PROTEIN PRODUCTION FROM POULTRY

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SUMMARY

World patterns in the production and consumption of eggs and poultry meat are reviewed. Most developed countries are self sufficient in eggs and there is a world market surplus in shell eggs and egg products. Meat chicken production in developed areas continues to grow substantially. In underdeveloped countries complete packages of stock, buildings, and technology have been uplifted from developed countries, but there has been little study of the possible uses of local avian species for meat or egg production or of wild duck, pheasant, geese or other avian species which could utilize efficiently highly-fibrous feeds and therefore be less competitive with man for available plant and animal protein.

The geneticist, the nutritionist, the engineer and the veterinarian have been able to provide the knowledge to enable businesses with an integrated structure to capitalize on available technology. There remains genetic problems with plateau situations in egg lines, of the broiler breeder hen and the leucosis disease complex. However, although the nutritional requirements of the fowl are well documented, a major problem is the supply of high-quality protein feedstuffs which are not directly utilizable by man. It is possible the industrial chemist and engineer may provide some help. There are considerable gaps in the knowledge of the physiology of the fowl. One egg per day per hen per year is not yet possible.

CONSIDERABLE PROGRESS has been made during the past two decades in increasing the animal output per unit of cereal input. However, when one considers the efficiency of a modern meat chicken, converting 1 kg of a 10% moisture feed into 0.5 kg of live carcass containing 60 to 65% moisture, it is obvious that much scope exists for increasing the utilization of feedstuffs.

The poultry industry embraces several sections, eggs and meat (from end of lay birds) from the domestic fowl, turkey, ducks and geese, and in recent years meat production from the specialized meat chicken bred from various lines of the domestic fowl. Of these various sections, the eggs from the domestic fowl and the specialized meat chicken are the most important. The turkey, too, can be important in some countries that already have a highly developed specialized meat chicken industry, but for the most part turkey, ducks and geese play a relatively minor role in the poultry industry.

The major part of the gross annual product of the poultry industry is from eggs. In some affluent countries *per capita* consumption of fresh eggs has been declining. This decline has been accompanied by increases in consumption of eggs for processing but these increases have been insufficient to offset the fall in consumption of fresh eggs (Rogers, 1970). According to Strang (1972) the beginnings of this trend are now becoming apparent in New Zealand. Estimated New Zealand annual *per capita* consumption declined from 324 in 1967 to 300 in 1969 (Anon., 1970a). As pointed out by Schroder (1972) there is some evidence that, in countries with high income levels with an income elasticity of demand for eggs of near zero or even negative, along with changes in food preferences and living habits, there will be a continuing decline in *per capita* egg consumption.

According to an FAO report (Anon., 1970b) world production of eggs expanded at an average annual rate of 4 to 5% in the ten years to 1969. In 1969 the increase was 3%. Conversely, world trade in shell eggs declined steadily until 1967 from its peak in 1960. According to the report, the decrease in the volume of trade over this period was around 45%. There were advances of 4% in 1968 and 11% in 1969 but these increases were accounted for by greater trade amongst member countries of the EEC. On the other hand, world trade in egg products has grown substantially since 1964. These changes indicate that most of the developed countries are self-sufficient in eggs. Indeed, all are troubled with embarrassing surplus production which has led to the rise in world trade of egg products with lowered prices. Thus, in developed countries eggs, either as fresh or in egg product form, are not expected to increase on a *per capita* basis; in fact, they may well decline in the future. In the aggregate, however, this decline is offset by population increases.

In many under-developed countries, many of the breeds of chickens developed in the U.S.A. are being raised successfully under trained managers providing proper chicken diets and appropriate disease control measures (Vohra and Wilson, 1970) but little systematic work has been done to develop the indigenous avian species which are climatically adapted to the local conditions. The use of wild ducks and geese to develop new strains could revolutionize the poultry industry of certain countries because these birds may be able to forage for their food. Chickens and turkeys by the very nature of their digestive tracts have to be fed much the same concentrated forms of energy and proteins as humans need. The efficiency of conversion of protein from feed to muscle and egg proteins is less than 25%, though the protein is of high quality. In the future, possibly 75% of the ingredients used in poultry diets may need to come from sources not competitive with human food. The development of new avian species which could utilize efficiently highly fibrous feeds would be best suited to the future.

