HOW GENETIC IMPROVEMENTS IMPACT ON MANAGEMENT AND HUSBANDRY

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Genetic Change

Genetic change over the last sixty years in broiler breeders has been achieved at an incredible rate with age to 2kg in the genetic stock of 2001 reducing by approximately 330% (31.4 vs 104.2 days) compared to the stock of 1957, whilst feed conversion ratio (FCR) to 2kg was reduced by 230% (1.48 vs 3.40). This equates to annual increases of 47g and -0.04 FCR points per annum, whilst mortality to a weight has remained broadly static (adapted from Havenstein et al., 2003a). At the same time meat yields increased as shown in Table1.

Table1. Estimated Carcass components of 1957 and 2001 genotypes fed the same diet at 2kg, (adapted from Havenstein et al., 2003b)

Carcass Component Weight	1957 Bird on 2001 Diet	2001 Bird on 2001 Diet	% Change
Carcass Weight (g)	1329	1399	5.26
Breast Meat Weight (g)	247	552	123.72
Leg and Saddle Weight (g)	614	848	37.96
Wing weight (g)	183	216	18.06
Heart Weight (g)	9	13	44.59
Lung Weight (g)	11	14	24.92
Abdominal Fat Weight (g)	42	37	-11.90
Carcass Fat Weight (g)	370	382	3.12
Ash weight (g)	55	62	13.03

This data demonstrates that whilst the key trait of interest to Western consumers (breast meat), has greatly increased that there is no evidence of loss of core support traits such as cardiovascular function or bone mineralization. Carcass yield was shown to have increased by 0.08% per annum; while breast meat and total leg increased at 0.35% and 0.27% per annum respectively.

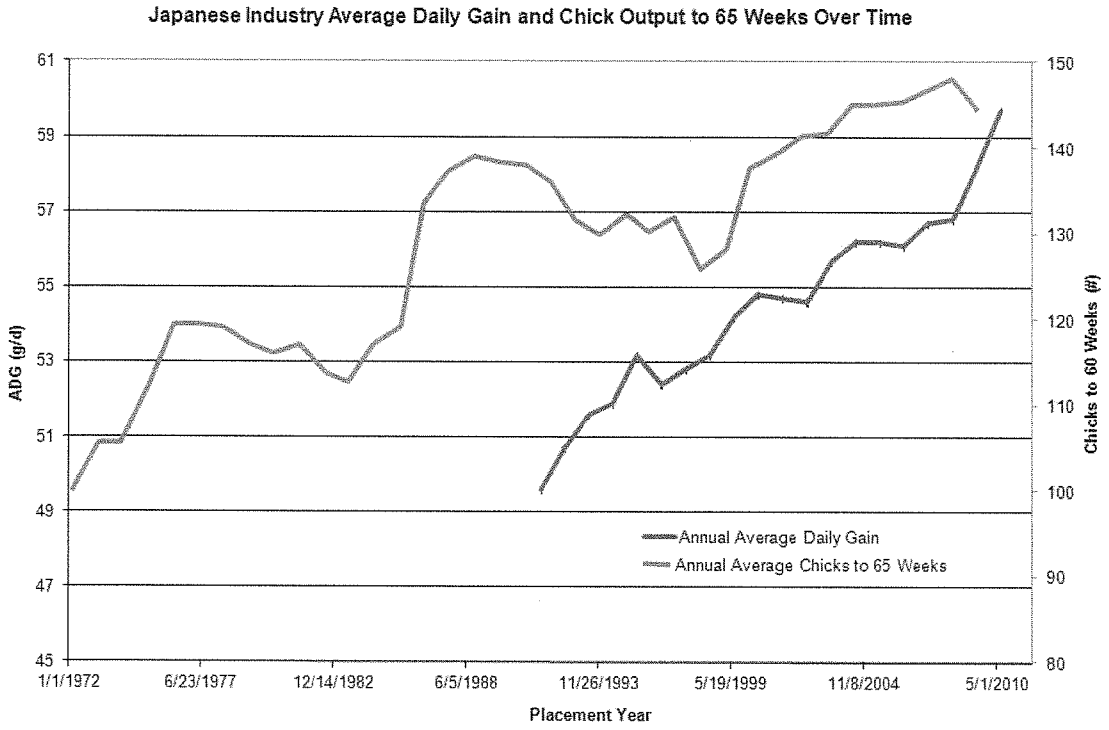
It could appear that these rates of improvement cannot continue indefinitely, however Emmerson (1997) demonstrated that there remained large variation between commercial breeds and that improvement in key traits could continue. Despite commercial breeding companies greatly increasing the range of traits that are selected for, the use of modern statistical packages such as Best Linear Unbiased Prediction (Meyer, 1989) has meant that the rates of improvement in these key commercial traits can continued to change at broadly the same rates as indicated by Havenstein et al. Both field and trial trends from Aviagen (2012 unpublished) demonstrate that this is the case in certain products (Table 2).

