Performance changes in poultry and livestock following 50 years of genetic selection

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Introduction

The science of Quantitative Genetics came into existence during the late 1940s and early 1950s, founded on the teachings of individuals such as Jay L. Lush and Arnie Nordskog at Iowa State University, Leon J. Cole and Arthur Chapman at the University of Wisconsin, R. George Jaap at The Ohio State University, Gordon Dickerson at the University of Missouri, Don Warren at Kansas State University, Fred B. Hutt at Cornell University, I. Michael Lerner and Everett Dempster at the University of California, D. S. Falconer and Alan Robertson at the Animal Breeding and Research Organization in Edinburgh, Scotland, and Sewall Wright at the U.S. Department of Agriculture. These individuals, their students, and many others changed the art of animal breeding to a science based on quantitative statistics that can be used for the selection of better performing populations of livestock and poultry. Students of the above individuals were hired to teach and conduct research on quantitative genetics at institutions throughout the U.S. land-grant system, at international agricultural institutions, and at worldwide specialized breeding companies.

Quantitative genetics and breeding procedures have continued to be taught at most agricultural universities since the mid to late 1950s. Those involved in teaching also continued to conduct research and to develop improved mathematical procedures for use in commercial breeding programs. The advent of high speed computers during the 1960s allowed commercial breeding organizations to gather, quickly summarize, and analyze huge amounts of data from their breeding populations. Commercial geneticists then used individual and family information to estimate breeding values for each individual's traits, and an index of those values that predicted the animal's overall genetic merit was then used to select the most meritorious males and females to produce the next generation. Those assessments and selections were done each generation to continue the genetic improvement over time. This process has been used over and over during the past 50 years, and it is the purpose of this paper to provide a brief summary of some of the evidence published over the past 10 – 15 years that demonstrate the changes in the performance of poultry and livestock.

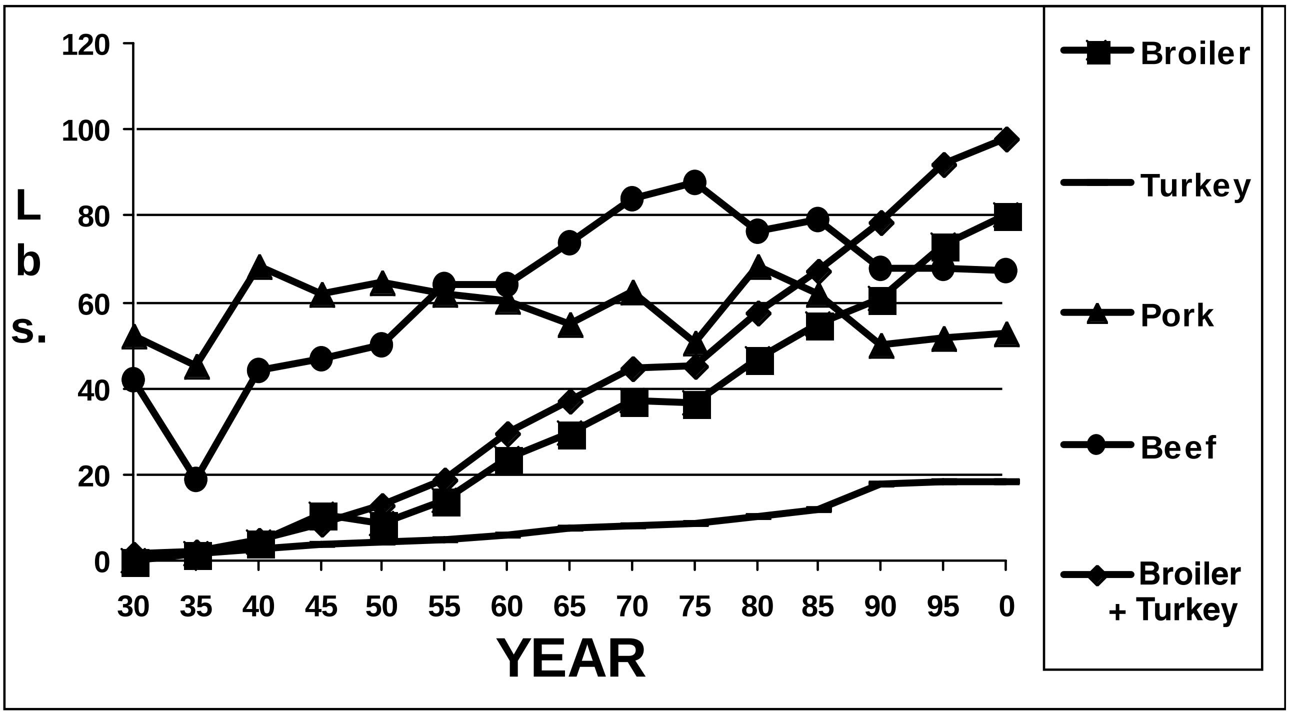
Trends in population growth and consumption of animal products