The egg industry is a traditional industry. A more modern development of the poultry industry has been the establishment of the specialized meat chicken or broiler trade. Production of poultry meat has increased at a much faster rate than any other form of meat production. The Organisation for Economic Co-operation and Development (Anon., 1968) has indicated that between 1950 and 1965 the annual compound rate of increase in poultry meat production in developed countries ranged from 5.8% in the U.S.A. to 21.4% in the Netherlands. Part of the variation is due to the fact that it is a comparatively new industry with different times of starting in different countries. The U.S.A. has had the longest period of development of meat chicken. New Zealand, in contrast, has about the shortest period of development. The O.E.C.D. found it difficult to make projections since poultry meat is virtually a new product and it is uncertain at what level a ceiling may be reached. Projections for the 1970s and beyond made by Cathcart (1971), show increasing production and consumption of broiler meat. Broiler numbers were first estimated by the USDA in 1934 and showed 34 million produced that year and expanded to about 2,750 million in 1969 (Cathcart, 1971). Turkeys were 20 million in 1934 and reached 127 million in 1967 which caused oversupply and a depressed production in 1968 and 1969. Consumption of poultry meat *per capita* in the States was 5.9 kg (13 lb) in 1934; in 1970 it was over 18.6 kg (41 lb), 16.8 kg (37 lb) of it broiler meat. A similar parallel can be drawn in other countries. The U.K. had no special meat chicken industry up to 1953 but as a consequence of the freeing of restrictions on the feed trade it has expanded at a phenomenal rate since that time. *Per capita* consumption of poultry meat in 1953 was 2.7 kg (6 lb), (mostly cull hen meat). In 1970 over 200 million broilers were produced and *per capita* consumption was 8.5 kg (18.7 lb).

In under-developed countries the situation with poultry meat is similar to that with eggs. With the aid of American stock and techology, meat chicken industries have been established but there has been little study of the possible uses of local avian species for meat production.

FACTORS AFFECTING EFFICIENCY

ORGANIZATION

The broiler industry is often used as a model to show what is possible by marrying technology and business methods. The broiler industry has been built up as a whole series of highly specialized research projects, involving new approaches to applied poultry genetics, the development of controlled environment housing, disease control, and new approaches to processing and marketing. The basic development has been the application of modern genetic knowledge by way of large-scale selection and testing programmes to improve the productive level of the egg or meat type stock. Such work is costly, hence it is imperative that the breeder mount large multiplication programmes to produce millions of chicks of the improved stock, thus spreading the cost of his breeding unit over a large volume of chick sales. Of the 2,000 million broilers produced in the U.S.A., the selection work of the vast bulk of this stock is pursued by four female line breeders and two male line breeders (Sykes, 1963).

With improved stock there was opportunity to develop an integrated enterprise where all aspects of production, processing and marketing were under the control of one organization. The broiler industry has become a highly concentrated vertically integrated industry and the product has moved from an occasional luxury item to an accepted stable convenience food. In terms of total world production of edible meat, the poultry industry is still quite small but it probably spends proportionately more on genetic improvement, nutrition research, product development, and market research than any other livestock industry. The trend will continue to be for fewer but larger growing units, processing plants, and integrated groups.

GENETICS

With broilers increased efficiency with time is evident. Biely *et al.* (1971) surveyed twenty-five years of progress in broiler production in Canada and U.S.A. The first Production and Broiler Test of commercial broiler stock in the U.S.A. was at Maine in 1946. Liveweight at fourteen weeks (average of both sexes) was 1.8 kg (3.96 lb) with a feed efficiency as measured in kg of feed to produce 1 kg liveweight of 2.68. Ten years ago the average liveweight of broilers at ten weeks of age was 1.7 kg (3.74 lb) with a feed conversion of 2.43. In 1970 the average liveweight of broilers was 1.85 kg (4.07 lb) at eight weeks of age with a feed conversion of 1.94. The improvement in liveweight, feed efficiency and reduction in the growing period from 10 to 8 weeks is a net gain result from the use of improved genetic stocks and more efficient feeds and disease control. The objective of the industry at present is a 1.8 kg (4 lb) broiler at seven weeks of age with a feed efficiency of 1.75. Rate of early growth in broilers is still increasing each year but at a lower rate than during the past 20 to 30 years. However, Jaap (1970) considers there is no evidence that the limit has yet been reached.

There are associated problems. Such rapidity of growth causes continued increases in the adult weight of pullets which produce the hatching eggs. Dams of broiler chicks may weigh up to 5 kg (11 lb) or more in weight if their feed supply is not restricted. Pullets of these large-bodied types not only lay fewer eggs but also more defective eggs (Jaap and Muir, 1968), and these problems create difficulties in meeting the hatching requirements for hatching eggs and increase the overhead costs of the broiler enterprise. Jaap (1969) has indicated that it may be possible to reduce the dam's body-weight by about 30% without reducing the growth rate of the broiler chicken offspring. This may be done by use of a sex-linked recessive dwarf gene (dw) to develop a line of small broiler breeder dams. Another sex-linked gene usually found in Bantam breeds, considered by Jaap (1971) as an allele of the dw gene, reduces body size proportionally about 7 to 10%, and is being used to explore the possibility of assisting in uncovering hidden genetic variances useful for genetic improvement in egg or broiler type populations.