Table2. Field and Trial Trends for broiler performance (Aviagen 2012 unpublished)

	Trait	2007	2008	2009	2010	2011	Average Annual Change
Aviagen Multipurpose Birds - Global Field Results	42 day weight (g)	2253	2309	2354	2417	2432	47
	2.25kg FCR (g:g)	1.874	1.864	1.846	1.833	1.809	-0.016
	42 day Livability (%)	95.21	95.02	94.98	94.87	94.87	-0.08
Aviagen Multipurpose Birds - US Pen Trial Results on Multiple diets and environments	ADG to 35 days (g/b/d)	51.10	51.99	50.85	54.00	55.66	1.11
	1.8kg FCR (g:g)	1.726	1.707	1.684	1.598	1.576	-0.041
	35 Day Livability (%)	96.17	97.74	97.58	97.18	97.24	0.16
	1.8kg Eviscerated yield (%)	68.46	68.67	69.18	70.21	70.13	0.49
	1.8kg Breast Meat yield (%)	19.84	19.42	19.51	20.37	20.61	0.25

Growth traits tend to be genetically negatively correlated with breeder traits (Chapuis, 1996) and a selection strategy that is focused primarily on broiler performance traits would result in a reduction in reproductive performance; however the current commercial breeding companies have taken a multi-trait approach to their product improvements (McKay et al., 2000) which has resulted in the improvement both of broiler performance and chick output as demonstrated in Figure1.

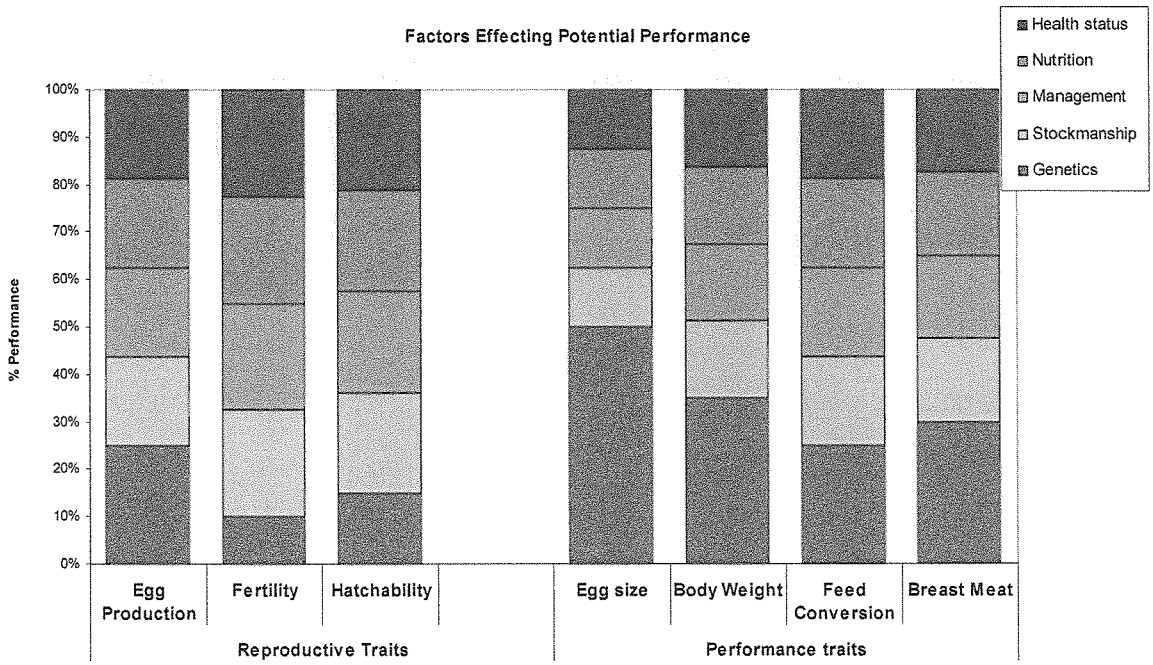
Figure1. Broiler growth rate and Hen Housed Chick output over time in a Japanese Industry data set (Japan Chunky Association 2011, unpublished).



Aviagen has extended its' breeding program to include not only the traditional performance and welfare traits, but inclusion of electronic feed stations to record "lifetime FCR" (similar to those described in Bley and Bessei, 2008) and multi-environment selection as described in Kapell et al. (2012). These methodologies have enabled faster progress in feed efficiency, by looking at the behavior of the birds as well as the final result, along with significant improvements in robustness, as evidenced in the most recent years' results in Table2. It is likely that these traits will remain commercially important into the future, however breeding companies are well placed to respond to changes in market demands with a range of products targeted to varying markets.

Impacts of Genetic Change

Figure2. The approximate relativities of genetic to environmental effects in broiler breeder chickens. Note: environmental effects have been arbitrarily divided equally for simplicity.



