ENVIRONMENTAL SUPPORT OF INCREASED GENETIC PERFORMANCE FOR INTENSIVELY MANAGED LIVESTOCK

Dewey L. Harris

USDA-ARS, RLHUSMARC, Clay Center, NE 68933-0166

SUMMARY

In contrast to extensively managed livestock for which there is limited capability to alter the environment at a location, modern poultry, swine and dairy production involves intensive management with considerable ability to manage nutrient intake and some ability to modify temperatures from weather conditions at a location to keep ambient conditions in the comfort zone of the livestock. These abilities have led to genetic improvements primarily being directed to increased production – more milk, more eggs or greater growth – with secondary emphasis on quality aspects of the product. A production system is usually arranged that will provide the necessary greater feed intake, shifts in feed composition and optimum ambient temperatures to support this increased performance. If the value of the increased production exceeds the increased feed costs, the combined change is economically advantageous. The effects of diseases are usually controlled by nongenetic means but elimination and control of pathogens have become an additional responsibility of the breeder. The observations raise the question for discussion of how far will and should this combined trend of genetics and supporting environment continue for intensive livestock production. Should there be exceptions to this observed trend? The trend seems to only be limited by economic practicality.

Keywords: genotype-environment-interaction, intensive-production, genetics, selection, breeding-objective

INTRODUCTION

Livestock production is practiced over a diverse range of environments represented in the attendance of this Congress. There have been scientific documentation and field experiences concerning the occurrence of interactions between many environmental differences and many genetic differences. The prevalent production systems of different livestock enterprises differ in approach to accommodating these interactions. Much of those differences in approach is associated with the dichotomy between intensively managed (layers, broilers, swine and dairy) and extensively managed (cattle, sheep and other grazers) livestock. This paper will review the major trends in managing these interacting factors for intensively managed swine and broiler and layer poultry. Other presenters will address approaches for extensively managed grazing species of beef cattle and sheep. For this discussion, dairy cattle are considered as being intensively managed and have more similarities to poultry and swine than to beef.

CONTRASTING PRODUCTION SYSTEMS

Grazing livestock spend most of their life cycle in the open with very little protection from weather conditions. At times the animals are too hot relative to optimum and at other times too cold. Nutrient intake is influenced by both temperature and what is available in a reasonable walking distance; this latter is seasonal, highly subject to rainfall and often less than the animal desires.

In the last half century, the nature of poultry production has drastically changed around the world. First, breeding became more industrialized around crossbreeding with more effective efforts at selection following. Both breeding and production for chickens split into two segments – meat production and egg production. In turn, during the 1960s and 1970s, production became more intensive with larger buildings, large complexes, separation of ages, vertical integration, etc. Emphasis on eradicating troublesome pathogens was more effective than genetic selection for general livability. The backyard flocks disappeared in most developed countries. Reports are that similar trends in production are occurring in developing countries with breeding improvements being supplied from the more developed countries. Very analogous changes have occurred or are occurring in the pork production industry in the U.S. and many other countries. Crossbreeding, intense testing and selection, pathogen control, ventilated, heated and cooled housing for labor savings and environmental modification and large integrated operations are all occurring with about a 20 to 25 year lag behind poultry.

GENOTYPE-ENVIRONMENT INTERACTION

Even though, in past decades, much research provided statistically significant evidence for the presence of genotype-environment (GxE) interaction, the specific genetic and environmental factors interacting was often not clear so the precise mechanisms were not clear. Sheridan (1990) reviewed research in poultry on genotype x environment interaction in chickens with much of this research conducted in the 1950s through 1970s. Even though much evidence of interaction was found, most major breeders of both layers and broilers today strive for worldwide use of their breeding stock. Some specificity of product for different locales is practiced focused on market preferences for shell color and egg size. Different breeders have recommended feeding programs and management practices for their genetic products but these usually are for improved nutrition and management to support high performance and differ in relation to body size and egg production. Disease conditions that can contribute major interactions tend to be controlled by nongenetic means. Thus, the impact of GxE interaction in poultry has largely been reduced in the trend to improved production environments and the remaining thrust is to adjust nutritional programs to genetic differences in performance.