Not only has the performance of our livestock and poultry changed, but many aspects of the world have changed as well. Before providing evidence as to how quantitative genetics has affected U.S. and worldwide animal production, we need to begin with a little background on the food-animal industries, and specifically how meat and egg consumption has changed over the past half-century, especially in context with the changes in our human population. The animal industries and the types of animals we produce for human food are very different today from what they were 50 years ago. The following summary shows not only how animal production has changed, but also how the human population has changed in terms of the consumption of animal foodstuffs.

The U.S. population doubled from 151 million in 1950 to over 300 million in 2006. If the current trend continues for the next 50 years, the U.S. will have a population of 550 - 580 million people by 2050. Concurrent with the change in the human population is the trend of fewer and fewer people involved in food production. From 1950 to 2000, the percent of the U.S. population engaged in agriculture has dropped from about 10 percent to about 2 percent. At the same time, the number of farms steadily dropped, and the farms producing food have been getting larger and larger, especially during the past 50 years. The number of farms decreased from 6.2 million in 1960 to less than 2 million today.

How do these trends relate to the subject of this paper? Let's take a look at what has happened to per capita meat consumption during this same time period (Figure 1, USDA ERS). The U.S has experienced a dramatic change during the past 50 years in the types and amounts of meat being consumed, as well as in the types and amounts of animals grown to meet consumer demands. From 1930 to 1950, pork was the meat of choice. During the 1950s through the 1980s beef was the most heavily consumed meat, but from 1985 until today, poultry has become the most consumed meat in the U.S.A. Since about 1993, more broiler meat has been consumed each year than any other type of meat.

Figure 1: U.S. Per Capita Meat Consumption 1930-2000 (Source: USDA)



The estimated change in total meat consumption in the U.S. from 1950 to 2000 is shown in Table 1. Meat consumption tripled during the past 50 years. The increased production and resultant increase in animal waste is a result of the animal industries' response to meet increased consumer demands. If the U.S. human population continues to increase at a similar rate over the next 50 years, input resources will become increasingly taxed and it will become more and more difficult to maintain meat production for this level of demand in the future.

Table 1: Meat Consumption in the U.S. in 1950 and in 2000.

Type of Meat	1950 Per Capita Consumption lbs.	kg	1950 Total U.S. Consumption (1000 Tons)	2000 Per Capita Consumption lbs.	kg	2000 Total U.S. Consumption (1000 Tons)
Beef	50.1	22.8	4,526	67.0	30.5	9,426
Pork	64.4	29.3	4,862	53.0	24.1	7,457
Broiler	8.7	4.0	657	80.0	36.4	11,256
Turkey	4.1	1.9	310	18.1	8.2	2,546
Total	127.3	57.9	10,355	218.1	99.1	30,686

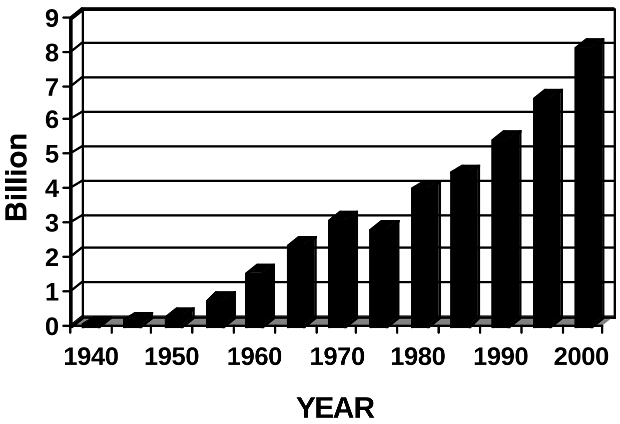
The current level of meat production would have been a lot more difficult if the agricultural community had not applied the scientific information that has come out of our universities and research institutions over the past 50 years to improve the performance of the animals. Science has been used to develop new and improved feedstuffs, it has been used to improve the nutrition and growth rate of the animals, it has been used to prevent devastating animal disease situations, it has been used to improve the general health of the animals, and it has been used to produce environmentally controlled growing facilities which allow us to maximize the growth and efficiency of our livestock and poultry. The greatest single boost to efficiency, however, has been the application of the science of quantitative genetics to select for faster and faster growing meat-type animals, for more efficient egg layers, and for cows with increased milk yield. The following is a brief summary of published data from the scientific literature that support this conclusion.

