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## THE DEVELOPMENT OF NEW FARMING SYSTEMS

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## Abstract

New farming systems are important, not because they bring more profit to farmers in general, but because it is always in the interests of the consumer to reduce the resource cost of producing food.

Consideration of the development of the poultry industry over the past 30 years leads to the conclusion that it has succeeded in capturing new markets because of close cooperation between veterinarians, geneticists, nutritionists, engineers and entrepreneurs in the industry.

Consideration of the needs of the dairy industry today leads to the conclusion that new farming systems will be developed from the work of molecular biologists, physiologists, biochemists, electronic engineers, model builders and farmers who will need a strong core of animal scientists to keep them on the right road.

State funded extension workers are needed to transmit existing knowledge to farmers where the industry is fragmented and consists of large numbers of independent producers with limited technical knowledge. For industries which have coalesced into a small number of much larger production units, direct contact between managers and agricultural scientists is a more effective system for ensuring the two-way flow of knowledge.

Objective

This paper considers some of the factors which contribute to the evolution of farming systems, or the discovery or invention of new systems, with particular emphasis on the roles of research and extension in these processes.

### Is Progress Wanted?

In case there should be sceptics who think that it is futile to talk about improving farming systems when Europe and North America are beset with problems of over-production, one should begin by saying why new farming systems are important. The surpluses in the developed world are the result of well-meaning interference by governments in the free market and are undoubtedly temporary, taking an historical view, rather than that of a politician with his sights set on the next election. The world as a whole needs more food now and will continue to need more food as populations in most countries continue to expand. However, for nation states and for free trade areas, the important argument is not about the total supply needed but about the efficiency with which it is produced. Improvements in productivity (ie. output in relation to resources used) benefit consumers as a whole and those countries which do not keep up with technical improvements leading to greater productivity will inevitably find themselves importing an increasing proportion of their food supplies. It is in the long-term economic interests of any country to see its agricultural sector producing food and fibres at lower and lower real cost, even though there will usually be social costs associated with this trend.

### How Is Progress Brought About?

Many important improvements are made by farmers, who invent new bits of machinery, improve building design by trial and error and, in the past, did much to improve livestock by selection on their own farms. For example, the invention of a rear-mounted rake (the "Buckrake") for gathering and carting grass to the silage clamp did much to make silage making a tolerable activity on British farms. This set the scene for silage to displace hay as the predominant method of conserving grass for winter feeding. The Buckrake was itself a development from another farm invention, the hay sweep, which used to be pushed in front of a tractor (or an old car) and in its day took much of the back-breaking work out of hay-making. In more recent times, engineers have developed forage harvesters which have superseded the buckrake.

Other developments have depended upon discoveries by scientists who may or may not have been thinking of potential applications to agriculture. The original discovery of selective herbicides, for example, came incidentally out of work aimed at understanding the regulation of growth in plants. The discovery of how to freeze bull semen without killing the sperm was made accidentally by someone who knew what he was looking for

and achieved it by getting some bottles mixed up in the laboratory.

Few, if any, of those developments which have led to new farming systems have been achieved by farmers alone or by scientists alone. They have needed close cooperation between agricultural scientists (who may have had to borrow ideas from pure science to get started) and innovative farmers, firstly because no new scientific development is of any value until someone has put it in the field and tested it and secondly because new systems almost always need a long period of development, to which both farmer and scientist contribute, before they are successful.

### Case Studies

I shall illustrate my theme, that new farming systems now evolve as the result of collaboration between agricultural scientists and innovative farmers, by taking two examples with which I am familiar. The first is the development of the poultry industry over the past 30 years and the second is an assessment of the development needs of the dairy industry in the UK in 1993.

#### The Poultry Industry, 1960-1990

The past thirty years have seen tremendous growth in the productivity and the output of the poultry industry in almost every country in the world. In some places the total volume of egg production has risen, only to fall again as myths about the nutritional value of eggs have been propagated. In other countries total production and per capita consumption of eggs are still rising. Poultry meat consumption has expanded and is still expanding almost everywhere, even in countries such as New Zealand and Japan which import nearly all the feedstuffs needed to sustain their poultry industry. In some places poultry meat is supplementary to traditional supplies of red meat and in others it has tended to displace the more expensive beef, pork or lamb, while total meat consumption has remained roughly static.

The success of the poultry industry is due to great improvements in productivity which have been associated with new systems of poultry farming. How have these new systems come about? Much of the gain has been due to entrepreneurs in the industry who have developed intensive systems of housing chickens. These systems entailed large reductions in labour costs, in capital costs (a densely stocked battery house costs less per bird space than a free-range hut, not to mention the associated land cost) and in feed costs in temperate climates. But intensive systems also carry greater disease risks (as do cities,

when people first build them) and the knowledge and skills of scientists were needed to offset these risks. Early attempts to keep chickens indoors all the year round failed because of ignorance of the need for vitamins. The discovery and isolation of the vitamins in the 1930's and their subsequent synthesis at affordable prices laid the foundation for the modern poultry industry. Other problems which arose when chickens were first kept together in large numbers were the smell of the droppings and the frequent recurrence of infectious diseases. As with people in cities, these problems had to be dealt with by efficient sewage disposal and a policy of mass immunisation against communicable diseases. The end result, as with people in modern cities, is that individuals living at high densities in very artificial surroundings are healthier than their cousins left behind in the countryside.