During the same period, statistical procedures for genetic evaluation within populations evolved from the simple model

$$P = G + E$$

which includes

$$P = G + (E + GxE)$$

where P = phenotypic deviation
G = genetic deviation
E = environmental deviation
GxE = genotype-environmental interaction

where the possibility of GxE interaction was acknowledged, but considered as being unidentifiable and random. The view was it should be considered along with the E term in models. Many fixed effects representing environmental factors associated with herds, years, seasons, age of dam, etc. have been added to statistical models over the years, but so as to statistically separate out those identifiable environmental effects to eliminate biases and to give "environment-free" evaluations. But aren't the interactions with the environment still providing disturbances to the evaluations? Perhaps they do not have to be handled as "random." We understand them better now. Three alternative questions are raised relative to the reality of GxE interactions

1) Do we need environment-specific genetic evaluations?
2) Do we need to manage the production environment to eliminate those disruptive and interacting environmental factors?
3) Should each genetic population (or cross) have its own set of environmental recommendations?

The choice of proper questions does not seem to be the same for different types of livestock. At least, observed industry trends to date have been in differing directions, but 1) has been ignored to a large degree and 2) and 3) are both frequently answered positively in intensively managed livestock.

SYNCHRONIZING GENETICS AND ENVIRONMENT

Because of the genotype-environment interactions that occur in livestock, there is a need to synchronize genetics and environment. The ideal would be to repeatedly evaluate a wide variety of genetic material in a wide variety of environments. Considering the diversity of both, it is next to impossible to do this experimentally. In poultry, that form of testing has ceased to happen. Alternatively, it might be considered practical to adapt genetic material to specific environments with different breeding programs for different sets of environments. Conversely, producers could consider adapting the environment to the genetics. Evaluating what has been done over the last few decades, the answer adopted for other intensively managed livestock has usually been the latter, the same as poultry, to provide an environment (nutrition and other aspects) that satisfies the requirements of the genetic population and strive to genetically improve the potential performance of that population. This trend has primarily reduced environmental differences, but in some cases, customized the environment to the stock. As genetic differences in performance potential are better understood, our ability to customize feeding programs to genetic differences increases. It is logical that nutritional requirements will change as genetics alters the metabolic processes underlying the shifts in performance characteristics. On the other hand, with limited ability to modify the environment the focus for extensively managed cattle and sheep has usually been to find the genetic material that will perform best in spite of the occurrence of adversities such as limited feed resources, heat, cold and maybe diseases and parasites. In the better environments, lush pastures and(or) feedlots, the need is for the ability to fully utilize these resources. This specificity of placement seems the best approach even though most breeders (when selling) would like to have the whole world as their market and feel their genetic products can perform well in all environments.

PORK PRODUCTION SYSTEMS

Pork production can be schematically represented as in Figure 1 (Pond *et al.* 1991). Numerous interactions can and do occur among the indicated components even with much standardization of environments. We will discuss the several interactions of genetics and the environment (nutrition, pathogens, ambient conditions, etc.) around this schematic. The breeding stock provides the genetics that determines potential performance for the biological processes of reproduction and growth with the product usually in the form of the pork carcass. These processes are fully possible only with the input of the proper nutrients in the feed. Inadequate nutrition can also reduce the expression of reproduction and growth below the full potential. Sometimes it is desirable to reduce the potential for fatness but usually it is preferred to fully support the potentials for high reproduction and fast, efficient growth if the cost of improved feeding programs is compensated by the increased value (or reduced cost) of the product.