Several sources of data will be used to illustrate the changes that have taken place in the efficiency of the animal populations currently used for meat, milk and egg production. Changes in efficiency have greatly reduced not only the amount of feedstuffs required to produce a unit of product, but also the amount of waste produced, compared to the inefficiencies in the 1950s.

Broiler data

Almost any food-animal species could be used to demonstrate the changes that have taken place in the efficiency of animal production, but the best example comes from the broiler industry. Figure 2 summarizes the numbers of broilers produced in the U.S. from 1940 through 2000. Broiler production has increased from about 280,000 in 1950 to over 8.2 billion in 2000 (USDA, 2006), and will likely surpass 9 billion in 2006. Many factors have contributed to the development of this agricultural industry, but genetics has played a very major part in the industry's growth.

Figure 2: U.S. Broiler Production, 1940-2000 (Source, USDA).



A number of studies have been conducted over the past 25 years that clearly document the changes that have taken place in broiler performance (e.g. Sherwood 1977; Havenstein et al. 1994 a,b; Havenstein et al. 2003a,b). These studies used the Athens-Canadian Randombred Control line established in 1957 and modern strains from 1976, 1991 and 2001 to measure growth rate, feed conversion and yield when the broilers were fed 1957 and modern feeds. Body weight data from the Georgia Station (Havenstein et al., 1994a) show that the ACRBC grows exactly the same way today as it grew in 1957 when it was first established as a randombred strain.

Havenstein et al. (2003a,b) summarized the data from two broiler studies carried out in 1991 and 2001, and the growth rate data from their summary is provided in Table 2. The data show that the modern broiler in the year 2001 was nearly five times as large at 42 and 56 days of age as the 1957 randombred broiler, and that the increase in body weight over the 10 year period from 1991 to 2001 was 49.9 and 81.6 grams/year at those two ages, respectively. Edible carcass yield has increased by 12.3 and 13.6 % at 42 and 56 days of age in the 2001 birds in comparison with the yield of the 1957 ACRBC. The data from the Sherwood (1977) and Havenstein et al. (1994a, 2003a) studies consistently show that about 85-90 percent of the change in growth rate has been due to genetic selection, only 10-15 percent of the change is due to improvements in nutrition and nutritional management.

Table 2: Live body weight of modern broilers reared on a modern diet vs. ACRBC broilers reared on a 1957 diet (two studies, 1991 and 2001)[a].

	1991 Comparison			2001 Comparison			
Strain Diet	Arbor Acres 1991	ACRBC 1957	1991 Diff.	Ross 308 2001	ACRBC 1957	2001 Diff.	Increase from 1991 to 2001
Age Days	Body Weight (g)						
21	700	190	510	743	176	567	+57
42	2132	508	1624	2672	539	2133	+509
56	3108	790	2318	3946	809	3137	+819
70	3812	1087	2725	4806	1117	3689	+964
84	4498	1400	3098	5521	1430	4091	+993

[a] Adapted from Table 1, Havenstein et al. (2003a)

Because of these changes in growth rate, the feed conversion of broilers at a given age has dropped dramatically over the past 45 years, as shown in Table 3. Feed conversion by age, however, doesn't tell the whole story. The data can be used to project that the modern broiler in 2001 reached 1800 g body weight at about 32 days of age with a feed conversion ratio of 1.46 (Havenstein et al., 2003a), while the ACRBC would have needed an additional 17 days to reach the same BW, and its feed conversion at that age would have been approximately 4.42. Thus, genetics, nutrition and other management changes over the 44 year period from 1957 to 2001 resulted in a broiler that requires approximately 1/3 the time and 1/3 the amount of feed to produce an 1800 g broiler.

