and being equivalent to the additional growth of all other meats. In addition, a striking 65% of the increase in additional poultry production is expected to come from developing countries while at the same time, the increase in consumption is expected regardless of region and income levels globally. This very positive global outlook represents a great opportunity from a breeding perspective, but it is against the backdrop of significant global constraints, emerging trends and economic challenges. These have a direct impact on the definition and evolution of breeding goals and the gene flow from the breeding program to the wider industry. This paper explores how a global poultry breeding company positions itself in the above scenario in terms of breeding goal setting, investment in Research and Development (R&D), product portfolio evolution and safeguarding the health status of high generation stock globally.

Global Constraints and Emerging Trends

Constraints

Biosecurity and disease challenge. Biosecurity is a condition *sine qua non* in global poultry breeding. Any breeding program must commit to deliver genetic stock free of transmissible diseases including Mycoplasmas, Salmonellas and Avian Influenza (AI). Strict biosecurity procedures must be in place for disease prevention and thousands of serology and bacteriology samples are analysed annually to ensure freedom from Salmonella and Mycoplasma. Avian Influenza represents the single most significant disease challenge, risk and threat to the poultry industry globally which in recent years had serious consequences to poultry trade and the poultry industry leading to the destruction of millions of domestic birds across the world (OIE, 2017a). In addition, while most AI viruses do not affect humans the current circulation of various strains (H5N1, H5N2, H5N8, H7N8, H7N9) means that AI outbreaks continue to be a global public health concern (OIE, 2017b). Breeders therefore need to protect their valuable elite stock from transmissible diseases. Replicated breeding programs and high generation multiplication operations which are separated geographically are major financial investments but essential to provide line security and ability to continue market supply. Further, compartmentalisation (OIE) is a key strategy to recognise the special health status of elite breeding stocks as sub-populations independently from the health status of the region or country in which the breeding program resides. In 2011, Aviagen was the first poultry breeding company to achieve compartment status recognised by a government body allowing greater security of supply worldwide. Maintaining a free of transmissible diseases status is very costly, but it is an essential part of operating a sound breeding program.

Global Sustainability. The well-known concerns about future population growth, the availability of natural resources (e.g., agricultural land and water) and the environmental impact of livestock production puts sustainability at the top of the breeding agenda. Improved feed efficiency is a key driver of higher productivity, better resource use and lower greenhouse gas emissions in livestock production (Herrero *et al*, (2013). In poultry production, feed accounts for at least 70% of production costs so continued improvements in biological efficiency are key not only for short term profitability of the producer's business but also for continued growth of the poultry industry and success of the breeding company. The realised genetic improvement in chicken biological efficiency is well documented. Both, experimental work comparing selected and unselected populations and industry data are conclusive of the long-term improvements in broiler chicken biological efficiency with yearly improvements ranging from 25 to 50 grs of bodyweight and 20 to 25 less feed required per kg of body weight (e.g., Fancher, 2014; Zuidhof *et al*., 2014; National Chicken Council, 2016). A moderate yearly rate of improvement of 15 grams less feed per kg of body weight can have significant impact improvements on agricultural land savings in the order of 400,000 hectares yearly (Neeteson *et al* (2013). Finally, due to better feed efficiency, conventional production systems and standard genotypes can yield 30% lower Global Warming Potential than free range, organic systems or slower growing breeds (Leinonen *et al*, 2012; Avendaño *et al*, 2017).

Emerging Trends. Breeders must constantly scan the market to detect changes in customer and consumer preferences, identify those which are likely to be long lasting, and adjust the breeding goals appropriately. Any lag in delivering genetic progress at commercial level presents a challenge when market developments are rapid. Maintaining large gene pools for product development is an essential investment to cater for changing market needs.

Welfare certification programmes. While broiler production and demand are growing globally, there has been an emergence of welfare certification schemes targeting thresholds for growth rates lower than 50 g/day and/or specific requirements regarding welfare attributes (e.g., 'Chicken of Tomorrow' and 'Beter Leven' in the Netherlands, 'Für mehr Tierschutz' in Germany, and 'RSPCA Assured' in the UK, '5 Step Animal Welfare Standard', Global Animal Partnership in USA). For a global breeder, this means the need for an enlarged and diverse portfolio of elite lines and commercial products to satisfy the whole spectrum of industry requirements. This ranges from conventional production systems, to cover the sheer scaling up of broiler meat production and demand globally, to emerging niche markets. Table 1 shows field biological performance adjusted to 2.5kg target live weight for seven Aviagen broiler genotypes ranging from conventional to a range of slower growth types. Ross 308 and 708 are well known and established commercial genotypes in the broiler industry worldwide. The remaining breeds are a range of slower growing genotypes which are part of Aviagen's Rowan Range (http://eu.aviagen.com/brands/rowan-range/) portfolio.