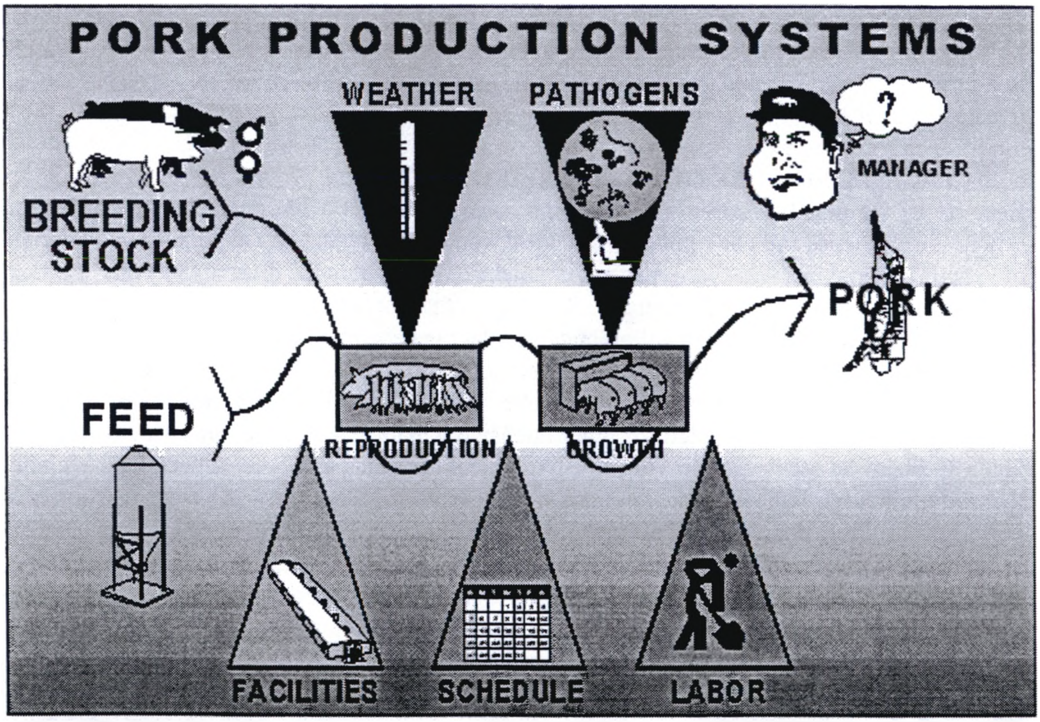

Figure 1. Schematic of pork production systems with interacting and interdependent components for synchronizing by manager. (Adapted from Pond *et al.* 1991).

A replacement for $P = G + E$ is possible as far as the interaction between genetically controlled potential for performance (symbolized by G) and the performance that the nutritional intake (NI) can support. Thus, we can write

$$P = \text{Min}\ (G, NI)$$

where Min indicates the minimum of the two quantities in the parentheses.

Growth and(or) reproduction may also be reduced below potential by either hot or cold conditions. So a primary function of housing is to modify the differences and fluctuations due to the local weather. The optimum temperature range moves to lower temperatures as the pig increases age, size, feed intake and thus metabolic heat loss. Cooler ambient temperatures make this loss of heat easier for the animal. Usually vulnerability to heat stress will be greater for more highly productive animals. This is likely due to difficulties in dissipating the greater heat load. This provides a major complication to improving tropical production.

Most modern production facilities are operated so as to minimize the chance of reintroducing pathogens eradicated from the specific farm and from the imported breeding stock. This is done with some risk and sometimes there are failures. Schematics very similar to Figure 1 are possible for all species and classes of livestock.

INTERACTIONS AND INTERDEPENDENCIES

Even though much effort has gone into providing improved environments (Clark 1981; Curtis 1983), numerous possible interactions and interdependencies that occur in the system represented in Figure 1 still need to be recognized as attempts are made to synchronize the environment and genetics of a herd with the greater effort usually being to customize the environment to support the performance potential coming from the genetic make-up of the breeding stock. These include

1. breeds, breeding systems and selected individuals influence performance potentials
2. performance potentials interact with feeds to influence growth rate
3. interactions of potentials and feeds influence carcass composition
4. interactions of potentials and feeds influence reproduction and lactation which influences facility needs or utilization
5. housing and equipment influence labor needs
6. location determines climate which interacts with housing which determines ambient conditions which interacts with feeds and potentials to determine animal performance
7. housing interacts with scheduling to determine diet and ambient conditions which interacts with performance potentials to determine animal performance
8. breeding stock can be the source of pathogens into a herd

MODELING SYSTEM INTERACTIONS

In swine, simulation modeling has been used in recent years to describe and analyze the interactions involved in production. This has been done in a form to facilitate decision making concerning production from different genetic populations with different performance potentials. In particular, several have studied how to adjust phase-feeding programs for swine for different ages, sexes, and genetic lean growth potentials (Whittemore and Fawcett 1976; Black *et al.* 1986; Moughan and Smith 1984; Pomar *et al.* 1991; Harris and Safranski 1995). The primary descriptor of diets in many of these programs is the relative amount of ideal protein to support lean growth to the amount of digestible energy to support other aspects of growth and performance. An animal's genetic potential for lean growth can only be expressed if intake includes adequate ideal protein. To illustrate interaction involving ambient temperature, energy intake and nutrient utilization, Figure 2 has been adapted from Hahn *et al.* (1987). This schematic shows that more energy is available for growth at intermediate temperature because 1) when conditions are cold, part of intake is used for homeothermy and when conditions are hot intake is reduced. Thus the expression of greatest growth is at intermediate temperatures between the critical temperatures as defined by Bruce and Clark (1979). If this is the condition for greatest expression of growth (or protein accretion) potential, what genetic differences are expressed in low temperatures or high