Table 3: Feed conversion by age of a modern broiler vs. the Athens-Canadian Randombred control in 2001[a]

Strain	Study	Feed	Day 21	Day 42	Day 56	Day 70	Day 84
Ross 308	2001	2001	1.32	1.63	1.96	2.26	2.72
ACRBC	2001	1957	1.81	2.34	2.54	3.36	3.84

[a] Havenstein et al. (2003a)

The production of broiler meat today requires roughly one-third the amount of resources (feed, manpower, housing, etc.) and we are producing only about one-third of the waste nutrients that would be produced for the same amount of poultry meat using 1950-type chickens.

Figure 3 demonstrates the incredible difference between 1957 ACRBC and modern-type broilers

Turkey data

The turkey industry has also applied quantitative genetic selection to its breeding populations. Havenstein et al. (2004a, b; 2007) have recently published a study summarizing the changes that have taken place in the turkey industry from 1966 through 2003. The 2003 turkeys were approximately twice as heavy as the controls representing 1966 turkeys at the four slaughter ages studied. Tom weights increased by 186, 208, 227, and 240 g/year, hen weights by 163, 177, 186, and 204

Figure 3: Broiler carcasses from the Ross 308 and the Control (ACRBC) broilers in the 2001 study (Havenstein et al., 2003a,b)

ACRBC Males - 2001 Feed

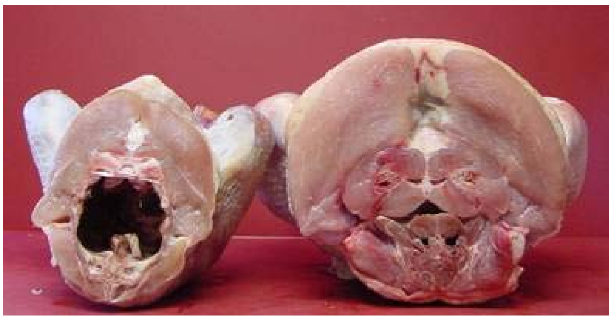
Ross Males - 2001 Feed

Day 43 **Day 57** **Day 71** **Day 85**

g/year, at 112, 140, 168, and 196 days of age, respectively, over the past 37 years. Total edible carcass yield increased by 6.5 % over this 37 year period. Feed efficiency to 11 kg of BW for the 2003 toms (2.132 at 98 d of age) was approximately 50 % better than for the 1966 RBC2 toms (4.208 at 196 d of age). The number of days to reach that weight was halved during that period of time. As for the broilers, Figure 4 demonstrates the dramatic difference between modern turkeys and those that were being used by the turkey industry during the mid-1960s.

Figure 4: Turkey carcasses at 196 days of age from the randombred RBC2 strain established in 1966 and maintained at Ohio State University and a modern turkey hatched in 2003 (Source: Havenstein et al., 2004a,b; 2007)

RBC2 **2003 Turkey**



For a number of years nutritionists have been collecting data on the commercial performance of turkeys. Ferket (2003) recently published tables summarizing the average field performance of commercial turkeys from 1966 through 2003. Those data showed that 18 week old turkey toms averaged 8.0 kg in 1966, whereas 2003 toms were nearly double that size at 15.2 kg. Market age to a 15.9 kg body weight for turkey toms was 220 days in 1966, only 133 days in 2003. Feed conversion to 18 weeks improved by 16 % from 1966 to 2003.

Egg-type chickens

Even though the differences between modern egg-type chickens, pigs and dairy cows may not be quite as dramatic as for broilers and turkeys, enormous improvements have been made in the productivity and efficiency of those species as well. For example, Anderson (1996) reported that egg production per hen housed was 344 for a 1993 commercial layer strain compared to 267 for the Ottawa randombred control strain (established in 1950) at 82 weeks of age. Average egg weight was 65.0 g/egg for the modern strain vs. 58.1 g/egg for the control, and the combination of improved production and egg size resulted in a 43 % increase in daily egg mass. Efficiency of egg production (egg mass/feed) improved by 32 % over this 43 year period. Body weights of layer strains have been reduced by about 20 percent during the same time, and in combination with the improved productivity, egg-layers require considerably less feed to produce a dozen eggs today than did the birds that were used a half century ago.