Genotype	ADG	Days	FCRadj	Evis%	Breast%	Liveability %
Ross 308	65.0	38.5	1.62	73.2	22.6	96.5
Ross 708	62.0	40.3	1.63	74.1	23.9	97.0
Ranger Classic	49.0	51.0	1.83	71.9	21.4	97.5
Ranger Premium	50.0	50.0	1.83	72.5	22.2	97.5
Ranger Gold	46.5	53.8	1.90	71.5	20.0	97.8
Rowan Ranger	43.5	57.5	1.99	70.8	19.1	98.0
Rambler Ranger	33.5	74.6	2.15	70.3	18.1	98.5

*Table 1. Biological performance of seven Aviagen genotypes to 2.5 kg live weight. ADG = Average Daily Gain; FCRadj = adjusted Feed Conversion; Evis% = Eviscerated Yield, (Eviscerated Weight/Live Weight*100);Breast%=Breast Yield,(Breast Weight/Live Weight*100).*

There are wide biological performance differences to reach 2.5kg between the fastest (Ross 308) and the slowest (Rambler Ranger) genotype: 31.5g per day for daily gain, 36.1 days to achieve the target weight and 0.53 kg feed per kg of live weight. Comparing with the highest yielding bird (Ross 708) the gap is 3.8% eviscerated and 5.8% breast yield. With a predicted yearly genetic rate of improvement of 0.025 (kg/kg) for FCR and 0.2% for Breast%, these performance differences, correspond to 21.2 and 29 years of genetic improvement, respectively. Importantly, in contrast with the wide differences in biological performance, the liveability differences between the fastest and the slowest genotype is only 2%. This is achieved by the use of balanced breeding goals combining biological performance and liveability and welfare related traits as explained by Kapell *et al* (2012 a,b) and Neeteson *et al* (2013) and will be addressed here. While there is no intrinsic antagonism between optimum biological efficiency and bird welfare, the balance will be driven by whether the market perceives sustainability as being driven by environmental impact or by welfare. While a broad portfolio of commercial genotypes is required to cover the needs of the wide range of market requirements and specifications niche markets need to be securely established and of a scale to support the additional cost of developing and supplying an appropriate breed.

Antibiotic free production. There is an increasing concern about antimicrobial resistance in humans and a possible link with antimicrobial use in livestock. Contrary to predicted increases of antimicrobial usage in livestock globally (Van Boeckel *et al*., 2015) both the European and USA poultry industry have already made significant reductions in the use of antibiotics. Since 2006, antibiotic growth promoters (low doses of antibiotics that are not suitable for therapeutic use) have been banned in Europe since 2006. The UK reports 71% antibiotic usage reduction (BPC, 2017) while in the USA about 40% of poultry is raised without antibiotics or ionophores. Aviagen has operated breeding programs without prophylactic antibiotic use since the early 90's. Good biosecurity, good disease control, access to high quality vaccines and good gut health all contribute to sustaining breeding programs without a requirement to use antibiotics. The development of breeds for antibiotic free production requires a high focus on traits related to liveability and robustness. Understanding gut and immune function will be paramount, in particular the link between gut function and nutrient absorption. In this scenario, there is a clear link between sustainability through biological performance and welfare through robustness and liveability.

Evolving customer value drivers. Consumer value drivers are shifting, such that in addition to price, purchase decisions are influenced by a much broader range of product features. Consumer trends in the US show that while historically consumers made purchase decisions based on 'Traditional Drivers' (price, convenience and taste), a new set of 'Evolving Drivers' (ED) including Health and Wellness, Safety, Social Impact, Experience and Transparency are now influencing consumer purchase decisions (Ringquist *et al,* 2015). This study showed that about 50% of the purchase decisions were influenced by ED independently from region, age and income level. Some of the ED will be more related to retail aspects (e.g., product safety), but social impact and health and wellness, have a direct link with breeding goals through sustainability, animal welfare and reduced use of antimicrobials, respectively. While there were no equivalent figures for other regions of the world, it would be rather safe to assert that this trend of ED influencing product purchase is growing globally, in particular the more affluent parts of society. The increased prevalence of these ED in purchase decisions makes transparency through the whole product supply chain a requirement, as clearly and very fairly, consumers want to know more about their food, where it comes from and how it is produced. Breeders contribute to the required transparency throughout the industry by informing the wider society of the improvements being made through selective balanced breeding and subscribing ISO certifications and to codes of good practice (CODEEFABAR, 2017).