Whilst it is possible to demonstrate genetic change over time in controlled trials or within industries, it is key to remember that only the genetic proportion of the variation (heritability or h^2) is under the control of the geneticists and that the environmental variation (housing, nutrition, health status, stockmanship, etc) to which the birds are exposed can have as great or greater effect than the genetic change (Figure2). Despite improved resistance to stressors and disease, along with an increased ability to thrive on poor quality raw ingredients, day to day management remains vital in order to maximize the well-being and economic performance of today's birds. Modern husbandry therefore must continue to adapt to best meet the changing needs of both the breeding stock and the broilers. Responding to the needs of the birds on a regular basis, through core stockmanship principles, remains one of the most important ways to realize maximum performance and bird well-being.

Growth Potential

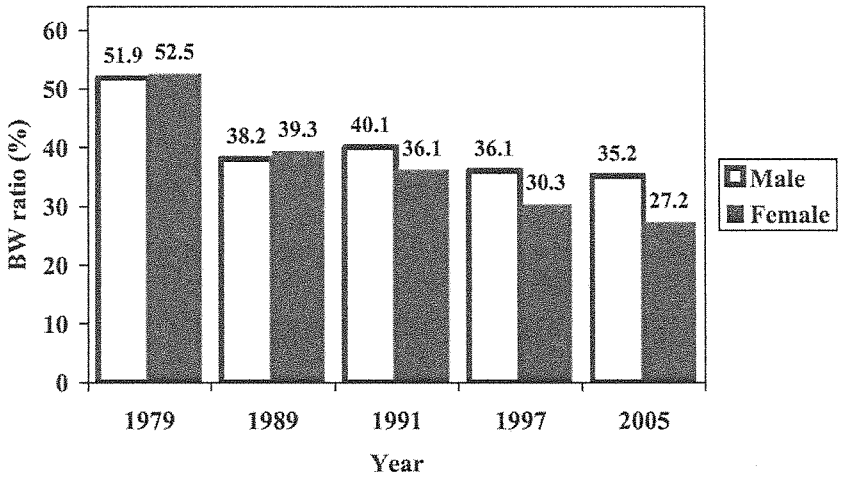
Impacts on Breeders

There is a wealth of literature (Fuller et al., 1969; Pym and Dillon, 1974; Watson,1975; Robblee et al., 1979; McDaniel et al., 1981; Bornstein and Lev, 1982; Siegel and Dunnington, 1985; Hocking et al., 1989; Katanbaf et al., 1989a,b) that demonstrates the reproductive advantages of feed intake control for both males and females during both the rearing and laying phases of breeder production. This is in broad agreement with all of the breeding company literature (Aviagen, 2011; Cobb, 2011; Hubbard, 2010). Feed intake control of breeders has also been reported to reduce mortality under disease situations and improve immune response (Han and Smyth, 1972) and whilst there are concerns over the welfare implications of controlling breeder weights, a number of authors are in agreement that the alternative, with its risks of obesity, reproductive disorders and associated health issues (Mench, 2002; Renema and Robinson, 2004), are of greater detriment to animal welfare. A recent scientific opinion by EFSA (2010) states that more research on this topic is required. Indicating that whilst there may be opportunities for the investigation of both management and breeding strategies to reduce the requirement for the current levels of weight control, such as the use of dwarf breeder genotypes (Renema and Robinson, 2004), at present when birds grow towards the reproductive stage, it is important that their

weight gain is appropriate. It may be that there exists a phase when ad lib feed is neither appropriate nor natural anymore.

Renema et al. (2007) (Figure 3.) demonstrated the changes 6 week broiler weight versus 6 week recommended weights in Hubbard breeders. This indicates that it is likely to be more challenging for the grower to achieve the targeted weight profile. It is therefore increasingly important to ensure that a representative sample (a minimum of 2% of the flock or 50 birds, whichever is greater (Ross, 2011)) of the flock is weighed on a routine (preferably weekly basis), in order to best understand and control weight gains.

Figure 3. Ratio of 6 week male and female Hubbard breeder Body weight : broiler body weight management guide recommendations between 1979 and 2005 (Renema et al., 2007).



Feed intake management to ensure that birds grow well into the reproductive phase is starting earlier, with field discussions showing that breeders feed intake is adapted from one to two weeks of age compared to four or five weeks, 10 years ago. Wijtten et al. (2010) showed in broilers, that care needs to be taken with feed intake management in the early part of growth for the good development of tissues such as the small intestine and heart, to maximize later life performance. Early growth management in breeders therefore should be conducted with care in order to optimize the growth of vital organs to promote efficiency in later life. Romero-Sanchez, et al. (2007) were able to demonstrate that a sigmoid feeding pattern that avoided large weight gains late in rear was beneficial to maintaining late fertility and hatch, supporting the moderate early, slow middle, moderate late shape of the growth curve recommended by Aviagen (2011)

Uniformity of the flock is as important, or potentially more so, to reproductive performance as body weight management. One of the greatest challenges to any producer of breeding stock today is to ensure the best uniformity of the flock possible. Hudson et al. (2001) demonstrated that flocks with good uniformity had higher egg output to 35 weeks, as the hens all started production at the same time. They were able to ameliorate the effect of poor uniformity by feeding into lay faster than normal however this resulted in higher bodyweight and slightly lower peaks. As this study was terminated relatively early in production the final outcome of this strategy to a typical commercial depletion age is unknown. Romero et al. (2009) confirmed that flocks with lower CV% produced more eggs to 60 weeks and had a longer prime sequence than flocks with poorer uniformity. They also were able to demonstrate that the ideal weight and feed intake to maximize production did vary between individuals.

