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"The Evolution of Genetics, Breeding and Production"

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I have been fortunate to meet and work with many of the geneticists, company and academic, who have made such enormous contributions to development of the poultry meat industry. They provided me with a privileged insight to their work and also ensured continuous technical challenges.

PREFACE

AVIAGEN

The world's leading poultry breeding company with wholly owned operations in Europe, the United States and Latin America and Joint Ventures in Asia and South Africa. The company has 1500 employees and a distribution network serving over 300 customers in more than 85 countries.

Aviagen is owned by the Erich Wesjohann Group, Germany which has worldwide leadership in both the egg layer and the broiler breeder sectors, with an unrivalled product portfolio. EW Group is committed to investment in R&D.

Aviagen encompasses the Arbor Acres, L.I.R. and Ross Brands of broiler meat chickens and also owns Nicholas Turkeys and British United Turkeys.

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Summary

In this presentation I shall examine the development of the poultry meat breeding industry from the beginning of its intensification in UK and Europe until the present. The report covers genetics [the basic science and method behind breeding] and the structure and evolution of the breeding industry. In order to understand some of the drivers and results of the breeding programmes it is necessary to provide performance and economic statistics, which will be primarily those of the UK, but where relevant comparisons from other world regions are presented.

The world's poultry meat industries have shown phenomenal growth in little over half a century. The focus of that growth has changed from the developed to the developing world driven by both changes in local consumption and international trade.

Poultry breeding evolved along with the opportunities provided from the sciences of genetics, statistics and computing whilst the biological sciences provided the rationale and measurement tools for including more complex traits into selection programmes.

The breeding companies evolved through specialization to develop complementary lines which provided hybrid crosses at the commercial level. The increasing complexity of breeding and selection has resulted in the focusing of poultry breeding activity into companies having the resources to develop and manage multiple products. All these lines and their products can benefit from the skills and investment in breeding whilst genetic diversity is retained and managed.

Data from the UK industry shows continued balanced improvement in biological performance along with cost reductions.

During the last 50 years the UK industry provided a challenging environment against which the breeding companies could develop their skills and their products to achieve worldwide leadership.

GLOSSARY

AI	avian influenza
AFRC	Agricultural and Food Research Council
ARC	Agricultural Research Council
BLUP	Best Linear Unbiased Predictor
DEFRA	Department for Environment Food and Rural Affairs
EPEF	European Production Efficiency Factor
EU	European Union
FAO	Food and Agricultural Organisation
FCR	Food Conversion Ratio
GGP	Great Grand Parent
GP	Grand Parent
kg	kilogram
KPI	key performance indicator
Mt	Metric tonne
MLC	Meat and Livestock Commission
NFU	National Farmers Union (UK)
PEF	Production Efficiency Factor
PS	Production Score (rarely used)
PS	Parent Stock (common use)
R&D	Research and Development
USDA	United States Department of Agriculture
WTO	World Trade Organisation

THE POULTRY INDUSTRY WORLDWIDE

The poultry industry has shown phenomenal growth worldwide over the last 50-60 years and this growth is forecast to continue. The top five producing regions – USA, China, Brazil, the European Union and Mexico – are predicting steady year on year growth and together produced over 50 million Mt out of a worldwide total of around 80 million Mt of broiler meat in 2006. The EU share of this production is however reducing as an increasing proportion of production moves to developing countries.

The consumption of poultry meat has outstripped the rising trend of animal protein consumption which in turn was a result of animal protein becoming more universally affordable. Worldwide pork consumption currently stands at 100 million Mt, poultry at 80 million Mt, beef at a little over 60 million Mt and eggs close to 60 million Mt. There are significant regional variations in the relative importance of meat types and in absolute consumption between the developed and developing world. **Production is however increasing rapidly in the developing world to supply both local markets and for export**.

Windhorst (2006) produced a detailed review of changes in poultry production and trade world wide based on the extensive FAO database which shows significant changes in the relative importance of the UK and EU poultry meat industries between 1970 and 2005. Worldwide production of poultry meat increased by 4.36 times in this period. However whilst the developed world had around 75% of poultry meat production in 1970 this had fallen to 45% by 2005(Table 1). In this major change of location Asian and South American countries, particularly China and Brazil, showed the greatest increase with Europe and North America having a *relative* decrease. Nevertheless developed countries still showed an increase of 227% over this time frame.

Year	World	Developed countries	Developing countries	Share% of developing countries
1970	15,101	11,219	3,882	**25.7**
1975	18,648	13,409	5,275	**28.2**
1980	25,965	17,986	7,979	**30.7**
1985	31,206	20,775	10,431	**33.4**
1990	41,041	25,827	15,214	**37.1**
1995	54,771	28,392	26,379	**48.2**
2000	69,191	32,708	36,483	**52.7**
2005	81,014	36,663	44,351	**54.7**
Increase %	**436.5**	**227.1**	**1,042.5**	

Table 1. Development of poultry meat production in developed and developing countries (1970 to 2005) ; in 1000t (FAO Database)

When the time trends of the top ten countries involved in poultry production are examined (table 2) the USA remains top but its world share has reduced from 30.8% to 22.9%. China has increased from 6.4% to 18.1% and Brazil from 2.55 to 11.0%. Production in the UK increased by 2.7 times but its share of the world market reduced from 3.8% to 1.9%.

The four major European producers, France, Spain, Italy and the UK, taken together declined from 15.4% of world production to around 7% (Italy dropped from the top 10 completely). The EU 25 would now represent around 12% of world total production. Whilst the top ten countries are responsible for 66% of world production the top three now produce 52%.

One significant change is that Russia which was in second place in 1970 (with more than 1 million metric tonnes or 7% of world total) is no longer in the top ten producers, having only around 1% of world production in 2005. Projections for 2007 are for a production of 1.8 million metric tonnes with imports around 1 million. In comparison with other countries this increase of only 2 to 3 times in production and consumption is very low for what is potentially a grain and oilseed rich country. Current changes and developments in that country would suggest that internal production will rise significantly and their dependence on imports will change in the next 5 to 10 years.

Country	1970 Production 1000t	Share (%)	Country	2005 Production 1000t	Share %
USA	4,645	30.8	USA	18,538	22.9
USSR	1,071	7.1	China	14,689	18.1
China	971	6.4	Brazil	8,895	11.0
France	637	4.2	Mexico	2,272	2.8
Italy	626	4.1	France	1,971	2.4
United Kingdom	578	3.8	India	1,965	2.4
Spain	499	3.3	United Kingdom	1,573	1.9
Japan	490	3.2	Spain	1,341	1.7
Canada	447	3.0	Indonesia	1,268	1.6
Brazil	378	2.5	Japan	1,240	1.5
Top 10	**10,342**	**68.4**	**Top 10**	**53,752**	**66.3**
World	**15,101**	**100.0**	**World**	**81,014**	**100.0**

Table 2. Ten leading countries in poultry meat production in 1970 and 2005 (FAO Database)

The FAO data also give a good indication of the relative importance of the various species of poultrymeat (Table 3). There was little change in the importance of chicken meat at around 87% whilst Turkey meat declined slightly from 8% to around 6.5% with this small opportunity being taken up by Duck and Goose meat. This would tend to justify the focus of this report on chicken meat.

Year	Chicken	Turkey	Duck	Goose	other	TOTAL
1970	87.0	8.1	3.3	1.5	0.1	100
1975	87.8	7.8	3.0	1.3	0.1	100
1980	88.2	7.9	2.7	1.1	0.1	100
1985	88.3	7.8	2.8	1.0	0.1	100
1990	86.4	9.0	3.0	1.5	0.1	100
1995	85.1	8.3	3.8	2.7	0.1	100
2000	85.3	7.4	4.3	2.9	0.1	100
2005	86.4	6.4	4.2	2.9	0.1	100

Table 3. Development of share of Global Poultry Meat Production from Windhorst (2006) and FAO Database

Poultrymeat consumption in the UK has increased threefold between 1970 and 2006 (Fig.1)

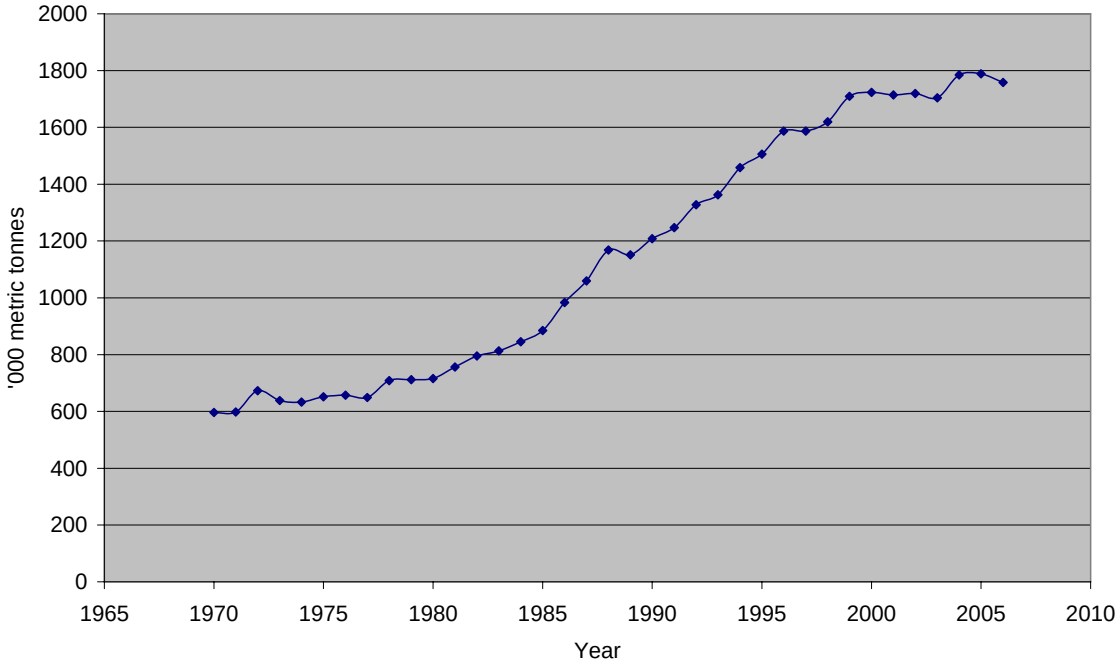

Fig 1 Long term trends in total poultrymeat consumption in the UK (Data from MLC)

More detailed data taken from the DEFRA website shows recent trends for broiler and turkeys separately, along with imports and total consumption (Fig.2). This covers the last 12 years. http://statistics.defra.gov.uk/esg/datasets/poulpsq.xls