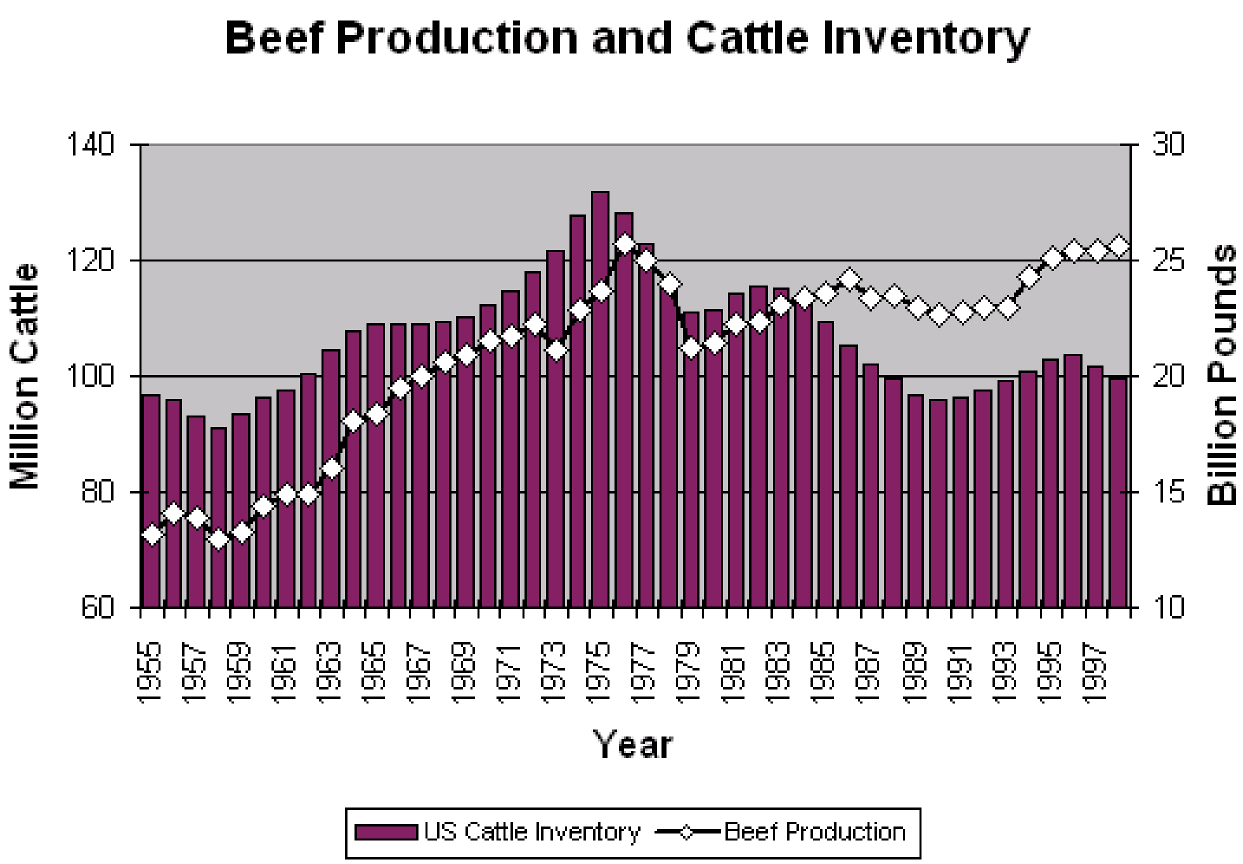
Swine

Performance has also changed dramatically for the swine industry. Although the same types of data are not available for the swine industry as for the broiler and turkey industries, the amount of retail meat per pig has increased by 282 g per year from 1955 to 1997 (Chen et al., 2002). Swine breeders are continuing to improve meat production efficiency by reducing the days to market, reducing the amount of backfat, and by increasing the lean growth rate and loin eye areas of the carcass. All these changes contribute to a reduction of the amount of feed required to produce a unit of marketable meat, and the amount of by-product waste.

Cattle

The beef industry has also greatly improved the output of meat per animal. The number of beef animals on inventory in 1999 (~100 million) is just slightly higher than in 1950 (~97 million), but the amount of beef produced has increased by about 62 percent from about 7.3 million metric tons (MT) in 1950 to over 11.8 MT in 1999. This is largely due to breeding faster growing beef animals. Figure 5 shows the changes in the U.S. beef industry from 1955 to 2000.