One tool available to the grower to improve uniformity of the flock is grading (Petitte el et, 1981) which has been shown to greatly improve uniformity when done correctly. First grading should occur around 4 weeks of age. Birds should be 2-way graded if CV% between 10 -12% and 3 way graded if the CV% is greater than 12% (Aviagen, 2011). Flocks with a CV% of less than 10% generally do not benefit from grading. All grading operations should be complete by 9 weeks, as at this time 90%+ of the skeletal development of the bird has occurred. From this point onwards, for overweight flocks redraw the bodyweight curve to maintain the differential from the breeder recommended weight profile, as removing more weight is likely to cause further uniformity deterioration and a lack of readiness for light stimulation. Redrawing of the curve on light flocks should occur at 11 weeks as increasing weight on these flocks from this point onwards is likely to result in over fleshed birds (the consequences of which will be discussed later in this paper).

Impact on hatcheries

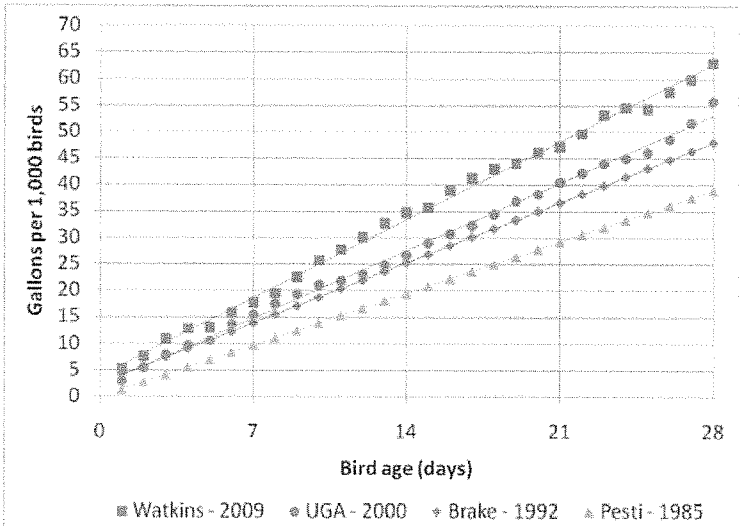
The proportion of the time that the bird spends in the shell as a percentage of total lifespan has increased (17% of age to 2kg in 1957 vs 40% in 2001).This means that the time as an embryo and neonate becomes increasingly critical. Various authors have described the advantages of enhanced timing of feed and water availability on subsequent chick performance (Careghi et al., 2005; Gonzales et al., 2003). Understanding of the uniformity of emergence and its relation to pull time in the hatchery must be maximized to enhance the time between emergence and placement at the farm in order to reduce weight loss during holding and growth and organ development in the first week of life. Failure to achieve this is likely to make 7 day and subsequent uniformity poor and more difficult to correct.

Impact on broilers

The brooding period (first 7 days) of the chick's life on the farm also accounts for a greater proportion of its life as a broiler (22% of age to 2kg in 2001 vs 7% in 1957). In the early post-hatch period, chickens act as poikilotherm (cold-blooded) animals and become fully homeotherm (warm-blooded) after about 10 d (Tazawa et al., 1988; Nichelmann and Tzschentke, 2002). It would appear that this period remains biologically fairly stable, although strategies that increase growth have been suggested as reducing the time period, due to higher muscle and digestive heat produced by the neonate (van den Brand et al., 2010). Therefore pre-preparation of the house to ensure that floor temperature, not just air temperature, is achieved in line with the breeders' recommendations is required. An understanding of bird behavior as an indication of comfort is critical and temperature must be adjusted for both humidity and bird activity in the first week of life in order to maximize feed intake, early growth and uniformity (Aviagen, 2009).

Most ventilation that occurs in poultry houses is designed to remove moisture as the first limiting by-product (Czarick, 2010b). As growth rate increases the total water intake of the house to an age also increases (Figure 4), as a consequence of a relatively stable water : feed ratio. It is therefore important to ensure that minimum ventilation rates are kept in line with water consumption / growth, to avoid the deleterious effects of poor quality litter, such as foot pad dermatitis and hock burn (Greene et al., 1985). In cold weather this can often be at odds with the desire to reduce ventilation and conserve heat within the house; however litter material with low moisture levels can reduce the risk of pathogenic microbial growth and lower ammonia production (Carlile, 1984). Low levels of ammonia (produced by bacterial metabolism of poultry nitrogenous waste) improves BW, feed conversion, and livability in poultry (Reece et al., 1980) and these factors may enhance return on investment to a much greater extent than the reduced fuel cost.