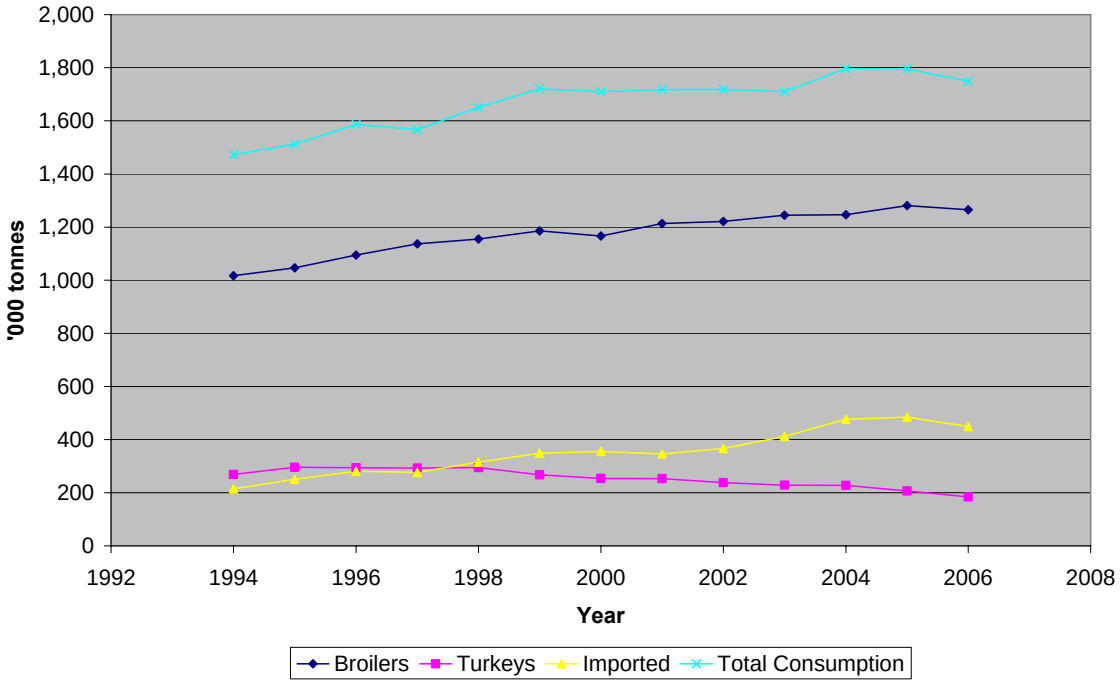

Fig. 2 Detailed recent data on Poultrymeat consumption in the UK (DEFRA)

Against this background we can then consider what the way forward will be for poultry meat and do this in comparison with other meats in Europe. EU projections indicate relatively little growth in *per capita* meat consumption (1.1kg) but most of that increase is in poultry (0.8kg) (Table 4).

	2007	**2008**	**2009**	**2010**	**2011**	**2012**
EU-25						
Beef and veal	17.9	17.7	17.6	17.5	17.5	17.5
Pork	43.0	43.5	43.5	43.5	43.7	44.0
Poultry	23.6	23.9	24.2	24.3	24.5	24.6
Sheep Goat	2.8	2.8	2.8	2.8	2.8	2.8
Total	**87.8**	**88.0**	**88.1**	**88.2**	**88.5**	**88.9**

http://ec.europa.eu/agriculture/publi/caprep/prospects2005b/tabmeat.pdf

Table 4. Meat per capita consumption projections in the EU, 2007-2012 (kg/head)

Breeding

All these data sources indicate a slowdown in the previously rapid increase in poultry meat consumption in the UK and more widely in the EU. The UK data in Fig.2 show the recent growth in imports which is likely to continue whilst DEFRA data for production only show a basically level situation since 1998.

Although the EU projections indicate some slight increase is poultrymeat consumption the table takes no account of or gives any indication of where this poultry meat will be produced.

A Truly Global industry

The statistics set out above indicate one aspect of the global nature of the poultry industry. The real global aspect is that essentially all the elements for a poultry industry can be purchased and transported to any part of the world which has the basic conditions to allow the growing of poultry. The breeds and feed raw materials can be purchased or produced worldwide. More than 90% of the breeding stock used in broiler production come from only three suppliers. The major raw materials, maize , wheat and sorghum for energy and oilseeds (with some animal material) for protein are the major components of poultry diets worldwide . The oilseeds first have the oil extracted and then the resulting meal is available for feed. Currently 97% of extracted soymeal is fed to livestock. The environmental control and husbandry equipment is universal and the same suppliers can be seen at any poultry exposition worldwide. Finally there is a globalization of Food Service and Retail buyers and therefore customer requirements and standards. To give some examples Yum (KFC), McDonalds, Tesco and Walmart would specify and source product on all continents.

Increasingly the poultry production will shift to regions of the world where the raw materials are available and the climate is favourable for chicken production. Finished product can then be transported to the international markets.

Genetics

The Evolution of the modern broiler from the original Jungle fowl has taken around 5000 years but by far the greatest development in meat birds has taken place in the last two centuries with massive advances in the last 50 years. These have been closely linked to advances in science of genetics.

Chicken breeds used today in commercial agriculture are considered to originate from the Red Jungle Fowl (*Gallus gallus*). The exact time and place of domestication are unclear, and this may have occurred more than once during human history. It is believed that the modern chicken derives from birds kept by the people of the Harappan culture (2500-2100 B.C.), primarily for fighting purposes. Thus the chicken has been domesticated for around 4000 years and it must be assumed that for much of that time some form of selection for desired characters was taking place. Selection for certain phenotypic characters (comb type, feather colour or length etc.) took place by breeding only from individuals which displayed the desired character long before Mendel's work on inheritance explained a possible mechanism.

In recent genetic analysis studies the greatest similarity was found between G.gallus and the egg type breeds often referred to as Mediterranean. This would suggest that these groups were developed first from the wild progenitor and led subsequently to the biodiversity of chicken breeds which had developed across the world by the 19th century.

During the 19th century in USA many specific breeds of chicken were developed for meat production. The most successful were Plymouth Rock types and the New Hampshires which along with the breeds of Cornish origin were used by the developers of the modern broiler lines. All these lines have a natural yellow skin and brown eggs typical of the modern broiler. The combination of Cornish, Plymouth Rock and New Hampshire shows that the original broiler breeding programmes were based on genetic sources developed on both sides of the Atlantic. Albeit most development of the Cornish breed apparently took place after its relocation to the USA. However this theme of interchange of genetic

material between breeding programmes and specific enhancements in both Europe and the USA can be followed throughout the development of the modern broiler.

Several publications appeared in the 1920's which laid the foundations of poultry genetic science and during that same decade some of the originators of the meat chicken breeding industry began their work.

Following the rediscovery of Mendel's work some confusion arose in trying to explain the inheritance of characteristics controlled by multiple genes. Further explanation and refinement of genetic principles was required and this was provided in the first half of the 20th century with the development of quantitative genetic theory. Thus during this time the evolution of the science of genetics and commercial poultry production became closely linked and mutually stimulated as people tried to apply methods for understanding and utilising the theory in commercial selection programmes

Quantitative Genetics

Albers (2006) has given a simple summary of one of the major milestone in the techniques of genetic selection, the development and application of the theory of quantitative genetics. This theory regards the animal as a black box with many genes contributing to the expression of all traits that can be measured. For every gene two copies are inherited from the parents, one from the mother and one from the father, and for the total genetic value this means that every offspring effectively samples fifty percent of its value from each of its parents. Two offspring from the same parent therefore share ½ * ½ = ¼ of their genetic value and full sibs (brothers and sisters), being two independent samplings from the same sets of genes of their parents, share 2* ¼= ½ of their genetic value. The impact of the genetic value of an animal on its phenotype is quantified by the heritability of a trait, i.e. the percentage of variance of a trait that is attributable to genetic origin rather than to environmental impacts. Around these two simple mathematical descriptions of genetic principles, i.e. 1) how genetic potential shows in the phenotype of an animal, and 2) how genetic potential transfers from one to the next generation, the whole theory of quantitative genetics has been built.

Today one could describe such continued evolution in the form of pure mathematics.

It is important to remember that at the same time as the developments in genetic science were occurring various reproductive technologies e.g. artificial incubation and hatching, lighting programmes to enable year round production and artificial insemination were developed. These techniques were also essential to enable the development of poultry breeding programmes and the production industry.

It is difficult to say precisely when the modern broiler breeding began since there have been a number of key developments. However, whilst special broiler lines have been available for almost a century the first “industrial” breeding could be said to have begun with the hybridization of selected pure breeding lines developed from the original breeds and continued with further more intense selection of the pure lines. This process then accelerated as genetic science advanced.

The first steps towards the mathematical-statistical approach to genetics were taken by R.A. Fisher in 1918. From the early 1950’s Alan Robertson of the ARC Unit of Animal Genetics provided major contribution to link theoretical population genetics, quantitative genetics and practical animal breeding. Robertson’s group and others associated with it in Edinburgh have been a significant factor in the success of the commercial breeding industry in UK and Europe.

A further critical breakthrough came about through the work of C.R. Henderson who developed methodology to combine all information about each individual’s breeding value into a genetic index of merit. In 1953 he introduced what we now know as BLUP (Best Linear Unbiased Prediction) breeding value estimation. However, it was not until computers were available having the capacity and speed that was required to do the extensive matrix calculations, that this technology was put to use in animal breeding.

Today’s poultry breeding programmes all apply full pedigree-ing of all birds and exploit BLUP-breeding value estimations to obtain the best possible identification of superior breeding candidates. Obviously, the parents of the next generation have to be identified as early as possible (to minimize the generation interval) and genetic selection has to be devoted with the right emphasis to the right traits as demanded by the market. Albers concluded “Competitive forces have assured that only those breeding programmes that have done this in the best possible way have survived until today!”

A comprehensive summary of the key contributions to the development of modern breeding programmes has been provided in Arthur and Albers (2003). Table 5.

Technique	Decade
Mass selection	1900
Trapnesting	1930
Hybrid crosses	1940
Pedigree	1940
Artificial Insemination	1960
Osborne index	1960
Family feed conversion	1970
Selection Indices	1980
Individual Feed conversion	1980
Physiological measurement – Oximeter	1980
Leg condition measurement -Lixiscope	1980
BLUP Breeding value estimation	1990
Lifetime FCR measurement	2000
Multi environment selection	2000
DNA Markers	2000

Table 5 Milestones in Breeding Technology (after Arthur and Albers 2003)

DNA and Genomics

Table 5 has brought us to the present century. Current and future developments in poultry breeding will focus heavily on DNA and Genomics which therefore require a simple introduction.

Genomics is the study of an organism's genome and the use of genes. The genome of an organism is the complete DNA sequence. DNA creates the genetic code for building and maintaining an organism. Within the DNA sequence are areas called genes and these genes are templates for protein synthesis. Differences in the sequence may alter the structure and function of a protein. Differences in DNA make individuals unique and offer

the opportunity for selection.

In December 2004, the scientific journal, Nature, published the sequence of the entire Chicken genome. This was 1,000,000,000 base pairs long ! This knowledge provided the opportunity for breeders to search for differences between individuals in their DNA sequence and potentially explain differences in observed phenotypic traits. One type of difference would be a single base change in the DNA. This is called a single nucleotide polymorphism (SNP – snip). In the chicken 2.8 million of these SNP markers have been mapped and are therefore available for evaluation.

Aviagen has established the Genomics Initiative which is a major commitment to identify SNP's in our lines which are associated with traits of interest. The core of this Genomics Initiative is a large scale genotyping project which utilizes data from the existing pedigree and sib test programme, a DNA or tissue sample bank, other academic research and the published chicken genome. The Initiative involves collaboration with Iowa State University, USA; Institute of Animal Health (Compton) UK; Roslin Institute UK, Wisconsin University, USA, Auburn University, USA and Avian Diseases and Oncology Laboratory Missouri USA. In addition joint funding has been provided to 7 current PhD students in UK Universities.

A significant opportunity presented by genomics is the case control study approach which allows information to be gathered from Aviagen birds under commercial conditions. This will help identify SNP markers which may help select for traits that are rarely seen in the pedigree or sib-test environment.