Figure 5: Changes in the U.S. beef industry from 1955 to 2000 (Source: USDA)



The dairy industry has been especially successful in improving the efficiency of milk production through the selection of superior performing cows and bulls from summaries of the Dairy Herd Improvement Association. In 1950, the U.S. had 22 million head of dairy cows producing an average of 2,415 kg of milk per year. In 2,000, the U.S. dairy industry had 9.2 million cows averaging 8,275 kg milk per year. Total U.S. milk production in 1950 was 53 MT, compared to 76.2 MT in 2000. The dairy industry produced 44% more milk in 2000 with 58 percent fewer cows than in 1950 (Blaney, 2002). Dry matter intake per dairy cow was about 12.3 kg per day in 1950 and had risen to about 20.9 kg per day in 2000 (from DART Ration program of the Dairy Records Management System, based on Brown et al., 1977). Again, these changes are largely the result of genetic selection applying the science of quantitative genetics.

These are but a few examples of the efficiencies that animal scientists and producers have built into the systems used for meat, milk and egg production. This process will continue into the future. The broiler data show that the gains realized in the most recent 10 years were greater than the rates of gain in the preceding decades. This reflects improvements in assessing genetic merit and increased selection pressure applied by primary breeding organizations.

In light of the continuing growth of the world population and increasing per capita demand for food of animal origin, all involved in animal production must continue to focus on both the efficiency of production and the management of by-products in order to keep the food-producing industries viable and to minimize the impact of animal production on the environment.

Conclusions

The take-home message from this review is that our food-animal industries exist to produce food for the human population. Increases in the human population and consumer choice will continue to drive the expansion of these industries. Quantitative genetics has made and will continue to make a major contribution to the efficiency of animal–based food production, and its application has greatly reduced the numbers of animals required to produce our foodstuffs. It has also had a great effect on reducing the amounts of forages and grains required to produce a unit of meat, eggs and milk. As these industries move forward into the future, all involved should not only continue to work toward improving the efficiency of production, but also continue to develop environmentally superior methods for handling by-products from our animal populations.

Consumers, producers, scientists, government officials, environmentalists and ethicists must remember that we are all in this together. Everything possible must be done to develop processes that are both economically sound and environmentally friendly, so that that our food animal industries remain viable and sustainable for the future. We cannot return to the past to produce the amount of animal-based foods needed today. The food-animal industries may have a long way to meet all demands of public concern, but continued genetic selection for increased efficiency and application of innovative technologies for animal waste management are contributing in a desired direction, from both a social and an environmental perspective.

Zusammenfassung

In den vergangenen 50 Jahren hat sich eine leistungsfähige Industrie entwickelt, um die wachsende Weltbevölkerung mit einem steigenden pro-Kopf Verbrauch an Lebensmitteln tierischen Ursprungs zu versorgen. Intensive Selektion auf hohe Leistung pro Tier und günstige Futterverwertung hat dazu geführt, dass der steigende Bedarf mit immer weniger Tieren bedient werden kann, die Fläche zur Futterproduktion abnimmt und die Umweltbelastung durch Ausscheidung von N und P verringert wird. Mit weiter steigender Nachfrage nach Lebensmitteln tierischen Ursprungs bleibt die produzierende Industrie gefordert, nicht nur die Futterverwertung weiter zu verbessern, sondern auch innovative Lösungen für umweltfreundliche Verarbeitung bzw. Entsorgung der Abfälle zu entwickeln.

Extensive Produktionsverfahren für Nischenmärkte sind keine Lösung für die Welternährung, und es wird keine Rückkehr zu Methoden der „guten alten Zeit" geben, als 2 Millarden Menschen auf der Welt lebten, von denen sich wenige regelmäßig Fleisch, Milch und/oder Eier leisten konnten. Verbraucher, Produzenten, Wissenschaftler, staatliche Behörden, Umweltschützer und Ethiker müssen zusammenarbeiten, damit die Produktionsabläufe umweltfreundlicher, gleichzeitig aber Wirtschaftlichkeit und Existenzfähigkeit der Betriebe nicht in Frage gestellt werden. Die landwirtschaftliche Industrie kann nicht alle Forderungen der Öffentlichkeit erfüllen, aber die Selektion auf verbesserte Futterverwertung und die Anwendung moderner Verfahren der Kotaufbereitung gehen in die richtige Richtung als wichtige Beiträge zur Entlastung der Umwelt.

ACKNOWLEDGEMENTS

The author wishes to thank Drs. Kenneth Anderson and Peter Ferket from the NC State University Department of Poultry Science and Drs. Roger McCraw, Lon Whitlow and Todd See from the NC State University Animal Science Department for helpful suggestions concerning sources of information on the historical performance of the various food-animal species. Their input was much appreciated.

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