Figure 4. Daily broiler water consumption. (Czarick and Fairchild, 2009)



Feed Efficiency

Impacts on breeders

Not only has the growth potential of the modern broiler breeder increased but its appetite and feed efficiency has improved along with it. DeBeer and Coon (2007) demonstrated the effect of different feed programs in rearing on egg production. They determined that Every Day (ED) feeding was more efficient than programs that skipped days; with FCR to 21 weeks 3.68 on ED vs 4.00 on a 5-2 program. The ED program also produced more eggs to 45 weeks than the skip programs and required less feed per egg. Whilst this experiment showed no significant difference in uniformity between treatments, skip programs have become a significant management tool in the field to improve feed distribution and therefore the uniformity of the breeder flock (Katanbaf et al., 1989a). From a commercial producers viewpoint therefore the advantages of feeding birds every day may be outweighed by the use of skip feeding programs to maximization of uniformity and economic returns. Feeding programs should be tailored to the available equipment. Chain / trough feeders or floor feeding tends to result in a more even distribution of feed than pan type systems. A number of articles which state that there is no advantage in either uniformity or growth to having all birds able to eat at the same time (van Key and Weaver, 1988; Leksrisompong, 2010), may be accurate in an experimental settings, however with the increased appetite of the modern breeder clean up times can be so short (less than 30 minutes in some cases) that this is likely to lead to increased variation in the flock in practical, commercial situations, so the provision of adequate feeding space is important. Not only can diet densities be adjusted to extend feeding time and allow more even access to feed, but feed form can be adjusted from pellet to crumble to mash, to optimize feed clean up time (Aviagen 2011). It is recommended that all mangers of stock attend feeding to observe bird behavior and adjust feeders and feed amounts based on their observations in order to maximize the uniformity and productivity of the flock.

Table 3 shows even within a very short time period (2 years) that the amount of feed required in the average US breeder operation has declined, but that the related micronutrients (vitamins, trace minerals, etc) have not kept pace with the reduction in feed intake. Some of this may be a result of previous over-feeding of these feed elements and increased feed prices causing re-evaluation of diets, however there is a very real risk that the feeds of today are border-line in micronutrients for breeder requirements. Nutritionists should review diet specifications on a consistent basis to ensure adequate provision of all nutrients.

Table 3. Average breeder diets in the USA 2009 and 2011, adapted from Agristats, 2009 and 2012.

		2009 Average	2011 Average
	20 Wk weight (g)	2009	2037
	Feed to Capitalization (kg)	13.30	13.17
	FCR (g:g)	6.62	6.47
	Total Calories to Capitalization	37527	37127
Total g of Ingredient to Capitalization	Phosphorous	5.59	6.06
	Calcium	13.30	13.43
	Sodium	3.06	2.90
	Vitamin Pack	9.98	9.74
	Trace Minerals	8.25	7.90
	Micronutrient Pack	19.02	14.75
	g of feed / dozen eggs	3048	2998

Influences on broilers

There is a growing body of evidence (Brickett et al., 2007; Schwean-Lardner et al., 2012) that indicates that there are benefits to FCR of having a more extended dark period during the day. Dark periods of four hours or more cause, as yet unexplained, physiological changes within the bird, which lead to an improvement in growth rate and feed intake, as well as changes in eye growth and the continuity of diurnal rhythms and melatonin production. The availability of these dark periods has been shown to reduce lethargy and increase comfort, exercise and nutritive behaviors (Schwean-Lardner and Classen, 2010).

FCR tends to improve with as dark period length increases, whilst growth rate is maximized at around 4 hours of darkness in a day, however yield tends to reduce with longer dark period. It is therefore important that a calculation involving feed cost, growth, product value, etc., is conducted in operation to maximize welfare and productivity.

The value of intermittent lighting programs on broiler performance has mixed reviews in the literature, with some publications indicating that broilers modify their behavior to account for the dark periods but no improvements in feed efficiency were seen (Duve et al., 2011; Cave et al., 1985) and others indicating that intermittent lighting or management methods to stimulate bursts of activity were conducive to improved FCR and the reduction of leg issues (Balog et al., 1997, Wilson et al., 1984). Howie et al., 2011, in the absence of intermittent lighting programs, demonstrated that the feeding behavior of birds had no relationship to feed efficiency, and therefore any improvements in performance are likely to be related to other mechanisms such as compensatory gain (Buyse et al. 1996).