Besides vitamins and vaccines, the poultry industry has benefitted from the work of environmental physiologists and nutritionists and, perhaps most of all, from the application of quantitative genetic theory to the breeding of better (or better adapted) chickens. It can be argued that the yield of the best laying hens today is not much more than that of the best chickens recorded in the 1930's. However, it is now possible to order 1,000 (or a hundred thousand) pullet chicks which will give an average yield equal to that of the prize winners of early laying trials. In the case of broilers, turkeys and ducks, the genotypes now available are at least twice as efficient at turning feed into meat as anything which existed thirty years ago. All this is the result of the systematic application of genetic theory by a small band of scientifically trained men and women in a shrinking number of international companies. The higher rate of genetic progress, compared with beef or sheep, has been achieved partly because the objective has always been profit (whereas cattle and sheep breeders have had mixed objectives) but mainly because of the short generation interval of the birds. In this respect, breeding chickens is like breeding maize or wheat and has shown similar annual gains in productivity. It is also the case that chicken breeding, like cereal breeding involves selection not just for increased yield but also for adaptation to changing production systems and for disease resistance because these are all components of profit. The development of new systems in the poultry industry could not have resulted from the efforts of geneticists, veterinarians, physiologists and nutritionists working alone nor from the efforts of entrepreneurs in the industry. The evolutionary process has required constant interchange between the farmer, who encountered problems

(some of which he solved by ingenuity and for some of which he had to seek technical help) and the scientifically-trained personnel who sometimes had the answers to the farmer's problem, but more often had to take the problem away and bring back a solution months or years later.

The flow of technical information has been good in the poultry industry because the lines of communication have been short. In the early days, the poultry farmer received advice from extension workers who were specifically trained in poultry science and husbandry and who gained new knowledge by regular contact with research workers in universities and research institutes. As the industry grew and integration took place, technical decisions, such as what stock to use, what to feed, how to control diseases and what lighting programme to follow, were made by a diminishing band of managers who each controlled increasing numbers of production units. These men sought advice directly from those with research experience and the need for extension workers disappeared. Some retired, some became private consultants and some became specialist investigators employed by the state.

The poultry industry, then, has succeeded in expanding its share of the food market because it has developed new farming systems by exploiting technical knowledge as fast as it has become available and by clamouring all the time for technical solutions to the problems which still confront it.

#### Research in the Dairy Industry in 1993

Dairy farming in the UK and elsewhere is a much more dispersed activity than chicken farming. There is a general trend in most countries for herd sizes to increase while the number of herds diminishes and in many countries total cow numbers decrease at about the same rate that average yields per cow are rising. But these processes are gradual and though they amount to substantial changes in the long run they have not generally been accompanied by dramatic changes in systems of production or in the scale and organisation of dairy farming. Most managers of dairy herds still spend a large part of their time milking cows.

An assessment of the research and development needs of the dairy industry throws up a number of interesting issues. The dairy farmer is, understandably, preoccupied with the market and the price received for his milk, though these will, in the long run, be determined by the supply of and demand for milk and milk products. A great deal can be done to find ways of selling more milk-derived products to the consumer but this is outside the farming system of most milk producers. The development of more efficient ways of producing milk is, however, the business of the

farmer, aided by research which is directed towards the efficiency goal.

Much has yet to be learned about feeding dairy cows and, especially, about characterising the feeds available on the farm by quick and cheap analyses (e.g. by Near-Infra-Red spectroscopy) in ways that will give reliable predictions of the feed intake and production to be expected from particular feeds, both singly and in combination. The performance of feed mixtures cannot at present be predicted from chemical analyses of the components and this is a matter which needs sorting out. The problem will not be resolved, however, by testing large numbers of feed combinations. It requires a robust theory explaining what happens to the diet in the rumen and capable of predicting quantitatively what metabolites (good and bad) are yielded by digestion so that a reliable model can be built to predict rates of milk fat and milk protein synthesis given the dietary inputs. This in turn requires an understanding of the control of milk protein synthesis at the molecular level and so we need direct linkage from molecular biologists, through animal physiologists to ruminant nutritionists and analytical chemists to solve this complex problem.

Another area where there is still much inefficiency is in the cost of producing a heifer replacement. A 55% chance of turning an egg into a live offspring is regarded as normal, though such wastage is not accepted in sheep or chicken farming. There is the other problem that half the offspring of dairy cows are bull calves. Here a number of possibilities are being investigated. These include the improvement of conception rates, the induction of twinning, either by controlled twin ovulation or by embryo transfer, and the manipulation of sex in calves.

