Nuclear Techniques in Animal Production and Health

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Terms such as isotopes and nuclear techniques often call to mind basic research of little or only minor practical importance for animal productivity and health. This is, however, not true. No other scientific tools have in our lifetime been of a significance equalling that of the isotopes in widening our insight into animal physiology and nutritional requirements. Last but not least, they have made us realize the importance of the soil-plant-animal relationship. This applies to both radioactive isotopes such as radiophosphorus and stable isotopes such as nitrogen-15.

Furthermore, no other scientific methods have contributed to such an extent to our understanding of the metabolic processes in economically important farm animals both under normal and pathological conditions.

In the fight against animal diseases, especially parasitic infections, nuclear techniques have also proved to be of great value, namely in the production of irradiated vaccines against helminthic diseases. In this context it should be stressed that reduced productivity due to protein loss caused by intestinal parasites is a problem of paramount economic importance in developing as well as developed countries.

Recently radioisotopes in the so-called radioimmunoassays have also been applied in determination of the hormonal status of farm animals and to elucidate its relation to the environment and to the physiological and nutritional condition of the animal. This rapidly developing technique may make it possible to control the reproductive performance of cattle and sheep more efficiently than has hitherto been the case.

Production of animal protein of a high biological value for human nutrition is still a problem of great concern for the less developed countries. Without doubt the use of nuclear techniques, hand in hand with other research methods, will be of great help in overcoming this condition, always provided that the countries in question possess the necessary equipment and trained personnel.

By means of examples I shall try to sketch what the use of nuclear techniques has meant and still means for the improvement of animal productivity. In many cases these results would not have been achieved by use of conventional research methods. For the sake of clarity I shall divide my statement into three sections, namely: Animal nutrition and physiology, animal reproductivity, and use of nuclear techniques in the production of vaccines against parasitic diseases.

Regarding nutrition and physiology it should be kept in mind that no animal can attain its full genetic potential for growth, milk production, reproductive performance, etc. unless its requirement for all essential nutrients is met. The problems concerning requirement of farm animals for nutrients to ensure optimal productive performance are therefore of world-wide importance. In this respect the use of isotopes has been of immense significance.

Since the turn of the century it has been known that phosphate deficiency in cattle and sheep can result in impaired productivity and fertility. Similarly it has been realized that lack of trace elements such as iron, copper, cobalt, and others might lead to reduced productivity or even serious diseases in farm animals. However, the basis for a rational prevention of these conditions, namely an elucidation of their causal relations, has in most cases only been obtainable by the use of radioisotopes.

George Hevesy, the Hungarian Nobel Prize winner, was the first to show by means of radiophosphorus that the utilization of phosphorus by animals depends on the calcium-phosphorus ratio in the feed. Since then numerous tracer experiments have been carried out to elucidate the absorption and metabolism of calcium, phosphorus and magnesium in farm animals.

These studies have radically changed our understanding of the absorption and fate in the animal body of the elements calcium, phosphorus and magnesium. We know by now that these minerals not only serve as structural elements in the skeleton. They do in addition form a depot, which to a certain extent can be mobilized if necessary. As a result of this research it has been possible to utilize phosphate in animal diets in a much more rational way than previously. Moreover, isotopes have been of great value in clarifying the causality of diseases of great economic importance such as aphosphorosis, milk fever and grass tetany, and thereby made an effective prevention possible.

Radioisotopes have for many years intensively been used in studies on the importance of trace elements for farm animals. Lack of or imbalance between such nutrients has proved to be limiting factors for animal productivity more frequently than hitherto believed, especially in herbivorous animals.

Deficiency of a trace element, as for example cobalt or copper, in the soil, may result in a decreased content of the element in plants. This in turn can cause reduced productivity and fertility or even lead to occurrence of manifest diseases in farm animals. In other cases excess of a trace element such as molybdenum or selenium in the soil and hence in the crops may bring about metabolic disturbances in animals. As an example it can be mentioned that excess of molybdenum can induce a copper deficiency due to biological competition between the two elements; such soil-plant-animal relations have to a great extent been detected by means of tracer techniques including activation analysis.

Studies of this kind have also brought to light why trace elements are of such essential importance. They may function in active compounds such as cobalt in vitamin B_{12} or be components of enzyme systems involved in the processes of absorption or metabolism.

Due to their symbiosis with bacteria in the forestomachs, ruminants are able to utilize urea and other inexpensive nitrogen containing compounds as protein sources. This is of world-wide economic importance. The use of such substances in feeds is, however, not without problems. Firstly, it is a prerequisite that the content of carbohydrate and minerals

in the rations is optimal for the growth of the ruminal bacteria. Secondly, the production of ammonia in the forestomachs must not exceed the capacity of the bacterial population for fixation of nitrogen as microbial protein.

In solving these problems, nitrogen-15 has proved to be of considerable value. Only by use of this stable isotope is it possible to estimate the effectiveness with which the nitrogen containing compound can be utilized in the synthesis of bacterial protein. Furthermore, the use of labelled non-protein-nitrogen is inevitable in order to get an exact estimate of the feed composition necessary for optimal utilization of such non-conventional protein sources.