Muscle Deposition

Impacts on Breeders

Whilst hens require a certain proportion of lean tissue to become sexually mature (DeBeer and Coon, 2007), over fleshing can result in higher maintenance requirements for hens, by the re-partitioning of energy and amino acids (AA) away from egg production and into lean tissue turnover (Hocking et al., 2002). As egg production falls, bodyweight will increase and a vicious cycle can ensue. Increased weight in laying broiler breeders has been shown to be related to increased fatness, due to excess energy consumption as egg production drops, which in turn reduces female fertility (Bilgili and Renden, 1985) and increases embryo mortality (Hocking et al., 2002). Hens fed ad libitum post peak have been shown to produce only 25% of the chicks that restrict fed birds produce. Mangers of breeding stock must judge post-peak feed management not only on egg production but on weight, conformation and fatness within the flock.

Lysine is the first limiting AA for broiler muscle deposition (Carew et al., 2005) and as demonstrated in Table 4 the requirements of amino acids for breeders are substantially different for that of broilers. Care should be taken with formulation of breeder diets not to over-feed lysine and encourage additional muscle deposition.

Table 4. Comparison of amino acid requirements relative to lysine between breeder and broilers adapted from Fisher, 1998 and Aviagen, 2007.

Amino Acid	Breeder at 29 weeks	Breeder at 31 weeks	Breeder at 64 weeks	Broiler starter	Broiler Grower	Broiler Finisher
Arg	90	90	89	103	104	105
His	34	34	33			
Ile	68	70	68			
Leu	112	114	111	67	68	69
Lys	100	100	100	100	100	100
Met	42	43	42	37	38	39
Met + Cys	71	73	71	74	76	78
Phe + Tyr	117	120	116			
Thr	63	64	63	65	66	67
Trp	21	22	21	16	16	16
Val	79	81	78	75	76	77

In males the issue of over-fleshing is as much mechanical as physiological (Fontana et al., 1990), with heavily fleshed males struggling to make contact with the cloaca of the females and copulate effectively (Hocking and Bernard, 1997). The use of separate male diets, lower in AA (Hocking, 1990) and calcium (Janssen, 2000) and higher in energy (Spratt and Leeson, 1987) than female diets has been shown to be effective in changing the conformation of the male and promoting higher late fertility.

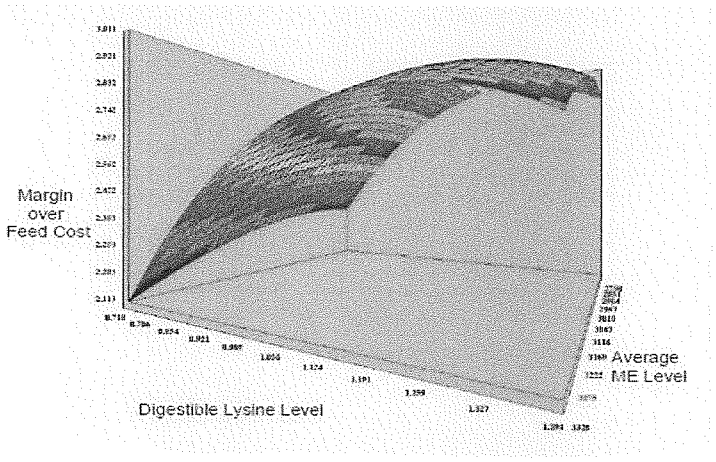
It is no longer effective to manage breeders based solely on weight and both sexes should be conformation scored on a routine basis throughout the rearing and laying periods to ensure that the fleshing of the breast is maintained at the appropriate level to maximize reproductive performance. As previously discussed, the sigmoid shape of the rearing curve may provide a useful tool for managing the ratio of bone to muscle, which may have positive impacts for the control of fleshing later in life.

For both males and females the heat generation from additional muscle mass can pose a challenge for hot weather ventilation of breeders, especially when humidity is high. Providing adequate fan capacity and air intakes to allow for cooling by wind chill and / or evaporative cooling should be considered when renovating of building breeder houses (Donaldson, 2010). Observation of bird behavior especially after feeding is important to determine the correct ventilation rate based on the comfort of the birds.

Impact on broilers

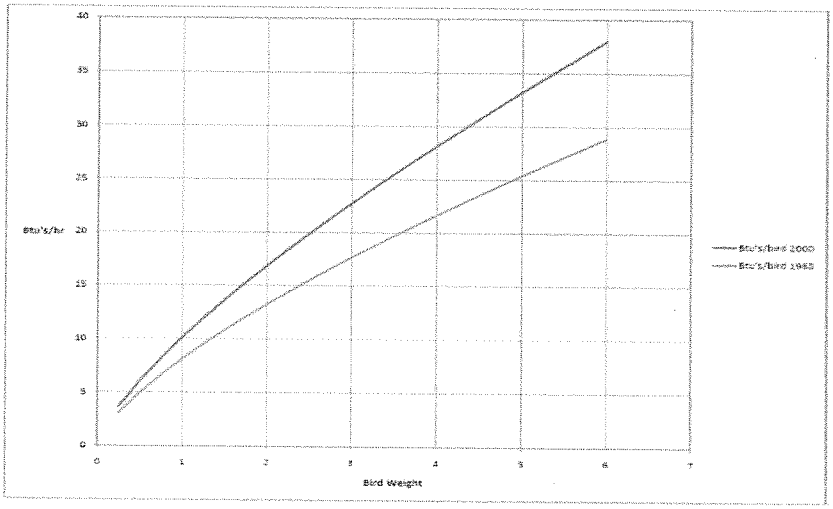
The improvement both in feed efficiency and increased potential for lean tissue deposition in modern broilers has resulted in substantial reduction in the cost to produce a unit of boneless meat (Havenstein et al., 2003b). Modern broilers are more responsive to amino acid density than birds from the 1970's. (DeBeer, 2010). In order to maximize return to the bottom line of the business, an understanding of ingredient price, finished feed cost, the effect on live and processing performance, plus the current market value of the finished product is required to determine the most effective density of diet for the current market situation (Figure 5, DeBeer 2009).