Impact on breeding goals

Poultry meat breeding goals have expanded enormously over the last 50 years from being focused mainly on productivity during the 50's to multi-dimensional breeding goals including much higher weights given to efficiency (productive and environmental), robustness (including welfare and liveability), environmental adaptability and product quality (Neeteson *et al*, 2013). The inclusion of welfare related traits in chicken and turkey breeding goals is not a new feature. Welfare related traits include skeletal support (clinical and sub-clinical leg health and locomotion), contact dermatitis, cardiovascular function and liveability. Antagonisms with production traits (e.g., live weight and yield) are dealt with within a selection index framework using knowledge of the relevant genetic correlations (Kapell *et al*., 2012a,b; Hiemstra and Napel, 2013 and Kapell *et al*., 2017). Neeteson *et al* (2013) illustrated how growth rate and leg strength can be improved simultaneously over the long term while the antagonistic genetic relationship between both traits holds within a year. Figure 2 extends their approach to include 22 years of Aviagen breeding program data showing the joint trajectory between live weight and leg strength and cardiovascular function.

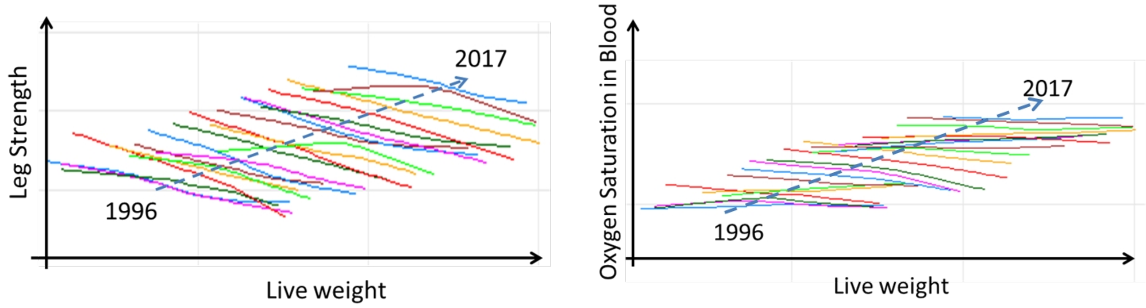

Figure 2. Long term relationships between Live Weight and Leg Strength (%) and Oxygen Saturation in Blood. Each coloured line represents the relationship between breeding values for each trait within a year. The broken arrow represents the joint direction of the average breeding value for each trait involved in the trade off.

Each coloured line shows the relationship between the traits' breeding values for selection candidates hatched in a specific year. The broken arrow represents the joint direction of the average breeding value for each trait involved in the trade-off. This illustrates how antagonistically related traits can be improved simultaneously if they are included within a multi-trait breeding goal and balanced selection is applied.

As poultry production expands globally, genetic potential is expressed in a multitude of production systems and geographical conditions highlighting the need of handling genotype by environment interactions (GxE) effectively. Aviagen uses a sib testing strategy in both chicken and turkeys in which selection candidates are typically recorded in high-bio secure and high-input environments aiming to maximise expression of genetic potential, while sibs are tested in a low input environment with an emphasis on robustness including gut health, digestive, and immune function along with liveability, growth, and uniformity. Figure 3 illustrates the GxE for broiler live weight and feed conversion rate at 35d. The high and low input environments represent the top and bottom quartile of the environmental production conditions, respectively. While there is a positive correlation between breeding values across both environments of around 0.6-0.7, it is clear that the same biological trait should be handled as two different genetic traits to account for the GxE.