A major challenge of this approach which is additional to the association studies is the development of implementation tools. Aviagen will develop the tools which will allow us to capitalize on the findings of the association studies. These capabilities to maximize the use of genomics in breeding programmes will result in economically viable delivery of enhancements in genetic progress. Genomics will become part of the ongoing continuous stock selection and improvement process. The research will also provide opportunities to deliver enhanced strain security and breed traceability. **In a climate of increasing consumer interest in the total food supply chain, Aviagen recognises the important part it plays as an integral component at the start of the human food chain.**

Breeding

The traditional way of describing a breeding system has been to use a pyramid. (Fig 3) Identifying the pedigree programme as the apex and expanding the levels as they pass through great grandparents (GGP), grandparents (GP), parents (PS) and commercial (broiler) production. The scale and timescale of the operation can be added to this to give an indication of the importance of both. We usually describe a situation where the time from pedigree selection to commercial broilers is 4-5 years. Each generation has a reproductive lifetime and this affects whether one refers to shortest time for gene flow or the average time over which these genes are operating in the commercial population. The size of the influence depends somewhat on the reproductive characters of each generation and the final broiler size but a pedigree base unit of 1 male and 10 females will produce about 50 million broilers or around 70,000 metric tonnes of broiler meat.

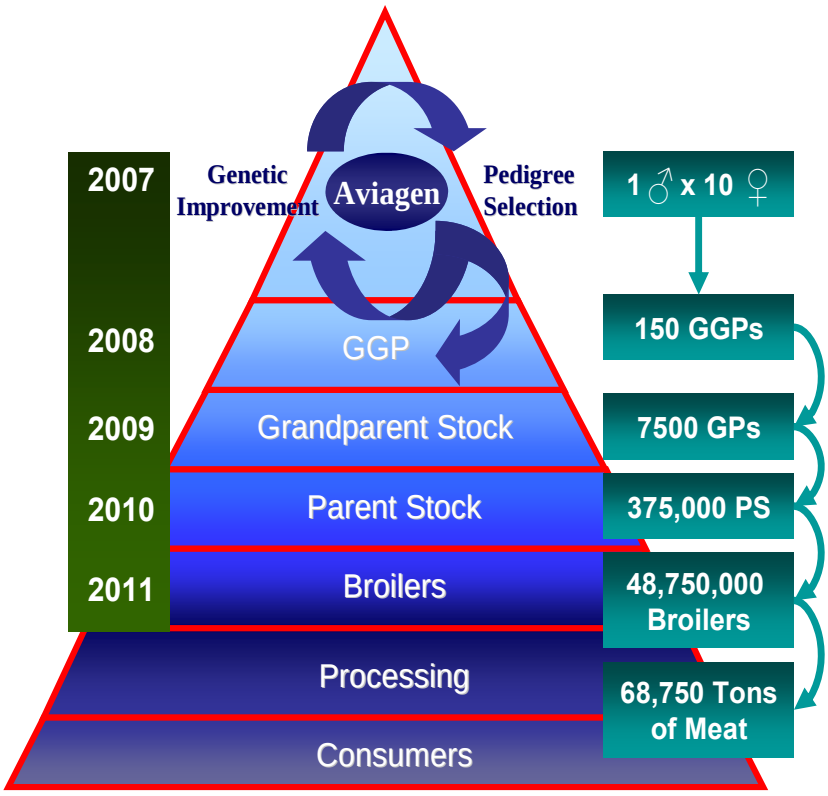

Fig 3. Traditional description of a Breeding Programme applied to the Broiler Industry

I believe that Fig. 3 is actually a false description of the modern programmes as it understates their current importance. This would be better described by two pyramids – one smaller which supports the larger (inverted) one. The latter contains all the elements necessary for an agricultural production system and the former all the requirements to develop and maintain a breeding programme – experimental lines, test lines, pure lines, and the not inconsiderable support systems of modern genetics (Fig.4).

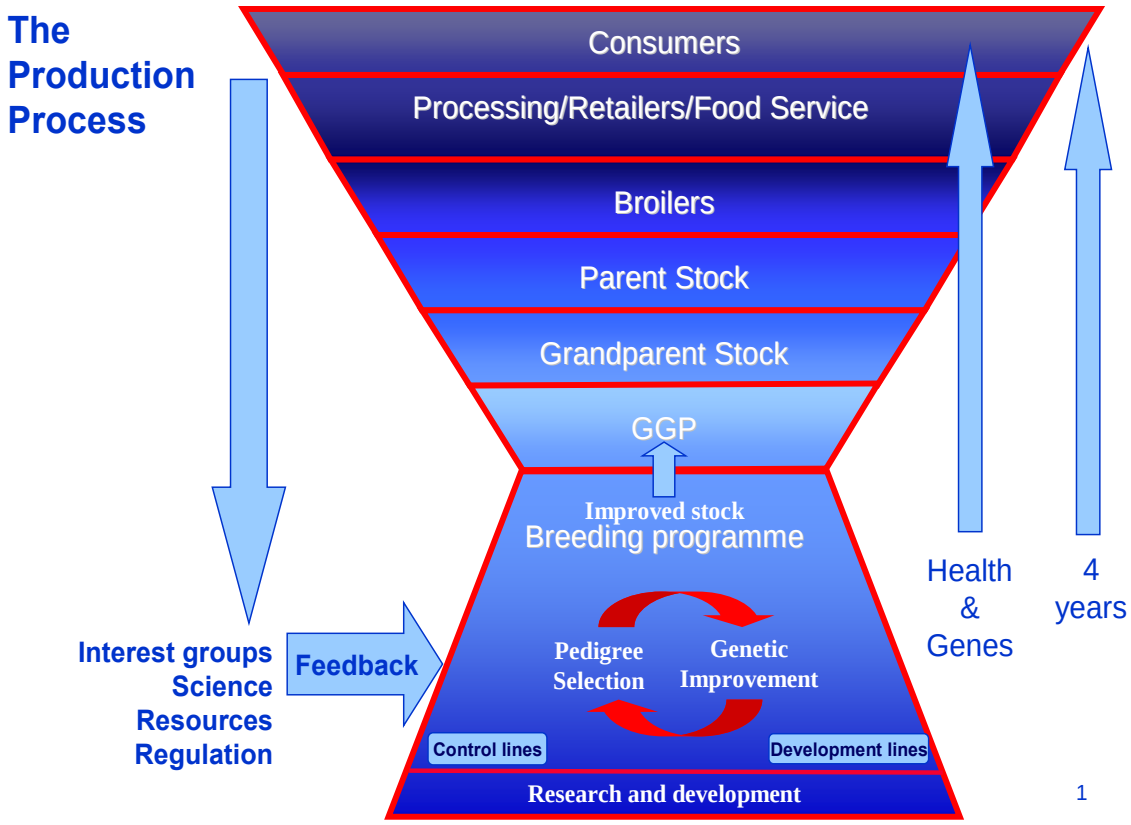

Fig 4. Representation of a modern breeding programme and its relationship to the production process

Thus the true representation of the primary breeding, genetic sector of the industry would be this inverted pyramid which "supports" the whole industry. This diagram also reinforces the fact that the breeding sector, with a lead time of 4 years to production even

after the contributory product lines have been developed, is truly leading and enabling the production sector. Where new products are involved the lead time is actually much longer than this since the research and development of lines before they can enter the "production" pedigree system is itself 4-6years. Thus the most likely lead time for a new product would be around 10 years. Even then this can only take place if the feedback mechanisms are in place and addressed to have identified the parameters required in the new product.

In the last forty years the company's genetic selection programme has become an increasingly sophisticated tool, achieving rapid balanced progress across the product range. Since the 1960's where live-weight was almost the only trait selected for, the number of traits has greatly increased, covering not only production traits but also traits related to the physical and metabolic support, livability and health of the selected bird.
This can be represented in simple diagrammatic form (Fig.5)

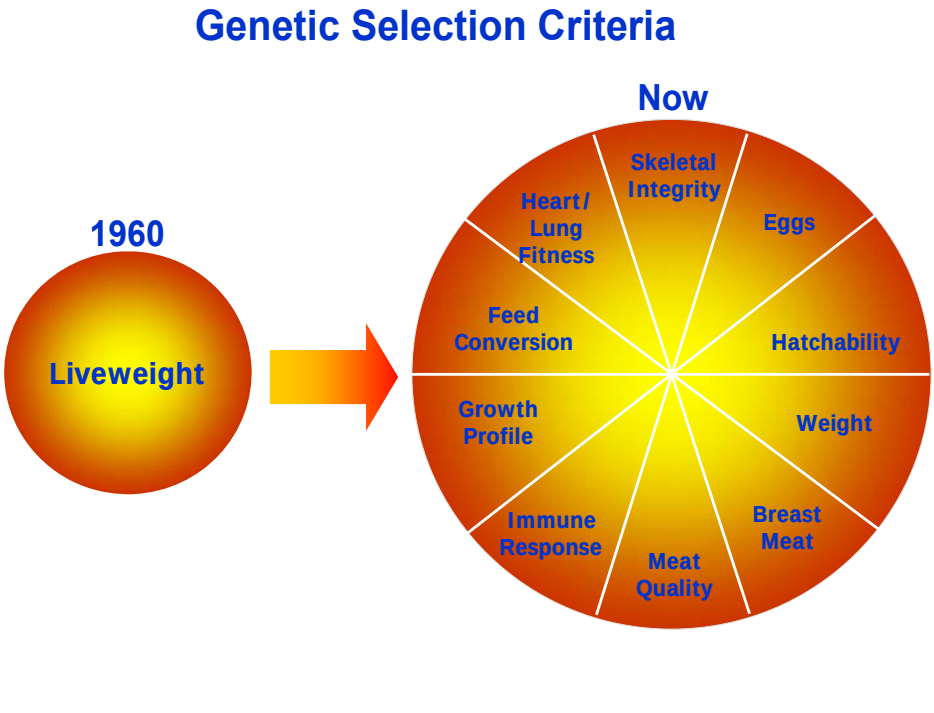

Fig. 5 Diagram of the development of Trait inclusion in a modern Breeding programme (N.B. Each sector would include several traits and sector sizes do NOT represent relative importance)

Unfortunately the basis for much of the criticism of broiler breeding assumes that the current programmes are still closer to the left side of the diagram than the right!

Some of these perceptions may originate from the fact that early descriptions of the breeding process often used the 'apple pie' analogy in which traits were assigned to slices of the pie. In this analogy it would be explained that putting more effort (larger slices) into a particular trait would result in less effort (smaller slices) in some other area – since there is only one pie. In the early days of mass selection and simple sire linked programmes relatively few traits were considered (3 to 5) and the technologies available were such that the analogy was valid.

In the modern programmes in which >40 traits may be considered it might be asked what happened to the apple pie analogy and the trade off between traits. Continuing the analogy we can explain that we now know that historically we were effectively dividing the slices of the pie using the extremely blunt handle of the knife whereas now we are making our cuts with the precision of a surgical scalpel or even a laser cutting tool. The extra traits have been acquired from what was previously the unrecognisable debris and crumbs of the earlier less precise systems.

The evolution of these multiple trait systems has been dependent on the development of genetic theory, computing power and technologies for more accurate and reliable measurement which can also be used quickly and easily with large numbers of birds.

Performance improvements in poultry breeding have been quite spectacular over the past 50 years and some of these are shown in the later section of this report which analyses the data collected by the NFU in UK for more than 30 years.