With egg production, possibilities of further genetic improvements do not appear as promising as with broilers. A "plateau" seems to have been reached for egg-laying performance in commercial stocks. From an analysis of random test results, Clayton (1968) concluded that a number of stocks have reached about similar levels of performance in most of the economically important traits such as egg number, size and mortality. There has been discussion about the possibility of using dwarf layers in the commercial egg industry. However, Summers (1971) considers that results for the egg production and egg size of these birds have not been good enough to make the dwarf layer a commercial proposition as yet, but active genetic, physiological, nutritional and husbandry research is under way and the dwarf layer may have a place in the future. The dwarfing gene, dw, lowers the rate of yolk production. This is detrimental in the egg type Leghorn because in these strains rate of yolk formation is harmonized with the ability of the oviduct to produce albumen, membranes and shell for egg formation and therefore dw which acts to reduce the rate of yolk deposition in the ovary is detrimental to egg production strains but apparently not detrimental to strains utilized for the production of broiler hatching eggs. The broiler type pullet's ovary is producing yolks much more rapidly than their oviducts can form eggs.

NUTRITION

In general, the intake of normal feed tends to be dependent more on dietary energy content than on physical distension of some portion of the alimentary tract such as is found in the ruminant — *i.e.*, birds tend to eat more of a low energy than a high energy ration. For meat chickens, therefore, high energy rations with maize and fat are used. Fibrous, bulky foods such as pollard are rarely seen in least cost rations for broilers. Laying hens also eat to satisfy their requirement for digestible or metabolizable energy and thus eat less of a high energy. maize/wheat diet, than of a low energy, barley/pollard diet, but can produce the same number of eggs with approximately the efficiency of conversion of metabolizable energy.

Protein energy ratios are important in poultry nutrition, particularly with broilers with their short growing period. It is recognized that the protein content of a ration must be adjusted in relation to energy level rather than a specified fixed percentage of protein. Excess protein in the diet does not affect feed intake or egg production; it is used wastefully as energy. As Davidson (1961) has shown, sub-optimal protein levels may also lead to waste as the uptake of feed per unit of liveweight may be increased to compensate for the low protein and in this case metabolizable energy is lost as heat. Particularly with broiler rations, considerable attention is paid to energy protein ratios or, to be more correct, energy amino acid levels. There are tables available giving the essential amino acid requirements of poultry as a percentage of the protein (Scott *et al.*, 1969). Methionine is used extensively in fortifying many grower and layer rations and lysine may shortly be available at a price justifying its use as a supplement to lysine-deficient ingredients.

Intense competition between the various feed firms servicing the poultry industry, intensive production and research resulting in a comprehensive knowledge of the nutrition of poultry, all have helped to ensure that the possibilities of the final ration limiting performance through mineral or vitamin inadequacy are substantially less than in other classes of farm stock. There is an extensive use of premixes for poultry mashes (Mills and Williams, 1961) containing more than adequate levels of a few limiting minerals and vitamins and often as an "insurance" factor there are substantial levels of other micronutrients. The chemical industry has made a substantial contribution towards the successful intensification of poultry (Eden, 1961). It is possible that the chemical industry may move to find new nutrient sources for poultry Yeast and bacteria which may serve in poultry rations may be grown on a petroleum basis. Many ingredients may be improved in nutrient value by appropriate processing — *e.g.*, pelleting of feeds, autoclaving of grain, enzyme treatment, protein hydrolysis, or irradiation. Some help from the plant geneticist may also be available. High lysine maize is one example but perhaps an even greater contribution could come from the development of grains of higher protein content which would lower the need for expensive supplementary protein concentrates, particularly when fortified with synthetic amino acids.

Disease Control

Without the advances that have been made in preventive medicine, the poultry industry could not have reached the high state of efficiency it now enjoys under commercial conditions. High concentrations of stock became possible with improved vaccines, drugs and management control measures. Many of the major hazards to poultry production may now be fairly readily controlled. Marek's disease, one of the deadliest diseases and one which was until recently the most difficult to control, has been intensively investigated by research workers around the world and as outlined by Gilchrist (1972), the effective control of this disease by the use of vaccines as well as genetic resistance is close at hand. Cumming (1972) has pointed out that till now there has been no difficulty in determining the most important disease problems but in the future the picture will not be so clear cut and the greatest economic loss will be due to diseases which, though not causing high mortality, through their subclinical effect will be a drain on production and efficiency. More detailed flock histories will be required to identify these less evident disease problems.