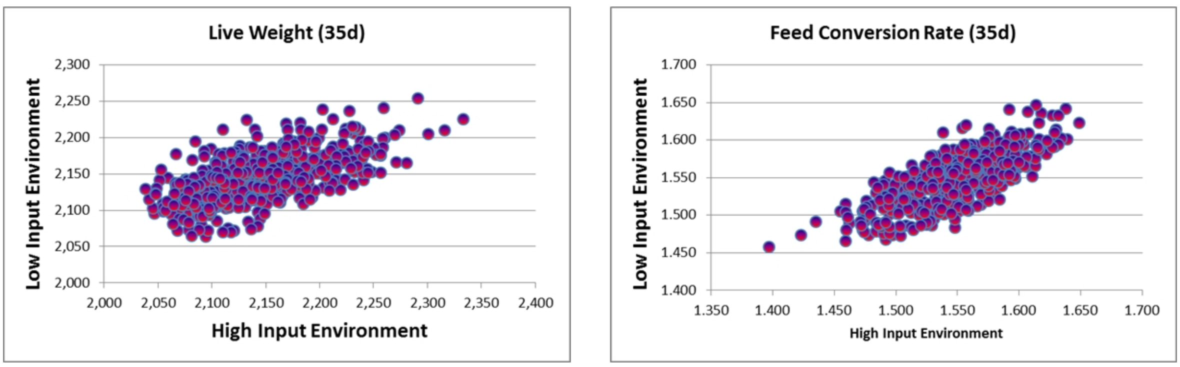

Figure 3. Estimated Breeding Values for broiler Live Weight (kg) and Feed Conversion Rate

(kg Feed/ kg Live Weigh) at 35d for a High and Low Input Environment.

In this example, the maximum absolute difference between both environments is about 250 grs for live weight at 35 days and 70 grs for feed conversion rate which are indeed biologically significant differences. This highlights the need to record the breeding goal traits in the relevant set of environments in which the commercial product will express its genetic potential which inevitably adds to the cost of recording and running the breeding program. Breeding goals will undoubtedly keep expanding to capture the current and future changes in global trends and feedback from customers, wider stakeholders and society. This just means more balanced progress for more traits, as a result of a continual evolution in the definition of balanced breeding! Future breeding goals will become increasingly complex: more traits, multiple trait antagonisms and multi-environment trait expression. This extra complexity is not at odds with the sustainability of long-term genetic response. Hill (2016) concluded that continued genetic responses for production efficiency while minimising demand on resources without sacrificing animal health and welfare are feasible within a multi-trait selection set up including both fitness and production traits.

R&D Investment – keeping up the pace with science

Investment in R&D and a long term view in line with product development are fundamental requirements for success in the global breeding business. Research investment carries a risk and whatever the subject is, from novel phenotypes or analytical techniques for predicting breeding values, the focus must be on breeding program implementation directly linked to field product performance. Figure 4 shows an arbitrary representation of the technology adoption opportunities and risks. The left panel summarises the so called 'Hype Cycle' (HP) by Gartner (1995) used for representing the maturity, adoption and social application of specific technologies. The HP is a conceptual presentation of the maturity of emerging technologies through five phases: i. technology trigger, ii. peak of inflated expectations iii. trough of disillusionment, iv. slope of enlightenment, v. plateau of productivity. This profile could also apply to breeding technologies and techniques. The use of Random regression to model longitudinal traits, Bayesian approaches for predicting breeding values and more recently the use of Genomics information have had their HP cycles. Usually, academia show the way forward by triggering the idea, there is a huge focus of interest reflected on research and publications, inevitably this is followed by a trough of disillusionment as practical feasibility conflicts with the postulated benefits. Finally there will be an extent of technological adoption and application to practical breeding which will vary depending on the feasibility and the investment required to incorporate it in routine breeding in an accurate fashion. The left panel in Figure 4 represents an arbitrary curve of technology adoption rate. Early successful adoption provides the greatest opportunities in terms of competitive advantage, but that comes linked to a greatest risk, cost and lower practical applicability potential. In contrast, waiting until the technology matures and becomes more affordable, represents lower risk and lower cost, but critically, limits potential competitive advantage. The key strategy is to articulate R&D investment using a combination of collaborative and proprietary funding so the timing of the implementation of novel technologies achieves the earliest and greatest benefits at the lowest possible risk and operational cost. A key point though, is that successful implementation comes only from within the breeding company.