It is reasonable to ask the question "How much of the performance gains over the past fifty years have been down to genetics and how much is attributable to improvements in feed formulation, environmental control and husbandry systems." Havenstein *et.al*. have carried out an elegant series of trials, the latest reported in 2003, in which Modern strains of broilers were compared with the Athens Canadian Randombred Control Strain

established in 1957. By using also 1957 and 2001 feed specifications these studies could conclude that for growth rate, carcase and parts yield the genetic selection brought about by commercial breeding companies had contributed 85 to 90% of the change over 45 years whilst nutrition had provided 10 to 15% of the change. For feed conversion and mortality this estimate was more difficult since age and weight must be allowed for but the modern strain showed an 18% higher FCR on the 1957 diet. Combining genetic and nutrition influences the modern strain grew to an identical weight in one third of the time with a three times better FCR.

In Aviagen we have retained control lines for three of the lines which continued to be developed and contribute to the current broiler crosses. This is a unique situation since there is direct evolutionary lineage and the control lines can be used for a direct comparison with their current form and their crosses. Two recent studies have examined the impact that selection for growth rate and yield has had on broiler body composition and on broiler welfare as measured by leg health and mortality. (Fleming et al 2007a, 2007b)

The conclusion of the first study was that Genetic progress has resulted in significant changes in the body composition of the broiler. The Modern lines were significantly heavier with a higher proportion of breast meat (almost 54% higher on a weight basis) and a lower amount of body fat than the Control lines (Modern lines were almost half as fat as Control lines). In addition, Modern lines were shown to be more responsive to dietary protein than Control lines.

The second study examined the effects of the dramatically increased growth potential of broilers. In view of an apparent positive correlation between growth rate and the occurrence of leg disorders and rapid growth rate, it is widely presumed to be a fundamental cause of leg ill-health in the modern broiler. However, it has been previously recognised that the simultaneous improvement of growth rate and reduction in incidence of leg disorders is possible (Sørensen, 1992). Using data from genetic control strains grown alongside modern broiler strains it is possible to explore directly the impact that selection for growth has had on broiler welfare.

The differences in performance between the Modern and Control lines were significant. Despite these differences in performance there was no significant difference in mortality between the Modern and Control lines, whilst leg health was generally better in the Modern lines. The Modern lines in this study were selected using a Best Linear Unbiased prediction (BLUP) of breeding values for a range of traits including growth rate and leg health. The data from this study show that it possible to select for increased growth rate with no detriment to welfare as measured by leg health and mortality.

These studies show the considerable benefit of having control lines which allow direct comparison of genetic lines differing only in the selection pressure which has been applied to them. Studies which do not rely on extrapolation of data drawn from widely differing genetic material evaluated in different environments and under different nutritional regimes.

The genetic development of bird types or products

During the 1980's broiler breeds were often referred to as heavy or light types the former giving best broiler and Roaster (heavier weight/ older age) performance whilst the latter was much more reproductive. Birds with these differing attributes fitted the different markets at the time but it was soon realized that selection for broiler characters and improvements in reproductive characters could be achieved at the same time. That is, the relationship between broiler traits and reproductive traits did not have to be negative in the commercial situation. Therefore since that time strain crosses have been produced and developed which have much superior reproductive performance with little or no slowdown in the improvements of broiler characters. The data on broiler and breeder performance taken from the NFU records over 30 years (presented later in this document) show that whilst broiler daily gain increased and FCR decreased in line with selection expectations, the reproductive traits of egg and chick numbers also showed continuous improvements. Therefore in these data, growth rate and reproductive efficiency would show a positive relationship. This has been possible by the incorporation of multiple traits into a balanced selection decision for each line and hence the final commercial cross. It could now be said that the previously "recognized" negative correlation between broiler

and reproductive traits may have resulted from selection programmes which could not or did not combine the relative effects of traits in these two groups.

I would suggest that the literature is strewn with "well known facts" about the relationships between various selection parameters showing positive or negative correlations which may be then perceived to be detrimental to the animal. Many of these difficult relationships have been addressed by breeding companies for very many years and there are now different relationships which can be demonstrated. The livestock and the relationships within them are evolving as are the feeds supplied to them and the environment and husbandry systems in which they are raised. It would therefore be surprising if relationships became permanently fixed.

The skill of the commercial geneticists over many years has been to recognize these difficulties, to react to them and whenever possible change the selection direction and/or the relationships.

The time frame of genetic selection

In order to demonstrate the difficulty and complexity of the selection process this can partly be described using the example of leg health.

Since the 1970's leg health has been recognized as a major concern in broiler production. (in the late 1970's I personally inherited a breeding programme which already included a selection process for leg condition based on sire progeny testing – partial pedigree)
Whilst it was clear that some progress in improving leg health could be achieved by including this as a selection trait it was also recognized that at least fifteen separate conditions could result in "lameness". Therefore to make significant improvement in individual traits which could be shown to have significant heritability would need to be addressed. In the early 1980's several breeding companies collaborated in a study of Tibial Dyschondroplasia (TD) which resulted in the PhD thesis of John Mercer (1983). This showed that TD was heritable and could be reduced by selection.
It was then necessary to find a way to assess TD which did not involve killing the bird and dissecting the tibia – which is not useful in a breeding programme ! In the late 1980's

the Lixiscope was identified as a tool to view the Tibia in a field situation and specific selection against TD could begin.
From the late 1980's to the present day the Aviagen broiler lines have shown a consistent reduction in variation and absolute incidence of TD.
A recent study of commercial broilers in Denmark (Petersen 2005) has shown a reduction from 57% TD in 1999 to 0.7% TD in 2005. Whilst this change did not directly parallel the genetic changes in the pure lines making the broiler cross it occurred during a time of changes in nutrition and husbandry recommended by the breeding company in order to gain from the known genetic improvements.

I believe this is just one good example of the challenges which have been addressed in identifying traits suitable for selection and developing techniques to address these and then the importance of linking the genetic developments to correct management practices.

Timeframes for genetic change may be long and outcomes depend also on changes in management practice.

One significant feature of the chicken meat industry is the detail and accuracy with which performance and profitability can be determined. This is particularly so in the United States where a major Industry reporting service produces monthly reports on all aspects of the production and slaughter with aggregate costs ranked in tables showing detail to 0.01 cents. With production numbers in tens of millions per month for several major companies this is not unrealistic. The existence of these data in formal national recording systems and within individual large companies has been a major driver for the activities of breeding companies.

The influence of this accuracy of recording should not be underestimated, it represents one of the many feedback mechanisms to the breeding programmes.

Historically this level of accuracy in performance recording was absent from the production systems of other species.

Breeders and the Breeding Business

As a preamble to this section it is necessary to make some definition of the way that I will use the terms Breed, Brand, Product since these have evolved along with the development of the industry.
It could be said that in the beginnings of the commercial broiler industry a breed or brand or product or company almost always meant the same thing.
However the Breeds/ Brands have developed different products and companies have acquired other Breeds/Brands. This is an important point in any debate about the dangers of concentrating breeding into fewer companies. Comparing say twenty-five years ago with the present time it would be necessary to compare the number of *breeds* then with the number of *products* now. Concentration of breeding into fewer companies has both assisted and driven the development of multiple products within brands and development of the gene pools of different breeds to facilitate this.

The Breeding Business

The evolution of the breeding business has been from many specialized single line breeders to a lesser number with multiple lines and sometimes multiple species or types. During the 80's (and 90's) primarily there began a process of rationalization which resulted in certain companies focusing on certain types or species e.g. layers or broilers or turkeys. Intellectual and production efforts were focused on the issues and multiple trait selection broadened.

For a while the remaining successful companies were selling only one product albeit with the initial aim of it satisfying several "markets".

Early in the development of the breeding industry companies began to focus on one sector of the market and develop a product for that sector. In effect we had a relatively large number of "one product" companies and this was portrayed as strength. There was however an apparent cycle in the success of a company aligned to that product. With 10-20 companies and hence 10-20 products a few would be "right" for the market needs at any point in time. As the market needs changed other companies and products would become a better match and market shares would change. The industry requirements were

always satisfied but breed dominance changed in both time and across world regions. With the decline in the number of companies, effectively if the “one product” failed to match the needs of the market the whole company was doomed! The current remaining companies are those which have developed good anticipatory skills and hence product portfolios which address several sectors of the market. The “one product fits all” approach which was very successful for many years and served the industry well has been replaced with a multi product approach tailored to the specific needs of the markets.

The diagram below (Fig.6) indicates this as a balance between breeder performance and broiler/processing performance – **with an increasing influence in many markets of the processing performance which financially can easily swamp the others! The “trade off” calculations which are used to determine the economically optimum products clearly demonstrate this.** It is important to note however that although they may guide the direction of a selection programme these trade off calculations must be done outwith the breeding programme decisions. Historically a number of breeders attempted to use financial values as a selection tool – none of them remain in business today, probably because all the traits could not be accurately assigned a financial value. For example whilst mortality of a flock is relative – for an individual it is absolute!

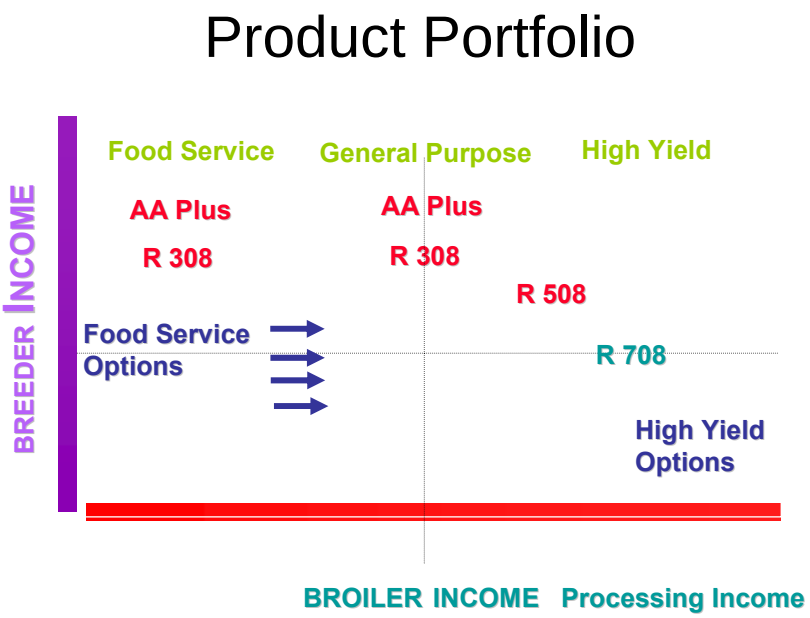

Fig. 6 Diagrammatic representation of a product portfolio to address market sector needs

The recent reduction in the number of companies and hence potentially a reduction in products was associated with the development of specialized lines and crosses for broilers [Food service , whole bird large and small and heavy yield type birds now used for complete meat stripping] and Turkeys [medium and heavy strains]. More recently with the arrival of molecular genetic technologies and genomics etc. the need for significant investment in an expensive process which can have applications across chicken types and even species there has been a certain "aggregation" of brands and products. This has reintroduced more choice to the overall market. However it is the market which ultimately determines the successful products which have usually been produced in response to market indications i.e. in anticipation of demands.