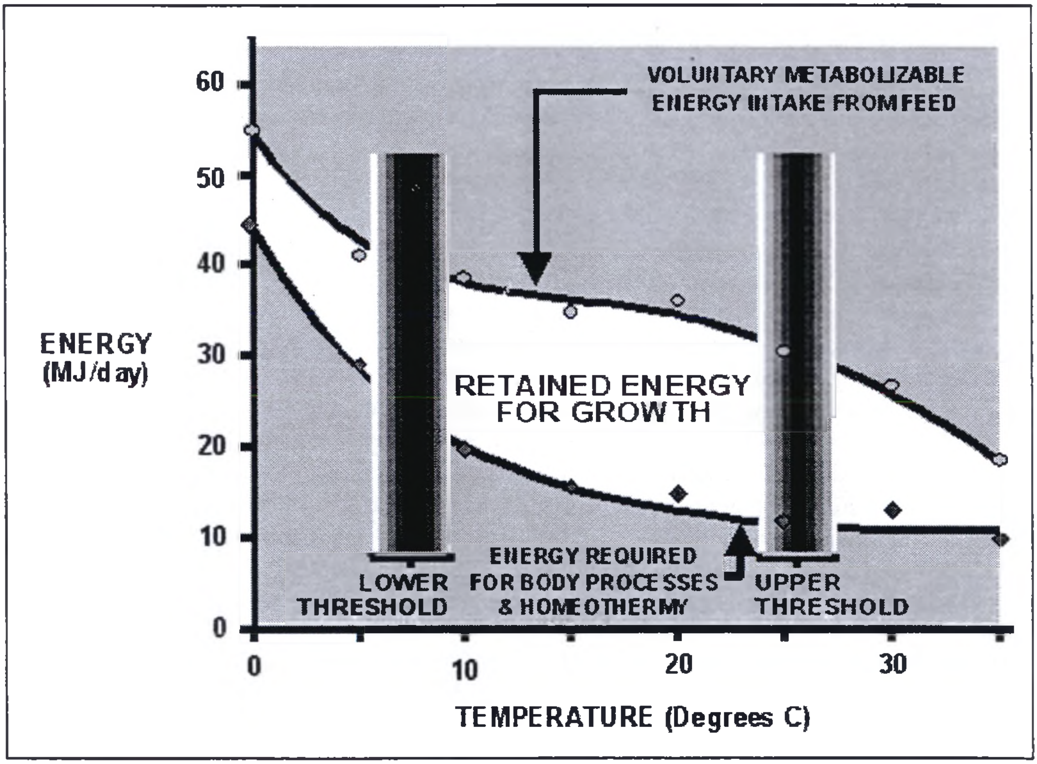

Figure 2. Diagram representing energy intake and utilization in relation to ambient temperature showing greater energy available to support growth processes (Adapted from Hahn *et al.* 1987).

temperatures? What should the test environment be when selecting for increased growth? What should be the production environment?

The upper curve in Figure 2 shows the relationship between energy (and thus feed and other nutrients) intake and ambient temperatures. This general shape of the relationship was reconfirmed in the data of Nienaber *et al.* (1987). Since intake of ideal protein is necessary to support genetic potential for protein accretion, and thus lean growth, it follows that changes in diet content are necessary to provide the appropriate nutritional intake as temperatures change. Alternatively, control of ambient conditions may become necessary to manage the correct intake for a specific diet to a specific genetic growth potential.

Thus, we come to the question of what determines the ambient conditions for a pig. Figure 3 represents schematically the numerous interactions and interdependencies between conditions of climate and weather, the insulation, fans, heaters and evaporation capacity of a building, the body heat production of pigs with huddling and skin wetting choices all determining ambient conditions, which influences feed intake, which in turn affects body heat production. A recent simulation program simulates the effects of heating, ventilation and evaporative cooling