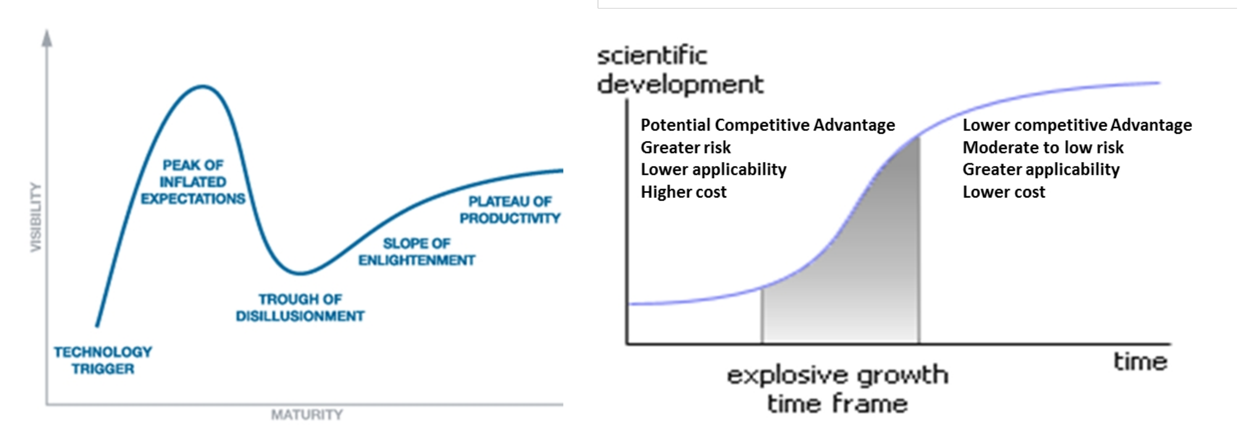

Figure 5. Arbitrary representation of a Technology Hype Cycle (right) and Rate of technological adoption (left).

The adoption of Genomics information in poultry deserves a specific mention. Poultry breeders went through several HP cycles, with significant expenditure and sequential ‘peaks of inflated expectations’ and ‘troughs of disillusionment’ while facing several technological hurdles in the pursuit of the postulated benefits of genomics information (Avendano *et al*, 2010, Avendano *et al*, 2012). Aviagen was the first poultry breeder to announce the introduction of genomic selection in routine broiler breeding (Aviagen, 2012), contributing with an extra 20-40% accuracy depending on the trait. Currently genomics is routinely used for breeding across broilers and layers (Wolc, *et al*, 2016) and Aviagen Turkeys since 2017. Genomics information for the purpose of breeding value prediction is now entering the ‘plateau of productivity’ of the HP cycle. Adoption is now generalised, the risk is lower but also the competitive advantage opportunities are more limited. Currently there are two novel genomics related technologies being put forward which inevitably dominate discussions and debates in academic forums and even beyond: Genotype by sequencing (GBS) and gene editing (GE). GBS is postulated as an alternative to SNPs with benefits like removing the ascertainment bias that is inherent to SNP arrays, and critically the capture of all the genetic variation including causal mutations and copy number variation. Our view is that GBS is at the peak of inflated expectations in the ‘HP’ cycle and it is very early to ascertain whether there are any realistic benefits in the short to medium term. GE is much trickier than GBS in the sense that it involves altering the naturally occurring genomics configuration to add/delete individual bases and/or DNA segments to achieve a specific phenotype. While there have been a few successful examples in both livestock (e.g., notoriously in pigs for porcine reproductive and respiratory syndrome virus, Whitworth et al, 2015) and plants (e.g., waxy corn, Pioneer, 2016) it is not clear whether GE will crystallize in applied breeding programs. In addition to the still significant scientific and technological questions, more critically, there is a huge level of uncertainty with regards to regulatory framework and public perception and acceptability. We would place GE just after the’ technological trigger’ and climbing the ‘peak of inflated expectations’. Time will tell whether GBS and GE materialise as tools for commercial breeding but at this stage perhaps the best approach is one of prudent expectation. Perhaps, the ideal timing for pursuing adoption of a new technique or tool is right after the ‘trough of disillusionment’ and at the beginning of the ‘slope of enlightenment’. In practical terms this will depend on the technology and the judgment call of the individual breeder.

Final considerations - the challenge of reclaiming value generated

Poultry breeders have a central role in contributing to the challenge of producing affordable animal protein to a growing population in a global scenario of limited agricultural resources. Breeding goals including both environmental and animal welfare sustainability will keep expanding and becoming more complex to accommodate new market and societal requirements. The ability to change and adapt and use R&D investment strategically and effectively will be key to future success. The cost base of maintaining modern poultry breeding programs will keep increasing and the economic survival of breeding companies depends on being able to reclaim a proportion of the additional value generated by the genetic improvement delivered. A clear understanding of the value generated by genetic improvement is crucially important to the economic success of a primary breeder. A poor understanding of the value forces breeders to compete on price alone resulting in pressure to reduce costs and limits their ability to invest in technologies required for further breed improvement. The net result is a loss of opportunity for producers and breeders and competitiveness of poultry meat production. A clear understanding of breed value and assistance for producers to utilise breed genetic potential and maximise value brings benefits to producers and breeders alike.