The breeding process has an extremely long time scale, 5 years from pedigree to broiler production, even after the product specification has been determined and the relevant lines have been assembled and developed. This latter process may be at least five years if a new product is not derived from existing lines. It is therefore necessary for the primary breeding companies to anticipate/ forecast the needs of the industry from a minimum of 5 years to potentially 10 years ahead. This must be a continuous ongoing process. Conversely it can be said that the production industry can only develop if the necessary genetic material is available. Thus there is a considerable synergy in the activities of the primary breeding companies and the future requirements of the industry (and its legislation). The feedback process indicated on Fig 4 (Page 24) is a very vital part of the activity of a successful breeding company.

This feedback may now come from any level of production or consumption or legislation or indeed across the total worldwide food chain.

The development of the modern Broiler breeding industry has been a very dynamic process. Individual breeders usually had single breeds and these gained success in time and region according to how well the product matched the needs of the market. A perception has often been voiced around the industry that breeds/ products have a finite life. This situation may have existed if a breeder committed excessively to certain traits in order to satisfy the then market without anticipating the way the market may change or the fact that markets around the world varied. Although we consider the development of broiler breeding from the point of view of Europe and USA, markets and broiler

industries quickly developed in all continents. Initially these markets “followed fashion” and took the breeds/ products which were available but gradually over time the breeding companies recognized different market requirements which required different products.

As I have just indicated the situation with regard to breeders and breeding companies has been a dynamic one and therefore any attempt to follow exactly the path of all companies from birth to death – or their present state could be the subject of a whole study. The following two figures give an indication of the recent evolution of breed/ brand ownership. Figure 7 shows a point in the late 70’s early 80’s with some of the breeds which were available from independent companies. This is by no means the complete list of breeders, simply it contains the major one’s at the time for whom logo’s are still available. The notable exceptions from this montage would be H&N, Kennebec, Tatum from USA, Marshall’s (UK) and Tegel and Steggles (Australia). This would lift the number to around 20 breeders worldwide some 25 to 30 years ago.

Fig. 7 A Snapshot of the major breeds available circa 1980

A process of breed/brand acquisition (and loss) over the last 25 years has resulted in ownership of the major breeds/brands by only four **major** breeding companies- Aviagen, Tyson, Hendrix Genetics and Groupe Grimaud. Three of these four have European ownership. A similar situation obtains in the Turkey breeding sector with Aviagen and Hendrix Genetics owning the three main brands.

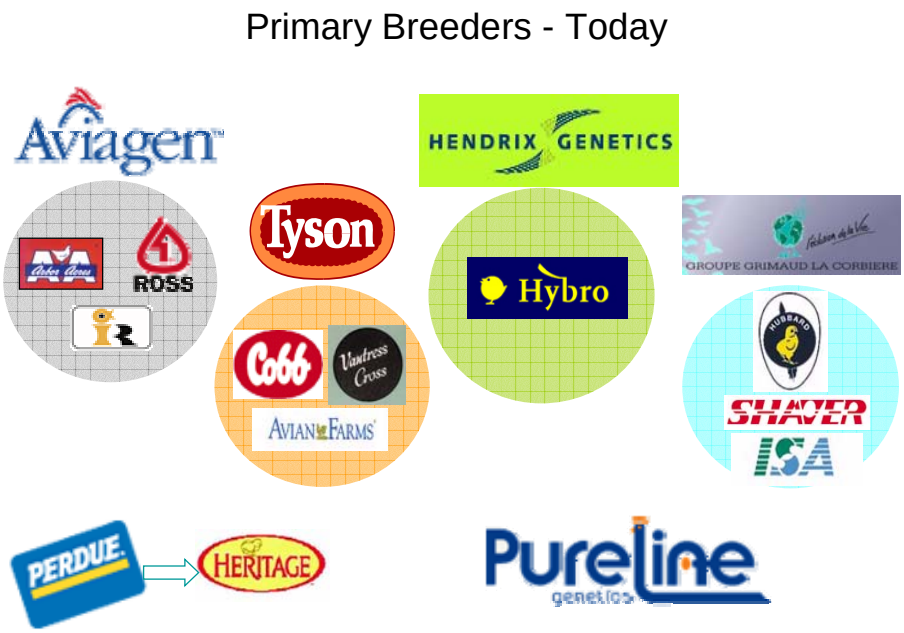

Fig. 8 Grouping and ownership of the main chicken breeds/brands in 2007.
(NB Groupe Grimaude no longer use the Shaver and ISA Breed names)

Depending on ones viewpoint the situation described in the figures above could be seen as positive or negative for the future of product diversity and opportunity for broiler poultry production worldwide. However as has already been indicated, new product development by breeders has run contra to the concentration of breeds in common ownership. In the historical situation the 14 logos represented no more than 15 products, each of which was the company's only available commercial product. Whilst it is somewhat difficult to be specific to a point in time regarding products which are available, examination of the 4 **major** company's current websites in early 2007 indicate that 17 products would be available at that time. It must therefore be assumed that the concentration of genetic resources and the loss of diversity often implied may not be as significant as has been portrayed. Clearly the fundamental strategies of the remaining primary breeding

companies have evolved significantly over the past 25 years and this change is closely aligned to their survival.

We have seen that the techniques and technologies involved in breeding have undergone continual refinement and development since the beginning of the 20th century. Several of the changes in the last 50 years have been as a direct result of the development of computers and the ongoing improvements in their processing capabilities. Nevertheless many companies remained in business until the 1980's using the basic mass selection techniques based on phenotypic measurements, sometimes with a simple sire pedigree system for the all important male lines.

Interestingly whilst Artificial insemination became the cornerstone of Turkey breeding and thence the production systems this technique has relatively little relevance in meat chicken breeding programmes or production. Around twenty years ago several of those people with experience of A.I. and Turkey breeding counseled the broiler breeders to avoid developing a dependence on that technique.

Those that heeded the warning survived!

I have already referred to the fact that the breeding industry is often criticized for its focus on growth rate with an implication that this is to the exclusion of other traits. However even in the early mass selection programmes traits such as leg condition and body conformation (the precursor to yield measurement) had a significant influence on the breeding goals and impact on the final product. These "Yield type or Roaster" birds capable of growing to heavier weights gained market share in the UK in the 1980's compared with the more reproductive types. This was driven in part by the retail need at the time for whole fresh birds which could be displayed without a label covering any breast blemishes. Incidentally this development removed a bird welfare issue and led to the development of higher yielding strains. The breast blemishes had resulted from a combination of sharp keel bones and poor litter conditions leading to pimples, bruises and blisters. Changing the shape of the bird effectively removed some of the components contributing to the damage. The driver for growth rate selection was not only that this is correlated with profitability but also that bird weight and bird age were the two

parameters which all producers could measure and record.

For many years this meant that it was a major feature of decision making by the producers/buyers of the products.

In many countries even today the critically important parameter of feed conversion is not measurable in any detailed way.

The UK Industry

Throughout this presentation some of the evolution of the UK meat industry has been implied.

This presentation offers the chance for some of the more specific points should be laid out.

During the 1970's there were 5 or 6 breeds represented in the UK, the NFU Bulletin recorded 55 hatcheries supplying broilers and an important consideration there were at least ten educational establishments providing courses aimed at supporting the Poultry industry. For comparison the current figures would be 4 breeds (available), <20 broiler hatcheries and 2 or 3 educational establishments – offering mainly partial courses or modules.

NFU Data

In the United States there are long term records of industry performance and economic statistics compiled by Agristats and Agrimetrix. In addition to the month by month management information which these data sets provide to the contributing companies they also generate a valuable data set on long term trends in the US industry. There has been no directly comparable data set collected in Europe or the UK with the exception of the Data collected by the NFU from 1971 to 2003. These data concentrated on the performance and economic statistics (costings) of the members who were either contract broiler growers or broiler breeder flock farmers.

I believe it is relevant to include in this document some data which represents a consistent, independent source of UK performance over a significant period of time. I am indebted to the NFU and in particular John Parsons (editor 1994 to 2000 [Temperton Fellow #9 – 2000]) who provided me with a complete set of both the Broiler and Breeder Bulletins one of which, the 100th issue already contained some summarisation split into 5 year periods. Beginning in 1971 this went through to 1996 and it was possible to add the 2001 figures before the publications ceased in 2003. Where possible I have added some comparable data for 2006 for completeness. These data cannot of course be taken as representing actual figures for all production in the UK i.e. the integrations are not

included but its value is its consistency, as evidenced by the growth and FCR data. *(By coincidence these data cover exactly my own involvement with the poultry industry which began in the UK at the AFRC Poultry Research Centre in April 1971.)*

In his 100th edition review the Editor noted that the annual figures used are not totally comparable, as data were collected in different ways for different periods of time but the trends are clear and well defined. I have re-examined the original data in order to determine which sets I am comfortable to reproduce. It is important to remember that these data represent the breeds used across the industry at any point in time but the major two featured in all years though in varying proportions.

Broiler Data

The production data reflect a remarkably consistent linear improvement in both Daily gain and FCR. Daily gain expressed as grammes per day of life (Fig. 9) removes the need to specify ages and until the last few years when average killing weight increased slightly was not affected by this. The regression indicates an annual improvement (in the field) of 0.89g per day per year – equivalent to 37.5 g per day to 42 days. This has an R^2 value of 0.989- a remarkably good fit for field data over this time

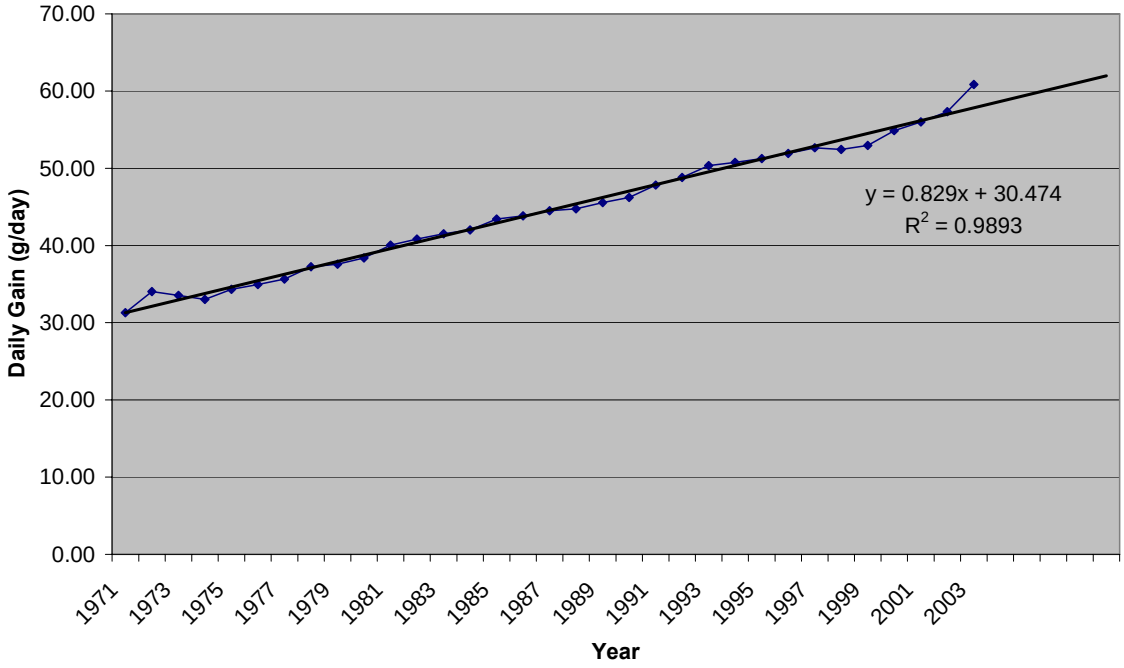

Fig. 9 Long term trend broiler daily gain (g/day) from UK industry data set (NFU Broiler Bulletins)

A linear regression has been fitted to the FCR data (Fig 10) which shows a reasonable fit (R^2 = 0.942) and an annual improvement of 0.016. This represents a major contribution to the profitability of the industry in terms of reduced feed inputs. Additionally it is a major reduction in waste outputs which are having an increasing relevance in the light of IPPC regulations.