In the field of applied physiology of domestic animals, isotopes have been used with great success. Valuable knowledge has thus been compiled concerning gastro-intestinal digestion and absorption of nutrients, transport of absorbed nutrients in the blood, intermediary metabolism and function of organs such as the mammary gland under normal as well as pathological conditions.

Due to the application of tracer techniques, our perception of the nature of the digestive processes has been altered fundamentally. A fact which is of decisive importance for prevention and combat of diseases in the digestive tract. Nor has any other method contributed so much to our understanding of the transport and turnover rate of nutrients in blood as the use of isotopes. As far as carbohydrates and lipids are concerned, tracer experiments with carbon-14 labelled metabolites have provided enhanced insight into the intermediary metabolism in ruminants. Hereby the basis for a nutritional prevention has been created against one of the most loss involving metabolic diseases in high yielding cows, namely ketosis.

Regarding the physiology of milk secretion corresponding research methods have made us realize that 50 per cent of the milk fat normally are synthesized from acetic acid produced in the forestomachs while the residual half is formed on the basis of saturated and unsaturated fatty acids produced in the liver. As far as casein, the most important protein in milk, is concerned, the use of labelled amino acids has demonstrated that the precursors of this protein are free amino acids in the blood.

These and other studies on the physiology of milk secretion may seem of merely theoretical interest. In reality, however, they have fundamental significance for cattle breeding programmes aiming at increased production of milk with the highest possible nutritional value. Likewise, such experiments have enhanced our possibilities of a rational fight against mastitis, a disease responsible for great economic losses in dairy farming.

In the field of applied animal physiology, tritiated water has proved to be a valuable tool in the determination of water requirements of animals. This application of isotopes is of considerable importance in certain arid countries.

A low reproductivity caused by malnutrition, climatic conditions or genetic factors is one of the major problems of animal husbandry in many areas, not least in the developing countries.

Irrespective of the causal relations, the essential factor of this condition is anomalies in the function of the hormonal system. Consequently, great efforts have been made on development of methods suitable for determination of the hormonal status of individual animals under various environmental conditions.

Among such methods can be mentioned elucidation of the function of the thyroid gland by measurement of radioiodine uptake and release by the glandular tissue. This technique has to a great extent been applied in the selection of cattle fitted for meat and milk production under hot climatic conditions.

Methods of this kind which involve administration of radioisotopes to the animals are now widely replaced by the so-called radioimmunoassays. The basic principle in such analysis is a competitive reaction between labelled and unlabelled antigenic hormone-compounds and their specific antibodies. This new technique has provided a new area in determinations of the hormone profile in blood of farm animals.

As a pregnancy test, radioimmunoassays have already found practical use in cattle breeding. Methods of this type also facilitate an evaluation of the influence of environmental and genetic factors on the hormonal status of animals, and in many countries attempts are made to use these techniques in selection of breeding animals with a desirable hormonal profile, such as a high production of growth hormone.

A continuously growing demand for high quality protein of animal origin has called for intensification of livestock production. As only farm animals free from parasitic and other infectious diseases can respond satisfactorily to improved management, prevention of such diseases becomes of paramount importance.

The most direct application of nuclear techniques in the control of parasitic infections is in the preparation of radiation-attenuated vaccines. Essentially the principles depend on treating the infective stage of the parasite with radiation and thereby reduce its pathogenecity without significantly impairing immunogenecity. Consequenlty, the host animal is exposed to all the natural antigens of the parasite.

Through an intensive international collaboration it has been accomplished to produce effective radiation-attenuated vaccines against lungworms and stomach worms in ruminants and also against roundworms as well as tracheal worms in poultry. It has, however, not yet been possible to produce a satisfactory vaccine against liver flukes in cattle, but there is reason to believe that it will be attained.

It deserves mentioning that work aiming at the production of vaccines against protozoal diseases in farm animals such as Theileriosis, Babesiosis and Trypanosomiasis is in progress.

In such projects the use of nuclear techniques is not limited to radiation. Isotopes are equally valuable in throwing light upon such problems as the parasite-host relation, the metabolism of the parasites and their nutritional requirement, conditions which must be known in order to be able to cultivate parasites for vaccine production.

It goes without saying that production and application of such vaccines against parasitic infections in domestic animals are projects of substantial economic importance for animal husbandry, especially so in tropic and sub-tropic areas, where diseases due to parasitic infections are prevailing. Consequently, such projects should have a high priority.

The two most actual problems of animal husbandry, especially in the less developed countries, are diseases caused by infections or deficiencies and lack of feed of sufficient nutritional quality. There can be no doubt that nuclear techniques will play in increasing role as well in the combat of diseases as in the solution of the nutritional problems.

Such research programmes, which preferably should be carried out in sufficiently equipped and staffed regional institutes facing the actual problems of the area, should also pave the way for a more efficient use of non-conventional feedstuffs produced on basis of agricultural and industrial waste products.

It is my hope that my statement has made it clear that nuclear techniques are very valuable tools in practically all fields of animal science when the goal is to improve productivity and health of economically important domestic animals.