Figure 5. Surface plot showing the effect of varying ME and amino acid levels on margin over feed cost for deboned birds under a specific set of market conditions (average feed price: $280/ton; boneless breast price: $3.68/kg; thighs: $2.68/kg;drums: $1.42/kg; wings: $3.00/kg)



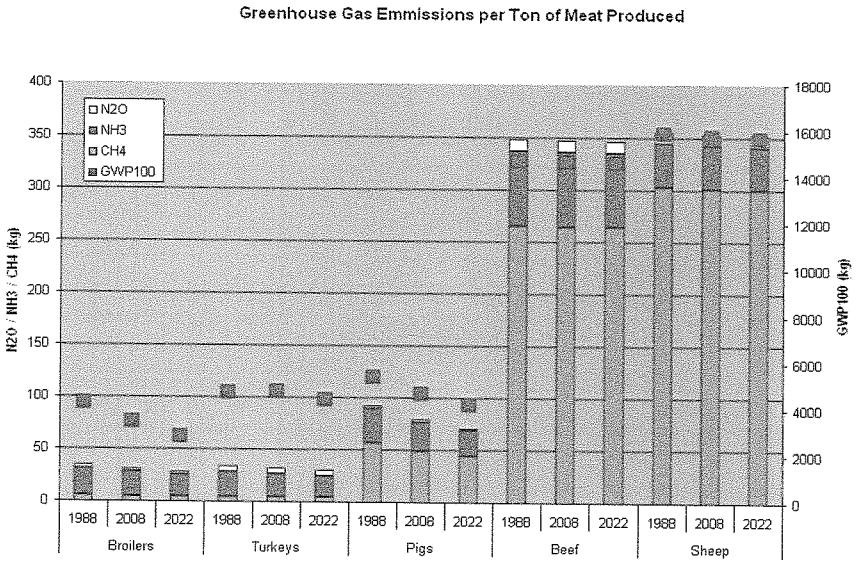
The heat production of the modern high yielding breeds (Figure 6) and their effects on ventilation rates is probably even more critical in the broiler house than the breeder house. Birds do not have the ability to lose heat to the environment through sweating so the greatest proportion of heat loss is through direct body to heat transfer (Donaldson, 2010). As birds age, the proportional surface area of the bird decreases, making heat transfer more challenging. Stocking density will have a significant impact on heat transfer as the more bird surface area that is exposed; the faster heat will be transferred. The installation of migration fences to keep birds evenly distributed within the house can be advantageous in this. Generally the faster the air speed the more heat is removed and the greater the broiler live performance, which had lead to people designing houses capable of airspeeds of 0.38 m^2/sec (800 ft^2/min). The cost of building and running this style of house should be considered when ventilation choices are being made. The speed of the air is not the only factor to consider but also the uniformity of that airflow within the house (Czarick, 2010a). Evaporative cooling can also assist in reducing bird temperature during hot weather but the efficiency of these systems is dependent on the environmental humidity. All factors should be considered along with observation of bird comfort when tuning the ventilation system.

Figure 6. The change in heat output from Broiler chickens 1968 and 2000 (Czarick 2008, personal communication).



Near term opportunities

Figure 7. Green House Gas emissions per Ton of Meat Produced (DEFRA, 2008)