Close examination of the data plot might suggest an acceleration in the rate of improvement. A simple calculation between 1971 and 1987 gives an improvement of only 0.0118 per year whereas the same calculation over the remaining period to 2001 gives 0.0214. Almost double the rate of improvement. This acceleration in the rate of FCR improvement would be expected from the increasing sophistication of the selection procedures for Feed efficiency over the last 20 years and hence field performance over the last 15 years. The further recent development by Aviagen of the "lifetime FCR" techniques should result in further acceleration of improvements in this trait (see page 50).

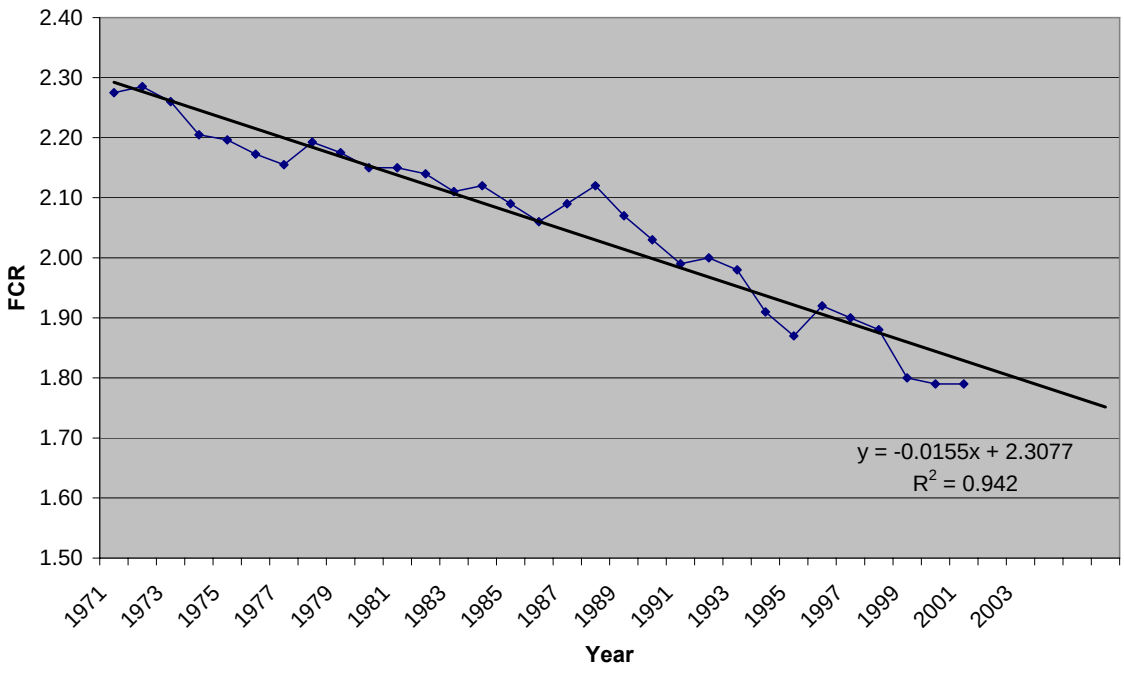

Fig. 10 Long term trend in FCR (kg feed per kg liveweight) from UK industry data set (NFU Broiler Bulletins)

As explained these data cover all breeds used over the data collection period but the fact that they show a good linear fit and a steady improvement in performance implies that over this extended time frame the breeds had to match each others performance. Though

having said this at certain times the then current leader would have a significant market share.

To conclude this section on broiler performance the change in average kill weight in the UK (Fig.11) is very similar to that seen in the USA which reflects both changes in the markets and recognition of the efficiencies of growing to heavier weights. Of course this is only possible if the products delivered from heavier carcases can be matched to the market needs. The development of a new market sector of having whole complexes producing birds averaging 3 and 4 kgs which has developed recently in the USA has not yet transferred to the UK and Europe.

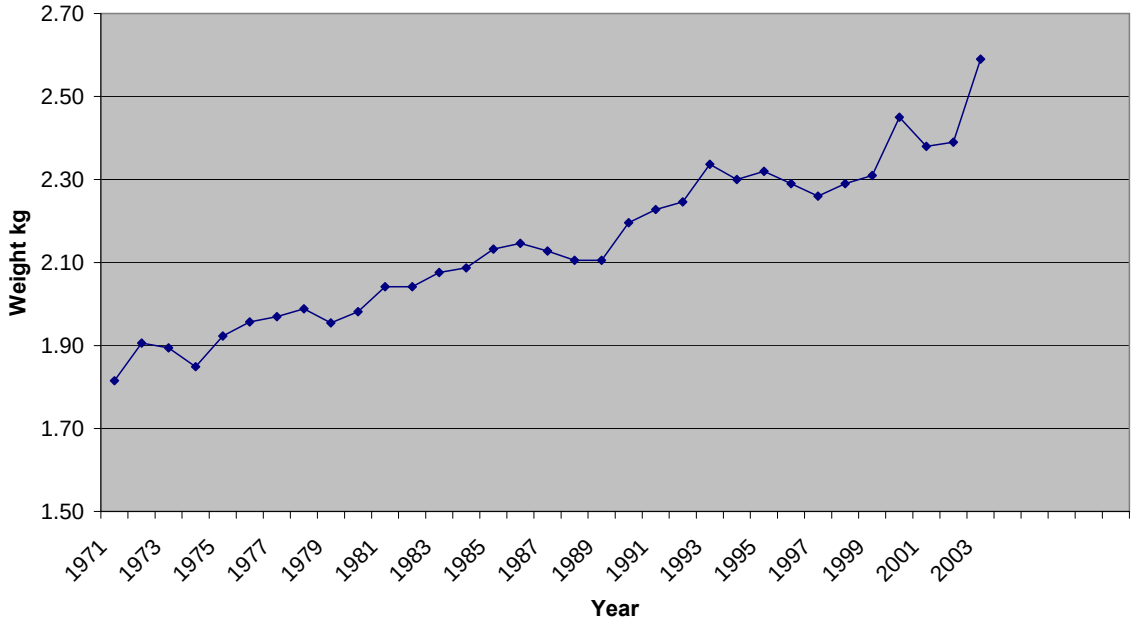

Fig. 11 Change in average slaughter live weight over time

These data also show another feature of the poultry industry – mirrored from repeated data sets worldwide- that is the accuracy and precision of data on which performance and hence breed buying decisions are made.

The financial implications of performance variations of only 1or 2% are

a) measurable

b) known and

c) acted on.

In this respect I believe the Poultry industry is significantly ahead of other agricultural livestock sectors although their sensitivity is fast improving. To return to the comments at the introduction of this section the comparative data collection systems which are available in the USA are much more detailed and more comprehensively used than anywhere else in UK or Europe. This willingness to supply and share data – anonymously – for benchmarking can be of considerable value to cost reduction in the industry. It allows realistic goals to be identified and pursued. **I believe the European industry has been particularly slow to see the value of such cross company data collection** – concentrating rather on the perceived disadvantages of such a system and apparent advantages of confidentiality (secrecy) of data release. A further argument has often been promoted that the various countries and companies have no standardisation of data collection and therefore any attempt at comparison is invalid. A main feature of the main system used in the USA is its focus on direct collection of data and standardisation before any analysis. **To repeat I believe that over many years European producers have missed a significant opportunity by failing to have any routine accurate benchmarking system.** Furthermore using a system of production efficiency measurement (EPEF, PS) which ignores direct cost information may have focussed attention on the wrong drivers.

Breeder data

Unfortunately the NFU breeder data is not such a clean and consistent data set as that for broilers and I have therefore been unable to collate as reliable and useful analyses as for the broilers. The data for flock farmers on breeder performance has significant gaps and therefore Aviagen company data was used for additional comparison over the latter period. (Fig. 12) Of course this added data relates to only one breed but the broad trend of improving performance is still evident. The data supports the breeding company aims of providing an improvement of 1 chick per breeder per year which represents a 25 to 30% improvement over the last 25 years. Over the same time period we have seen broiler daily gains and FCR showing considerable improvements. Although the data does not extend far into the 1970's I believe we can see some indication of the higher breeder performance at that time which would have been when the breeds were often the lighter, higher egg producing types before the serious introduction of higher yielding-lower reproductive strains. This transition is probably the point at which some critics of broiler breeding were persuaded that growth and meat yield were negatively correlated with reproductive performance. **I believe the long term trends show that the breeding companies and their geneticists recognised this problem and have for over 20 years delivered stock with positively correlated outputs for both broiler characters and reproduction.**

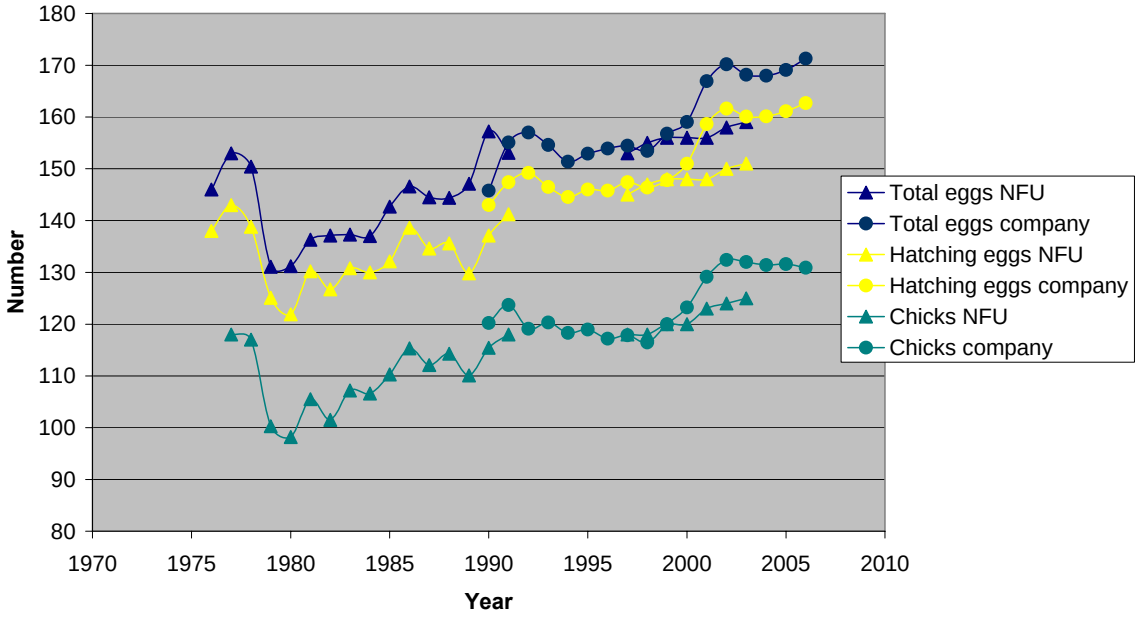

Fig. 12 Long term trends in breeder performance – Total eggs, hatching eggs and chicks. Data from two sources combined

Cost Data

The NFU bulletins also contain data on costs as they apply to certain sectors of the Uk industry over time. Whilst they do not represent costs for the integrated companies they can demonstrate long term trends and hence relative changes over time. The major inputs to the breeder operation are feed and parent chick cost. The following graph (Fig.13) shows changes in breeder feed cost in pence per bird (lifetime to 60 weeks) and the day old parent cost over the last 30 years.