PHYSIOLOGY

National averages for egg production have shown a substantial increase in the last thirty years. As Becker (1964) indicated, there is equally little doubt that much of this improvement is due to the widespread elimination of stock of inferior productivity, plus a substantial improvement in knowledge of disease control, nutrition and management. Present levels of production range between 220 and 250 eggs per bird on a hen housed basis depending on the type of stock as shown by USDA Random Sample Test records (Anon., 1971). Even in New Zealand an average of 232 eggs per hen housed has been reached (Anon., 1969), an average based on all the various stocks available for sale in that year. In that test one stock averaged 272 eggs per hen housed. But the 365 eggs per hen on a flock basis is not likely yet. The efficiency of conversion of poultry feeds into better quality egg proteins could be improved if one egg per day was attainable and markedly improved with two eggs or more per day. Twenty hours elapse before shell formation is completed in the oviduct of the hen. The thick shell is of great importance for packing and transport. But the shell contributes nothing towards the nutritive value. Reduction of the time an egg spends in the shell gland to about four hours (enough to give rigidity to the egg to roll away and be packed in plastic containers) will give enough time for a second ovulation during the twenty-four hour period. Any success will involve active studies in the fields of genetics and physiology. The role of calcium in ovulation and egg-shell formation is being actively researched (Gilbert, 1967; Smith *et al.*, 1972), with a view to understanding the mechanism of ovulation and egg-shell formation in the hen.

The artificial insemination of domestic fowl is practised to obtain hatching eggs. It has been limited in the domestic fowl to genetic and physiological studies, though it is used widely by turkey breeders, since conformation precludes the economic production of poults by natural mating. One of the main difficulties that is encountered in the avian species is the storage of sperm. In contrast to frozen semen of bulls which can be stored for several years, the sperm of the avian species cannot be stored over any prolonged period to maintain normal fertility in a hen extending over several days. Some studies on storage conditions of avian sperm at sub-zero temperatures have been reported (Watanabe, 1967; Cooper, 1969), but the successful deep freezing preservation of avian semen is still awaited.

Poultry are now housed intensively with control over light, temperature, and humidity, and active work on many fronts is in progress to find the manner in which the climatic environment can be manipulated for the best economic production (reviewed by Charles, 1970). The commercial need for intensive housing and the technical development of the heat and moisture balance concept in poultry houses led to the power ventilated and insulated poultry house that is becoming quite common today. The desire to use light patterns caused the elimination of windows so that control of temperature became feasible. Nutrition/temperature interactions have been studied by Payne (1964, 1966) together with high temperature and cyclic temperature patterns on performance, and this work has stimulated interest in heating laying houses, and the heat calories versus feed calories debate (Walters, 1971; Smith and Oliver, 1971).

The progress that has been made in poultry production illustrates the rapid practical use of scientific results. It is a unique feature of poultry farming that new technologies are applied quite quickly. Integration has played a vital role in the growth of the industry, and its high degree of technology in all its operations, and this is likely to continue in the future. The geneticist has been responsible for a new type of chicken capable of fast growth rate and high efficiency. Egg production in laying strains has been brought to an apparent plateau but the physiologist may provide some clues for the geneticists to move beyond this in the future. The nutritionist has formulated efficient rations but his role in the future must concentrate on developing new sources of food for poultry, food not in direct competition with man. The pathologist has developed various procedures to protect the health of birds but he will need to be ever-watchful of the consequences of greater intensification. The agricultural engineer has designed suitable buildings that allow the raising of tens of thousands of birds in one building in which some degree of control over light, temperature, humidity and feeding is possible; his skill in the future will be required to put into practice new findings of the environmental physiologist concerned with the optimum manipulation of environmental factors. The engineer has also helped with increasing mechanization, so that thousands of birds may be fed and watered automatically and eggs collected with the aid of moving belts and elevators, so that one man can attend 50,000 broilers, or 20,000 layers at a time, or birds can be slaughtered and processed at the rate of 20,000 per day. The meat chicken in particular has been a significant development in the poultry industry in recent years and it could become an important item of animal food in developing countries that are deficient in good quality protein. Much depends, however, on resources and these depend on education and social factors of man himself as well as on good poultry husbandry. Religious and cultural prohibitions, the changing consumption patterns as economic status rises, the stigma of "poor man's food" for some of the synthetic protein products which can be devised, are some factors contributing to the problem of supplies of protein which arise from the make-up of man himself.

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