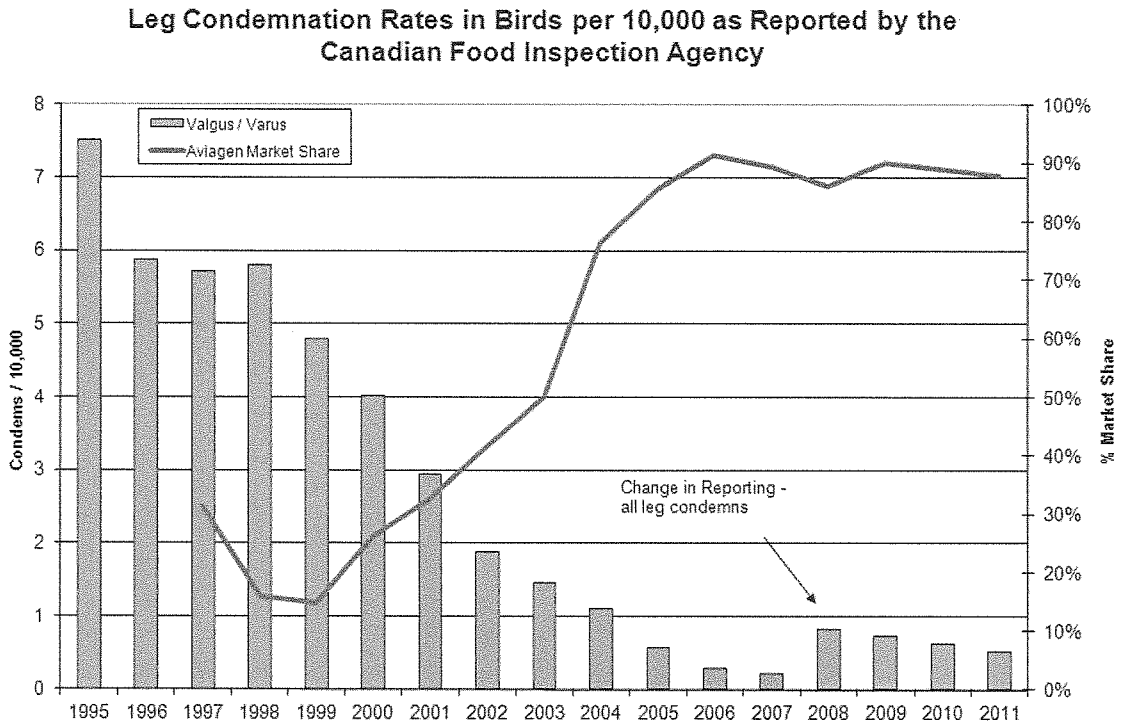


On a per kg basis broiler chicken is the most efficient terrestrial farmed species (FAO, 2006). This efficiency in utilization of feed, energy and space also makes it the species with the lowest levels of Green House Gas (GHG) emissions (Figure 7, DEFRA, 2006) and the reduction of these emissions is predicted to continue in line with genetic improvements in efficiency, growth, muscle potential, etc. However there remains a substantial variation in the amount of GHG emitted by various operations (Vellinga and de Boer, 2009). Full lifecycle analysis of broiler farming from grain production through to the back door of the processing plant has yet to be completed but a number of studies looking at difference portions of the full cycle have been complete. These studies demonstrate that the method of production (Durali, 2012; Leinonen 2012) and the sourcing of ingredients (Mosnier, 2011) and makeup of the nutrition (Applegate, 2012) can have profound effects on the overall output of GHG's. Of all the GHG emissions from poultry, ammonia (NH4) is the most prevalent and has 7.7 times the warming potential of carbon dioxide (CO2) (Nemecek and Kägi, 2007).

Balancing the AA requirements of the bird in the diet has been shown to reduce the excretion of excess nitrogen and reduce the output of Ammonia, having benefits in terms of reduction of pollutants, lower neighbor complaints, improved performance and lower cost (Kidd and Tillman, 2012; Al Homidan et al., 2003).

All the commercial breeding companies have expended a great deal of selection pressure into improving both cardio-vascular fitness and skeletal strength (McKay et al., 2000) and the effects of these can be demonstrated in the field (Figure 8). Whilst these genetic changes will continue, the operation of any management system needs to consider maximizing welfare in order that the industry is seen by both retailers and consumers to be proactive. Manning et al. (2007) describe "lead" indicators of welfare, such as feed and water intake, air and litter quality, as well as weight gain, which all producers should monitor on a daily basis. As most producers will say, animals in distress or exposed to disease are unlikely to achieve their productive potential, demonstrating that poor welfare generally returns poor returns. The risk of industry complacency is uninformed groups, often without the best interests of the industry at heart, dictating the methods and production systems that the broiler industry is to use.

Figure 8. Leg Condemnation Rates from the Canadian Food Inspection Service (Agriculture and AgriFood Canada, 2012)



Conclusions

Changes in broiler efficiency since the 1950's has been enormous and through the use of multiple trait selection the reproductive potential of these birds has also increased, whilst critical measures of welfare have been held at a constant rate or improved. The principles of production have not changed over this time but the requirement for attention to detail to maximize performance has not lessened. For most performance traits the management elements continue to have a greater impact on a day-to-day basis than genetics. Understanding the background requirements for management practices and how to effectively implement them under the range of conditions that broilers and breeders are exposed to globally will improve performance and bird well-being. Near term opportunities, in areas like climate change and welfare, exist to set the industry up as one that people look to for guidance, rather than one which is guided. Breeding companies will constantly develop the products that are demanded by their clients and whilst today the focus is generally on robustness and efficiency, it is likely that there will be a greater range of products demanded in the future.

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