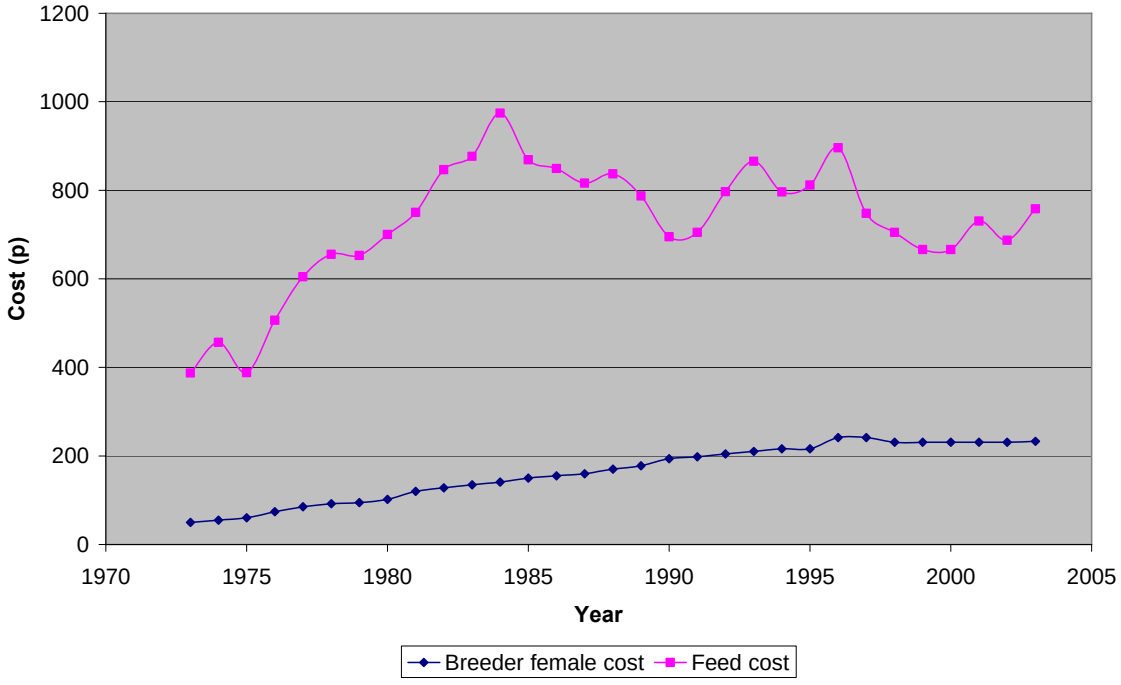

Fig. 13 Changes in major input costs over time –Day old breeder female and total feed cost to 60 weeks.

For the breeder sector we can also follow the change in first input cost – the parent breeder chick – over time. Fig. 14 shows the relative change in price of a one day old parent chick for each five year interval from 1973 to 2004. In the initial five years of this period breeder price increased by over 80%. Over time this % increase has steadily declined. As the quality of the genetic potential delivered to the start of the chain increased its relative cost decreased significantly.

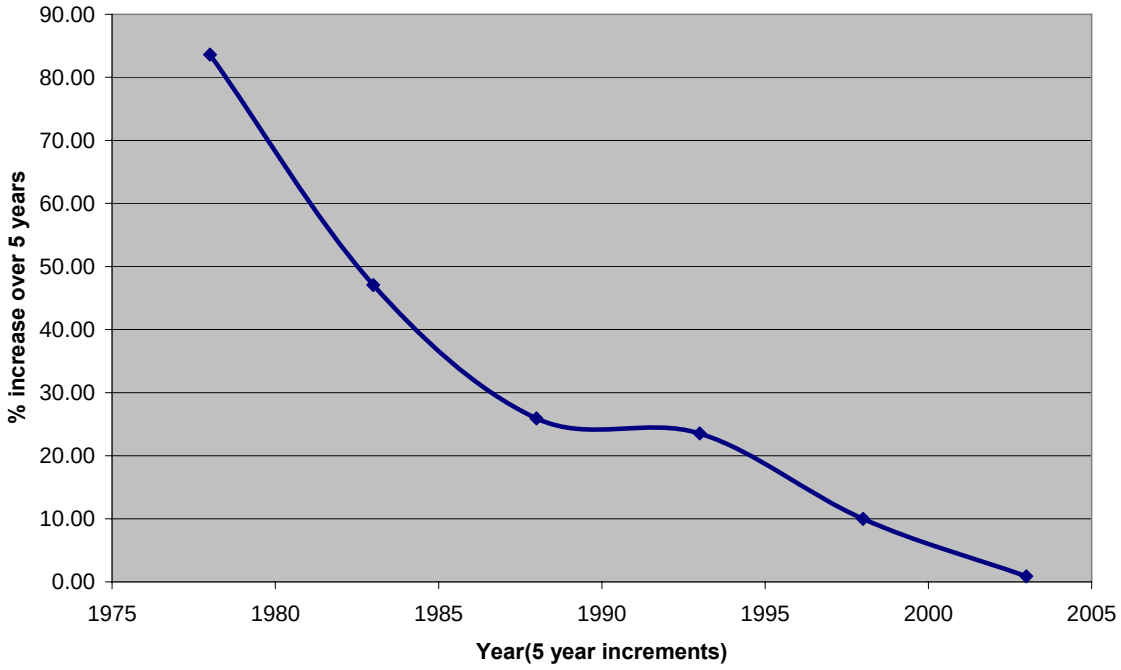

Fig. 14 Relative increment in breeder price for each five year period

The data on returns to the contact egg producers in the NFU data are quite incomplete but the graph (Fig. 15) covering the early period shows a significant change in the prices paid per hatching egg or per chick in the early 1980's. After this point rates of increase slowed probably linked to the levelling of feed costs (Fig 13)

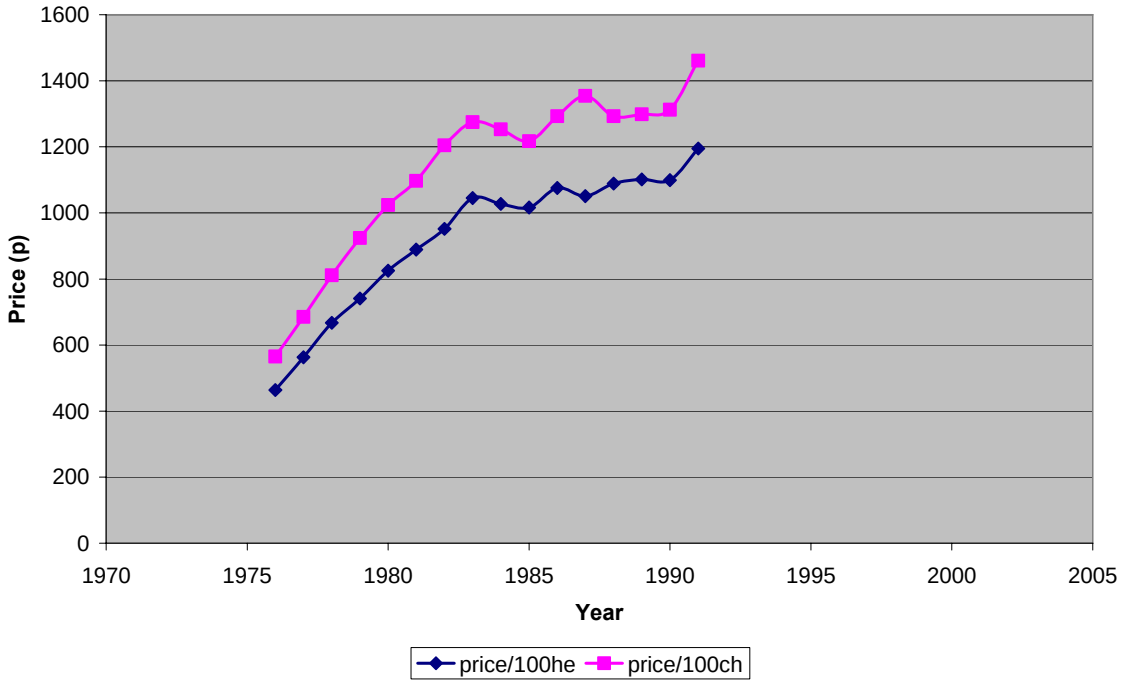

Fig. 15 Prices paid to the flock farmer per 100 chicks or 100 hatching eggs

Moving on to the costings data from the Broiler Bulletins which are much more complete it is possible to plot changes in the major input costs over time (Fig. 16), feed prices have clearly fluctuated considerably. Chick costs have increased but the rate of that increase has slowed. Energy and labour and catching cost have remained quite steady over the last 15years which presumably reflects the increasing farm and house sizes which lead to efficiencies and hence savings in both these costs.

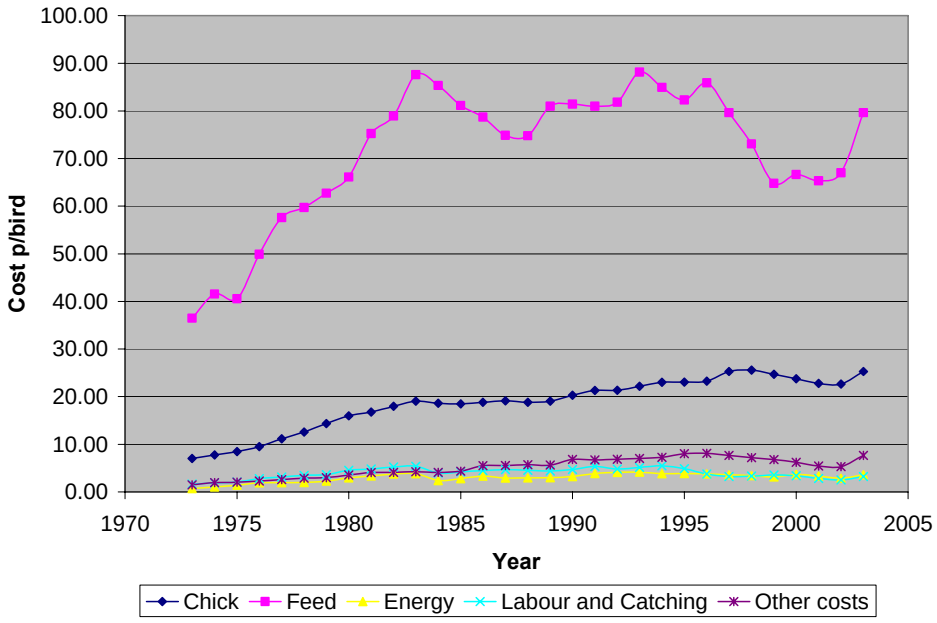

Fig. 16 Major input costs to produce a broiler chicken to slaughter weight

If we examine the two major costs *as a percentage of the total* over time we see a slight fall in feed cost which in addition to the absolute cost of feed must be reflecting the significant fall in FCR. There is then a relative rise in % chick cost. Interestingly the change in both these relative costs is almost perfectly linear over a thirty year period. However close examination of the data over the latter years might suggest that the linear trends were not continuing leading to a question of what any forward projection should be.