List of References

Avendaño, S., K.A. Watson, and Kranis A. 2010. In: Proc. 9th *WCGALP*. http://www.kongressband.de/wcgalp2010/assets/pdf/0049.pdf.

Avendaño, S., K.A. Watson, and Kranis A. 2012. In: Proc 24th WPC. http://www.facta.org.br/wpc2012-cd/pdfs/plenary/Santiago_Avendano.pdf.

Avendaño, S., Fancher B.I., Neeteson-van Nieuwenhoven, A.M. 2017. *Proceedings of the New Zealand Poultry Beyond 2030 Conference.*

Aviagen,2012. http://eu.aviagen.com/about-us/research-development/

British Poultry Council (BPC), Stewardship report, June 2017.

CODEEFABAR 2017. http://www.responsiblebreeding.eu/

Fancher, B.I., 2014. *Proceedings of the New Zealand Poultry Beyond 2020 Conference*.

Gartner .1995. http://www.gartner.com/technology/research/methodologies/hype-cycle.jsp

Herrero, M., Havlík, P., Valin, H., Notenbaert, A., Rufino, M.C., Thornton, P.K., Blümmel, M., Weiss, F., Grace, D., Obersteiner, M., 2013. *PNAS* 110 (52): 20888–20893.

Hill, W.G., 2016. *Genetics* 202: 887-881.

Hiemstra, S.J. and Napel, J.T., 2016. https://ec.europa.eu/food/sites/food/files/animals/docs/aw_practice_farm_broilers_653020_final-report_en.pdf

Kapell D.N.R.G., Hill W.G., Neeteson A.M., McAdam J., Koerhuis A.N.M., Avendaño S., 2012a. *Poult Sci* 91: 565–574.

Kapell, D. N. R. G., Hill, W. G., Neeteson, A. M., Mc Adam, J., Koerhuis, A. N. M., Avendaño S., 2012b. *Poult Sci* 91: 3032-3043.

Kapell D.N.R.G., Hocking P.M., Glover P.K., Kremer V.D. and Avendaño S. 2017. *Poult Sci*. 96 (6): 1553-1562.

Leinonen I, Williams A.G., Wiseman J., Guy J., Kyriazakis I., 2012. *Poult Sci* 91: 8-25.

National Chicken Council, 2016. http://www.nationalchickencouncil.org/about-the-industry/statistics/u-s-broiler-performance/.

Neeteson-van Nieuwenhoven, A.M., Knap, P., Avendaño, S., 2013. *Animal Frontiers* 3 (1): 52-57. http://www.animalfrontiers.org/content/3/1/52.full.pdf+html

OECD/FAO 2016. http://dx.doi.org/10.1787/agr_outlook-2016-en

OIE,2017a.http://www.oie.int/fileadmin/Home/eng/Animal_Health_in_the_World/docs/pdf/OIE_AI_situation_report/OIE_SituationReport_AI__6_8May2017.pdf

OIE, 2017b. http://www.oie.int/en/animal-health-in-the-world/web-portal-on-avian-influenza/

Pioneer,2016.https://www.pioneer.com/home/site/about/news-media/news-releases/template.CONTENT/guid.1DB8FB71-1117-9A56-E0B6-3EA6F85AAE92

Ringquist, J, Phillips, T., Renner, B., Sides, R., Stuart, K., Baum, M., Flannery, J., 2015. *Deloitte.*

Van Boeckel,T.P., Brower, C., Gilbert M., Grenfella B.T., Levina, S.A., Robinsoni T. P., Teillanta A. and Laxminarayanb, R. 2015. *PNAS* 112 (18) 5649-5654.

Whitworth K. M., Rowland R.R., Ewen C.L., Trible B.R., Kerrigan M. A., Cino-Ozuna A.G., Samuel M. S., Lightner J.E., McLaren D. G., Mileham A. J., Wells K. D. and Prather R.S. 2016. *Nat Biotech* 34 20–22.

Wolc, A., A. Kranis, J. Arango, P. Settar, J.E. Fulton, N.P. O'Sullivan, A. Avendano, K.A. Watson, J.M. Hickey, G. de los Campos, R.L. Fernando, D.J. Garrick, and J.C.M. Dekkers. 2016. *Animal Frontiers* 6:23-31.

Zuidhof, M.J., Schneider B. L., Carney V. L., Korver D. R. Korver, Robinson F. E. , 2014. *Poult. Sci.* 93 (12): 2970–2982. https://doi.org/10.3382/ps.2014-04291.