Physiological limits to growth manipulation and the related effects on meat quality

E.C. Webb
Head: Department of Animal and Wildlife Sciences, University of Pretoria,
Pretoria 0002, South Africa

Summary

Livestock, poultry and pigs were domesticated between 5,000 and 11,000 years ago in the Neolithic period, also referred to as the "Neolithic revolution". This occurred simultaneously and quite spontaneously in different regions around the world and forever changed the history and fate of humankind. The most significant consequence of the domestication of animals was the emancipation of humankind, driven primarily by peoples' need to secure food for times when hunting was poor. People were "freed" from the labour of collecting food into doing other work, like building shelters, houses and later cities, developing the sciences, arts and philosophies and refining religions. Sedentary communities arose across the world – the most prominent examples include the Iranian highlands, Syria and Levant as established from tools, artefacts and artistic expressions in caves at Lascaux and Altamira. This represents the first important shift, namely that from hunter-gatherer to agriculturalists.

Keywords: Livestock, physiological limits, meat quality, nutrition, tenderness
E-mail: Edward.webb@up.ac.za

Figure 1a & b: Examples of rock paintings of the now extinct Auroch breed of cattle which is regarded as the ancestors of modern cattle breeds.

Figure 1 a

Figure 1 b

Figure 2: (a) Fossilised skull of Auroch (above) and (b) Phenotypic Auroch-like breed (below) and (c) artists impression of an ancient Auroch (below)

Figure 2 b

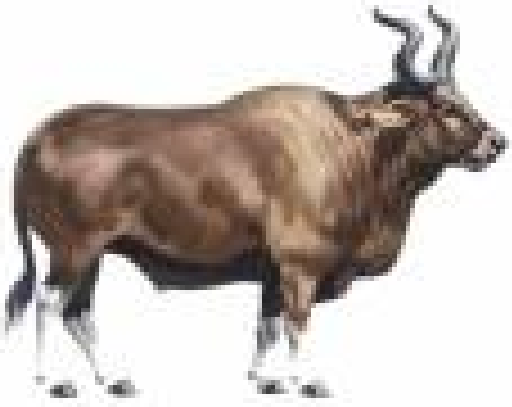

Figure 2 c

Table 1 Evolution of the meat production industry

18,000-10,000 Years ago	Magdalenian period - hunter-gatherer systems
10,000-5000 Years ago	Neolithic period – domestication of animals and emancipation of humankind
2,000-1,000 Years ago	Progressively more emphasis on production and yield
Ca. 600-100 Years ago	Emphasis on yield and breeding becomes "fashionable"
1800 onwards	Emphasis on independent farming operation
1810	Canning of food
1830-1840	Meat slaughter facilities established
1840-1850	Meat packers
1870	Mechanical refrigeration
1893	Technical training institute
1900	Produce food for others – emphasis on commercialisation
1906	Meat inspection service
1930-1940	Meat laboratories
1940	Packaging and research on packaging
1940-1950	World War II Major focus on packaging, food born pathogens, radiation, automation, carcass and meat quality, AI
1950-1960	"Golden age of meat science" Carcass and meat quality, efficiency, AI, Shift to consumer issues
1970-2000	Growth efficiency, manipulation and production efficiency
2000-2005	Consumer era Product safety, quality and perceptions Meat industry not geared to address media
2005-current	"Food safety era"

Domestication and the increasing dependence on animal agriculture eventually prompted the livestock industry to focus on maximum yield through improved breeding, feeding, caring and management of domestic animals. Initially the quality of animal products was determined by the quantitative aspects of livestock production e.g. amounts produced. The principles of animal physiology, breeding and nutrition were applied very successfully to manipulate the underlying principles of growth notably hypertrophy, hyperplasia and differentiation. This represents the second important shift namely that from merely providing food to providing a consistently high amount of food for financial gain. In addition, it became increasingly fashionable to breed domesticated animals and to put selection pressure on specific phenotypic characteristics, often without any economic merit.

These attributes for many years dominated the livestock industry and were propagated at all major agricultural fairs and shows until the early 1950's. It became increasingly apparent that injudicious animal breeding and selection is a risky business that requires a more scientifically responsible approach. The emphasis in livestock breeding started shifting toward accurate measurement and quantification of a variety of internal and external effects and their interactions on genetic and phenotypic variation. This occurred almost simultaneously along with the focus on efficiency of livestock production, limited resources and the economy of feeding and fattening livestock in semi-extensive and intensive production systems. Animals were selected for functional efficiency by means of visual appraisal and other measurements of efficiency like average daily

gain and feed conversion efficiency. This probably represents the third shift notably from maximum yield to efficiency.

Significant progress has been made in terms of the quantification of growth and growth limits, the factors that affect growth, development, nutrient partitioning, manipulating growth by nutritional interventions, endocrine manipulation and gene technologies, while the recent advent of molecular techniques, identification of quantitative trait loci (QTL) and candidate genes have also added a new dimension to our understanding of these processes. These technologies represent the epitome of modern animal production.