There is a good chance that conception rates could be improved if we understood more about the signalling system between the developing embryo and the dam. This requires the isolation and characterisation of proteins secreted by the trophoblast, which could then lead to the identification and synthesis of key amino acid sequences in those proteins and to practicable treatments which would increase the proportion of viable embryos that succeed in setting up a pregnant status in the uterus, even in high-yielding cows.

Many dairy farmers say that they do not want twin calvings but some do and are convinced they can manage twin-calving cows successfully. Here is an important area for management research. The production of embryos in large numbers by the in vitro culture of oocytes taken from the ovaries of slaughtered cows and heifers is now a commercial business, though very "hi-tech" and still

needing research to improve its efficiency. The alternative technique of inducing twin ovulations, with few if any higher-number ovulations, by immunising the cow against inhibin, is now close to success at the research level and may be available commercially in a few years' time. This procedure uses a man-made fragment of the natural inhibin molecule and is another example of the deliberate application of molecular biology in an attempt to solve a farmer's problem.

Separation of male and female sperm, by cell sorting after marking the DNA with a fluorescent stain, is now an established technique which can be combined with in vitro fertilisation to give embryos which are mainly male or mainly female.

The potential of these techniques to change dairy farming is enormous. It is not simply that farmers can choose whether to order a female embryo of a dairy breed or a male embryo of a beef breed or cross, although this choice will in itself increase the efficiency of the dairy herd by largely eliminating the unwanted dairy-type bull calves whilst shifting the output of beef calves towards a substantial proportion of males. More importantly, once it is just as easy and nearly as cheap to order an embryo of known sex and genotype as it now is to order a dose of semen, the dairy farmer will find himself in the position which poultry farmers and many pig farmers have reached; that is, selection policies and the improvement of livestock will no longer be in the hands of farmers whose resources are limited and objectives diverse. Dairy cattle breeding will become the province of a small number of international companies which will set up the organisation needed to maintain elite herds and to deliver sexed frozen embryos to the farmer on a very large scale. The female embryos will almost certainly be  $F_1$  hybrids which will in due course serve as surrogate mothers but will not be a genetic source of further dairy replacements. This will indeed be a new farming system and though it may not look very different to an observer leaning over the cowshed gate, it will improve the efficiency of milk production dramatically. One of the greatest potential benefits of hybrid heifers will be their longer milking life in the herd and this is perhaps a reason why it could be a mistake to invest large sums of money on long-term research aimed at curing the metabolic and morphological disorders of our present high-yielding black-and-white dairy cows.

Even new hybrid cows will need milking, though perhaps not by men and women. Robotic milking machines are in an advanced experimental stage and it will not be long before commercial prototypes appear. No doubt there will be developmental problems to solve and maybe cows will have to

be selected to suit the robot milker (just as cereals had to be selected to suit the combine harvester). There is an obvious potential gain in labour efficiency arising from robotic milking, although one line of argument is that labour per cow should not be reduced: the cowman should spend more time observing and caring for his animals and less time in the pit of a milking parlour. However, the greater benefit may be realised in yield per cow when systems are developed which allow each cow to determine the frequency of her milking. The integration of free-choice robotic milking with fully automatic cow identification and recording of milk yield, milk composition and body weight (and perhaps free-choice feeding of a complete diet) would lead to a new system of farming dairy cows which would look very different from what we know today, even to a casual observer leaning on the cowshed gate.

All these developments, in feeding, in reproductive technology, in dairy cow selection and in milking systems require close cooperation along a chain which starts with molecular biologists and physiologists or electronic engineers, leads through agricultural scientists who understand the practical objectives and enough of the science to be able to talk to the laboratory-based innovators and who control the resources to test things out and evaluate them, to the entrepreneurial farmers who can see that some crazy idea is perhaps not so crazy and might be worth trying in a herd which has to make a profit to pay his grocery bills.

Meanwhile, there is a great deal of established knowledge about feeding and managing dairy cows which it is the business of extension workers, whether paid by the state or hired as private consultants, to convey to the many small businesses which make up the dairy industry.

### Conclusions

New farming systems are sometimes initiated by farmers and sometimes arise because of technical developments which may, in turn, be a spin-off from fundamental scientific discoveries. In both cases a team effort is required to develop and perfect these systems. If farmers invent a new way of doing things they soon run into snags which they cannot resolve without the help of agricultural scientists. If scientists produce a new potential technology, it cannot be turned into a successful farming system until farmers have found the snags and ironed them out and then decided to adopt the technology because they can see that it is an improvement on what they were doing before.

An advisory network is essential to maintain the connections between research scientists and their farmer

customers. In highly integrated sectors, the advisors can be privately funded, either as consultants or as employees of the large production companies. Where there are modest numbers of medium-sized units, co-operation between producers may be the best basis for gaining advice and passing problems back to the research service. In developing agricultural economies, such as the USA sixty years ago or as in some Eastern European countries today, state-funded extension workers are essential to service the large number of small producers who have only limited access to technical information.

In all three cases, the ultimate beneficiary of the advice and the research on which that advice is based is the consumer, not the farmer, since the long-run result is always cheaper food, not higher profits. That is why state investment in agricultural research and extension is always highly profitable for society at large.