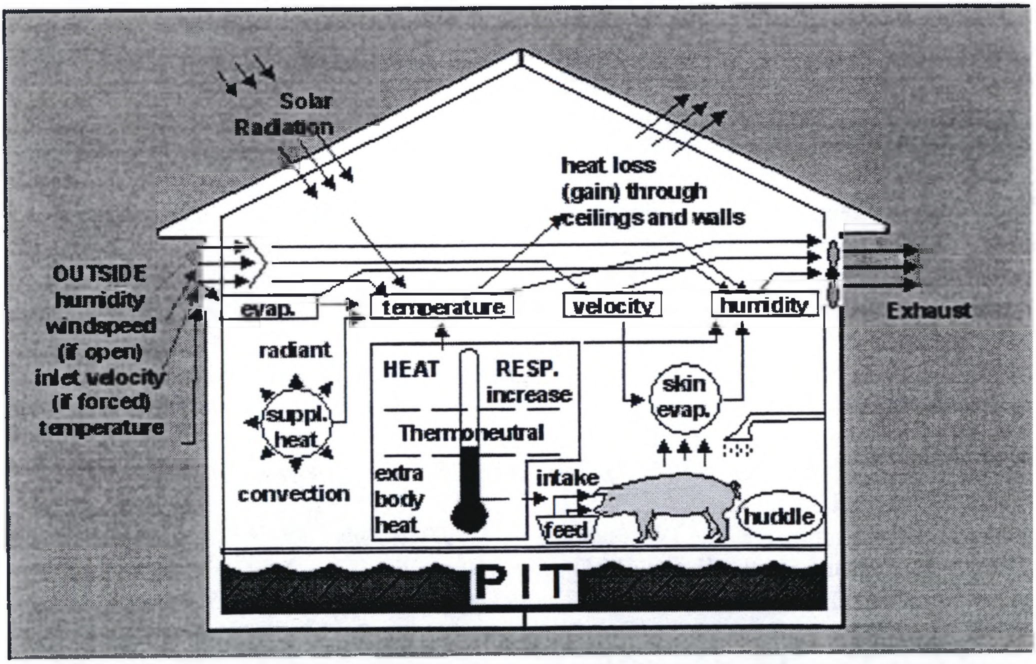

Figure 3. Schematic to illustrate the several interacting and interdependent factors involved in models of how buildings modify weather to determine ambient conditions.

capabilities of a building upon ambient conditions within the building (Harris *et al.* 1997). Another program to simulate a swine herd enterprise is being developed (Harris, 1995).

The interactions mentioned here are complex and difficult to describe mathematically but that seems to be the route for bringing back together the several disciplinary and subdisciplinary parts that our research has investigated separately. Is the added potential for customizing environments to genetic differences enough to justify the necessary effort? A complex interaction that has not yet been adequately understood to incorporate into simulation models involves the interactions of genetic potential for performance with nutrient intake and, in turn, with the disease inducing effects of pathogens (Spurlock, 1997). More research is needed. Even though breeding organizations have put considerable effort into eradication or reduction of pathogens, much of pork production is still plagued by problems from reintroduction of pathogens and the disease outbreaks they trigger. Can performance under such conditions be predicted? Can breeders select for performance under such adverse conditions?

IMPLICATIONS UPON GENETIC IMPROVEMENT

To the degree that modern intensive production systems have eliminated disease stress, heat stress, cold stress and inadequate nutrition, it could be argued there is little compelling reason for breeding for resistance to such adverse conditions. Breeding can focus on achieving efficient performance under conditions close to optimum. However, not all current production systems provide near-optimum conditions. Will the less than optimum environments continue to occur long enough to justify continued breeding effort?

REFERENCES

Black, J. L., Campbell, R. G., Williams, I. H., James, K. J. and Davies, G. T. (1986) *Res. and Develop. in Agric.* **3**:121-145.

Bruce, J. M. and Clark, J. J. (1979) *Anim. Prod.* **28**:353-369.

Clark, J. A. (editor) (1981) "Environmental Aspects of Housing for Animal Production", Butterworths, London.

Curtis, S. E., (1983) "Environmental Management in Animal Agriculture", Iowa State Univ. Press, Ames.

Hahn, G. L., Nienaber, J. A. and DeShazer, J. A. (1987) *Appl. Engr. in Agric.* **3**(2):295-302.

Harris, D. L. (1995) *Proc. FACTs 95 Conf.*, Mar. 7-9, 1995, Orlando, FL. pp. 11-20.

Harris, D. L. and Safranski, T. J. (1995) *J. Anim. Sci.* **73**(1):192.

Harris, D. L., Temple, J. E. and Pordesimo, L. O. (1997) *J. Anim. Sci.* (Abstr.) (Accepted 4/97).

Moughan, P. J. and Smith, W. C. (1984) *N.Z. J. Agric. Res.* **27**:501-507.

Nienaber, J. A., Hahn, G. L. and Yen, J. T. (1987) *Trans. ASAE* **30**(6):1772-1775.

Pomar, C., Harris, D. L. and Minvielle, F. (1991) *J. Anim. Sci.* **69**:1468-1488.

Pond, W. G., Maner, J. H. and Harris, D. L. (1991) "Pork Production Systems: Efficient Use of Swine and Feed Resources", Van Nostrand Reinhold, New York.

Spurlock, M. D. (1997) *J. Anim. Sci.* **75**:1773-1783.

Whittemore, C. T. and Fawcett, R. H. (1976) *Anim. Prod.* **22**:87-96.