The commercialisation of animal agriculture has clearly resulted in a significant change in terms of both the phenotype and production characteristics of modern breeds of livestock. Although the basic form of the sigmoidal growth curve as well as the sequence of physiological events remained virtually unchanged, the rate and extent of these processes increased remarkably. The fattening period of feedlot cattle was reduced to approximately 100 days, with growth rates of up to 2 kg per day and feed efficiencies varying between 5 and 6 kg of feed for 1 kg of live weight gain. Milk yields of dairy cattle of up to 90 kg per day have been recorded, while consistent yields of up to 27000 kg over a 365 day lactation period (75 kg /day) are achievable with modern breeding and nutritional inputs. The hatching weight of chicks is *ca*. 44g only a few years ago broilers were only market ready after a 16 week feeding period, but due selection pressure on growth and appropriate nutritional inputs, broilers can be marketed at 2.4 kg after an intensive feeding period of only 42 days and a feed conversion rate of ca. 1.8 kg of feed for 1 kg live weight gain. Similar changes occurred in commercial pig production systems by increasing the selection pressure on lean carcass yield, resulting in a significant decrease in back fat thickness (<12 cm) and carcass fat content.

Despite the significant progress in animal science, it appears that we have reached the physiological limits to growth in a number of species notably the double muscled cattle (doppelender gene in Belgian Blue cattle and other breeds), the callipage gene in sheep (heavy muscled sheep breeds), ascites and associated metabolic defects in broilers selected for accelerated growth rates, leg problems in high producing layers, stress sensitivity, PSE and DFD syndromes in pigs selected for accelerated protein accretion, abortions in Angora goats selected for mohair production, wet carcass syndrome in sheep, as well as a variety of tissue defects and reproductive failure in herds selected for high yields through interactions between the growth hormone cascade, the gonadotrophic axis and other endocrine factors that regulate metabolism like thyroxin and leptin.

Mathematical growth modelling and the quantification and improvement of growth and feed efficiency were also emphasised, which resulted in the marginalisation of the smaller and less productive breeds of livestock, typically those on the far left of the normal distribution curve. The physiology of animals is generally quite forgiving and most of the modern genotypes are well managed, but there are warning lights on the horizon. There is a notable shift towards biological and environmental sustainability, but the most important challenge is certainly consumer safety, satisfaction and perceptions. Unfortunately the livestock industry is not adequately prepared for this scenario.

More recently the concept of product “quality”, was adopted which exposed the multi-dimensional nature of consumers’ perceptions regarding meat quality. The challenge in livestock production is now shifting towards synchronising the best genotypes in a specific environment with the most appropriate and environmentally acceptable technologies available to produce consistently high quality meat. Manipulation of the quality of animal products through feeding, breeding and physiology will become increasingly important, provided that these technologies are practical, economical and do not detract from the intrinsic and extrinsic attributes of animal products, or any other aspect relating to environmentally acceptable or ethical livestock production.

Similar trends are also evident in an increasing number of wildlife species. Game farming has evolved to game farming systems with similar inputs and demands on infrastructure and capital.

Table 2 Examples of breaches of animal product safety and strategies to address the problems

Listeria action plan (farm to table risk assessment)
Salmonella enteriditis in shell fish
Vibrio risk in raw oysters
Methyl mercury in fish
Refrigeration becoming essential in terms of modern packaging and food habits
TSE's
BSE feed rule (1996/97)
CWD (Chronic wasting disease)
Antibiotic resistance
Anabolic steroids and growth modifiers
Emphasis on manipulating product composition to reduce CHD risk

The complexities of these unique livestock and game farming systems in arid and semi-arid areas like Southern Africa and the subsequent effects on animal product quality, requires well qualified graduates and appropriate research initiatives to ensure financial sustainability.

The Department of Animal and Wildlife Sciences (DAWS) is characterised by a multidisciplinary approach due to the nature of the field of study. Animal Science is based on three main pillars namely animal breeding and genetics, animal nutrition and animal physiology, which finds application in a variety of animal production systems and products, and includes livestock, game and companion animals. The DAWS has a big responsibility in terms of training graduates who have a clear and growing understanding of animal science in the southern African context, but also with the ability to develop and contribute to the international animal industry.

This department is one of the most prominent and highly regarded departments locally and abroad. Research collaboration with other research institutes and universities is essential in order to achieve the goals of the National livestock research and development programme, which is essentially an integrated implementation program for the "National Animal Improvement Policy" and the "Livestock Development Strategy". Research collaboration has been established with the Agricultural Research Council at Irene, the National Department of Agriculture, various departments at the faculty of Veterinary Science, other prominent role players in the livestock industry, a number of local and international universities, private consultants, breed societies and professional bodies. The appropriateness and content of the curricula are regularly reviewed and staff is encouraged to develop their own research fields and publish scientific papers in peer reviewed journals.

A concerted effort is made to address staff diversity, coupled with staff development, exchange programmes with other universities and the acquisition of external funds for research and post-doctoral fellowships. Attention is also given to the establishment of internationally acceptable research facilities and capacity in the department and at the Hatfield experimental farm, which is widely recognised as a key factor contributing to the success of the DAWS and the Faculty of Natural and Agricultural Sciences. There are a number of challenges like increasing student

numbers in certain modules of the Veterinary Biology degree program, but the DAWS has already proven that it has the ability to turn these into opportunities by making use of computer aided assessment and the implementation of new teaching technologies as implemented in the Animal Anatomy and Physiology, and Animal Science modules.

A university is a unique institution where emphasis is placed on training and research. Future postgraduate students will clearly influence the research outputs of the DAWS, so their scientific and intellectual development should be promoted by pursuing the ideal of excellence at all levels. Publications of research findings in scientific and popular journals are important, while the principles should be applied locally in order to ensure continuous interaction between research priorities and the needs of the South African community in a broader sense.