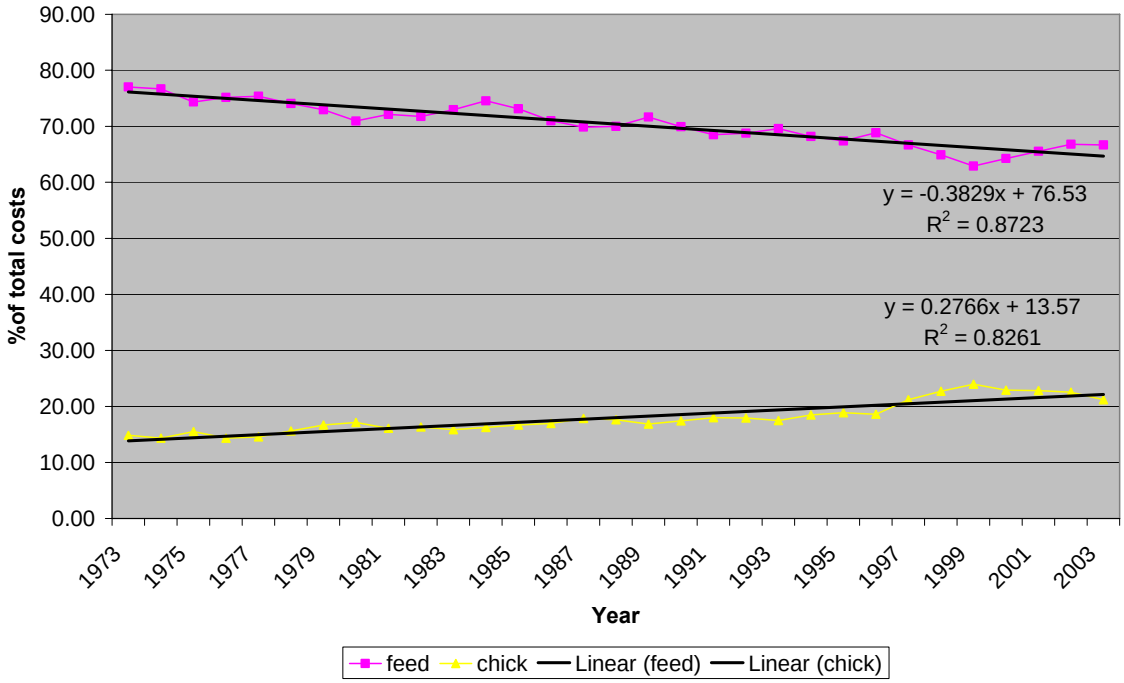

Fig. 17 Changes in feed and d.o.chick cost as % of total costs over time

NFU Summary

The data set which is available from the NFU bulletins shows quite remarkable and logical steady changes in many of the parameters measured. This suggests that the data set is valid and represents at least the trends in performance and cost over more than 30 years even if it does not directly reflect the actual cost within integrations.

The genetic changes are steady and consistent for both broiler and breeder parameters. The long term success of two breeding companies which operated in this detailed and critical market for both qualitative and quantitative measurements reflects the value of learning the craft of breeding in such an environment. The steady consistent increase in measured performance parameters means that only a product which can match these standards will survive and succeed in the market at any point in time. The early influence of the retail companies with regard to traits associated with conformation, quality and welfare provided an extremely valuable stimulus which later ensured that products were developed with demonstrable yield and health values.

In many respects the demands of the UK market led the UK based breeders to develop products which subsequently found interested buyers across the world.

Discussion

Throughout the factual part of this report I have added relevant comments and views in order that they could be read alongside the information to which they related. This discussion section will therefore simply attempt to review the main points of the report and look to some of the future opportunities and responsibilities for a breeding company as part of the World wide poultry production industry.

The main message of the review of global production is that poultry meat continues to see significant increases in consumption and hence production. This is predominantly in the chicken sector. The trend is towards more production in the developing world for consumption both in developing countries and for export to the developed countries. It can be expected that as the interest in and influence of climate change accelerates we will see further concentration of production in the regions producing the major feed raw materials, Brazil, USA, Southern Russia and eventually Southern Africa.

The essential theme of the genetics section is the close parallel of advances in science of genetics and practical breeding. For almost a century commercial breeding companies have maintained close contact with the science and were quick to utilise the new techniques. This situation continues with the new science of genomics where the massive commercial data sets on phenotypic traits are being made available along with genotype information to develop the next generation of computer analysis.

It is of concern that the aims, methods, objectives and achievements of commercial breeding programmes have often been misunderstood, even by many people close to the industry, but specifically by consumers and society. **This highlights the need for an industry such as ours to make a greater effort to explain its position, aims and objectives. This must be seen as one of the aims of this report.**

The skill of the commercial geneticists over many years has been to recognize the difficulties of selecting for apparently incompatible traits, to react to them and whenever possible change the selection direction and/or the relationships. Closely related to this is the challenge, which has been successfully addressed, of identifying traits suitable for selection (those which are heritable) and then developing techniques to correctly measure

these. The timeframes for genetic change may be long and the final outcome may depend also on changes in management practice. Recognizing the importance of linking the genetic developments to correct management practices has had to be addressed by the successful breeding companies. However correct the DNA is in the livestock supplied, support must also be given to ensuring development of the correct HUSBANDRY and stockmanship skills by the end users. The technical support and service teams for any breeding company has been integral to its success.

The essential synergy of a successful breeding company is that the geneticists ensure the correct genetic content of the livestock supplied and the technicians ensure that it is correctly expressed in the customers enterprise.

The technical teams and ultimately the geneticists can only respond to objective accurate information. The influence and therefore importance of this accuracy of recording should not be underestimated; it represents one of the most important of many feedback mechanisms to the breeding programmes. It is worth restating that historically this level of accuracy in performance recording was absent from the production systems of other species and is one of many reasons why poultry breeding and production has achieved its leading position in animal agriculture.

Throughout the development of broilers we have seen an increasing influence in many markets of the processing performance which, financially, can easily swamp the others! The “trade off” calculations which are used to determine the economically optimum products clearly demonstrate this. Many companies saw the opportunities of this and included it as part of a balanced breeding programme. Equally, some companies either failed to recognize the true significance of yield: by either under or overestimating its importance. Economic evaluation must give broad direction to breeding strategy but cannot be applied within the selection decisions.

The essential role of feedback in developing strategy in a breeding programme has already been mentioned in regard to data collection. However this feedback has to be much broader and must now come from all levels of production or consumption and anticipate legislation. In view of the global nature of this industry all aspects of the worldwide food chain must be considered with a view to potential needs and

developments. In view of the long term nature of breeding and product development which I have described the most useful feedback is visionary and anticipatory (if this is not contradictory to the concept of feedback!)

I have highlighted the absence of *comparative* objective measurement systems in some markets, however most individual companies would have their own detailed data sets. The accuracy and precision of data on which performance and hence breed buying decisions are made is unique to the poultry industry and mirrored in repeated data sets worldwide. This meant that for many years this was a major feature of decision making by the producers/buyers of the products. The consistency of the overall improvements seen in the NFU data set would indicate that unless a product could lead or match this trend it would not feature in the market.

This does not detract from my earlier statement that I believe that over many years European producers have missed a significant opportunity by failing to have any routine accurate *benchmarking* system.

Looking to the future I can only draw on the information available from my current employers and the evidence from their past. Throughout the development of the breeding and selection process innovation has been sought and utilized at Aviagen, we have many examples.

From the field of human medicine the oximeter, which measures oxygen carrying capacity of the blood, has been adapted and applied to ensure animals have strong hearts and healthy lungs.
Aviagen was the first primary breeding company to utilise the lixiscope, a hand held, real time x-ray device, in selecting for skeletal leg strength.
More recently the company has successfully adapted radio transponder and weighing technology to monitor feeding behaviour and feed conversion rates. This unique system of "Lifetime Feed Conversion" recording allows assessment of the behavioural drivers of feeding, meal frequency, meal amounts etc. which may have significant impact on the overall efficiency of feed utilization. At a time when the Global Warming Potential of various agricultural sectors is under close scrutiny (Williams *et al* 2006) this new

technique should further accelerate the improvements in FCR and reinforce the leading position of broiler production in this regard.
Ultrasound measurement of muscle development has been routinely used for many years as one of the strategies to improve meat yield. The new generation of these devices allows improved visualisation of the anatomical structure of the bird to ensure the correct balance of meat deposition.

In an increasingly competitive market, Aviagen has continued to invest in research and development techniques and the company's focus is now on efficient progress across more traits. The sequencing of the chicken genome and its public release during 2004, coupled with successes in initial studies and a reduction in the cost of typing markers, has led Aviagen with the assistance of the Scottish Enterprise Research and Development Plus programme, to make a multi-million pound investment in their Genomics Initiative. An extension of the company's existing technologies, genomics, provides additional information about the products' existing natural variation and provides a new tool for further stock improvement through selective breeding. The uptake of genomic approaches in breeding programmes of other livestock species is growing, and Aviagen is confident of the potential for genetic markers in poultry breeding. The development of the research will lead to further identification of genetic markers for improving selection accuracy in current and new traits, including disease resistance.

In conclusion

I would say that I believe the long term trends show that the breeding companies and their geneticists recognised the problem of conflicting biological and performance traits and have for over 20 years delivered stock with positively correlated outputs for both broiler characters and reproduction and have addressed many aspects of the health and welfare debate successfully.

In many respects it has been the demands of the UK market over the last 50 years that led the UK based breeding companies to develop the genetic skills and from those, the superior products which subsequently found interested buyers across the world.

Significant Contributions of H.A.A.C. and N.I.P.H. to the Evolution of Poultry Meat Breeding in the UK.

A Temperton Fellowship presentation would not be complete if it did not acknowledge the contribution which Harper Adams and the National Institute for Poultry Husbandry has made to the topic of the fellowship.

Following my observations earlier that much of broiler development was a synergy of inputs from USA and Europe we should note that the establishment of N.I.P.H. at Harper Adams was a result of the sabbatical visit of Professor Willard C .Thompson of New Jersey College of Agriculture in 1924.

Since the creation of the Institute the list of students is a testimony to the contribution which has been made to the UK poultry industry by their education. The list of activities of the College and Institute also demonstrate the fundamental place that they have had in developing the Poultry industry in the UK.

Finally I should specifically acknowledge the education by the college of two of my current colleagues David Butler (1963) and Ian Panton (1966). I have enjoyed and benefited from my interactions with both over many years as competitors and colleagues.

David is the longest serving and world respected member of the Ross and later Aviagen technical teams. David’s contribution to the management of broiler breeders and broilers has been immense and many hundreds of technicians and company managers worldwide have benefited from his knowledge and wisdom.

Ian held many positions during his career at Ross Breeders and then Aviagen culminating in his role as CEO of Aviagen Group which he has led to be the world’s largest and most successful poultry meat breeding company.

The last word

The last words in any report on Evolution should be those of Charles Darwin. I am indebted to Dr Trefor Campbell (Temperton Fellow 13, 2005) for using the following quote which I believe could summarise my report.

"It is not the strongest of the species that survives,
but the ones most responsive to change."

Charles Darwin

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