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A review of the use of isotopic and nuclear techniques in animal production

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Abstract

Isotopic and nuclear techniques play an important role in food and agriculture, health and industry. This paper discusses the use of these techniques and highlights potential for their use in the area of Animal Production. These techniques are discussed in two parts: (1) Isotopic methods and (2) non-isotopic nuclear methods. The isotopic techniques discussed are: stable- (^{15}N) and radio-isotope (^{35}S or ^{32}P) incorporation methods for measuring microbial mass *in vitro* and *in vivo*; ^{125}I-labelled bovine serum albumin and ^{14}C-labelled polyethylene glycol assays for measuring tannin in feeds; a method based on the feeding of isotope-labelled protein (^{15}N or ^{125}I) complexed with tannin for ranking different tannins for their abilities to release protein for digestion *in vivo*; ^{14}C-uric acid and ^{14}C-allantoin infusion methods for development of models describing excretion of purine derivatives in urine and microbial protein supply to ruminants, which permit assessment of nutritional status of animals and determination of nutritional quality of feed resources; a ^{15}N isotope dilution technique using ^{15}N-leucine to distinguish feed and endogenous secretions at the ileum, for determination of true digestibility of protein-rich tree leaves and aquatic plants in pigs; progesterone radioimmunoassay (RIA) for enhancing reproductive efficiency of ruminants, and RIA based leptin and insulin like growth factor assays for assessing the nutritional status of animals; feeding of ^{15}N enriched plant material to generate ^{15}N-labelled excreta for research on the fate of excreta N in the environment;

Abbreviations: RIA, radioimmunoassay; FAO, Food and Agriculture Organisation; IAEA, International Atomic Energy Agency; VFA, volatile fatty acids; CT, condensed tannins; IRMA, immunoradiometric assays; EDTA, ethylene diamine tetra acetic acid; ELISA, enzyme-linked immunosorbent assay; IGF-I, insulin-like growth factor I; PCR, polymerase chain reaction; ICP, induced coupled plasma mass spectrometry

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^{15}N, ^{13}C and ^{34}S isotopic methods for nutrient budgeting and for following the nutrient pathways in the soil–plant–animal continuum; ^{32}P- or ^{33}P-labelled fertilizers for estimating the efficiency of P utilization in legume leaf production used for livestock feeding; double labelled water (^{18}O and ^{2}H labelled) method for estimating energy expenditures of grazing animals, body composition, basal metabolic rate, and milk output in cows with calves; $NaH^{13}CO_3/NaH^{14}CO_3$ infusion for estimation of the carbon dioxide production, which in turn is used to estimate energy expenditure in free-ranging animals; ^{3}H- or ^{14}C-labelled methane and ^{14}C-labelled volatile fatty acids dilution technique for direct and indirect (using stoichiometry of carbohydrate fermentation) for determination of methane emission from livestock; ^{15}N dilution technique requiring labeling the soil with ^{15}N fertilizer (^{15}N-ammonium sulphate or ^{15}N-urea) for estimation of nitrogen fixation by leguminous trees and pastures.

The non-isotopic nuclear techniques that have been used or have the potential for use are: dual energy X-ray absorptionmetry and computer tomography for body composition determination; nuclear magnetic resonance techniques, fast atom bombardment mass spectroscopy, and mass ionisation spectroscopy for identification and structure determination of bioactive moieties of plant origin having potential for rumen manipulation or controlling internal parasites; gamma irradiation for inactivating antinutrients such as protease inhibitors, lectin, phytic acid, non-starch polysaccharides and oligosaccharides in feeds; induced mutations with gamma radiation, electron beam and fast neutrons for producing useful mutants of forage plants with improved yield, nutrient profiles and uptake.

Keywords: Isotopic techniques; Nuclear techniques; Animal nutrition; Animal reproduction; Animal breeding; Animal production

1. Introduction

Nuclear and related biotechnological techniques have played, and continue to play, a significant role in improving livestock productivity. The Joint FAO/IAEA Division has assisted Member Countries of FAO and IAEA for over 40 years to use nuclear techniques and related biotechnologies for developing improved strategies for sustainable food security. In the 1970s and 1980s, the Joint Division promoted the use of isotopes for generating information on various metabolic processes with the aim of effectively utilizing unconventional feed resources. These studies dealt with the use of ^{15}N-urea, ^{15}N ammonium bicarbonate, ^{15}N-ammonium chloride to study the utilization of non-protein nitrogen, urea recycling, microbial protein synthesis and amino acid interconversions. The rate of microbial protein synthesis was determined by ^{32}P, ^{33}P, ^{15}N, ^{35}S incorporation into the microbes. Other studies included the use of labelled minerals such as ^{32}P, ^{75}Se, ^{45}Ca, ^{76}As, ^{67}Cu etc. to investigate mineral imbalances in farm animals; ^{58}Co-EDTA, ^{103}Ru-phenanthroline, ^{51}Cr-labelled forages for passage rate determinations; infusion of ^{14}C-labelled acetic and propionic acid to estimate volatile fatty acid production rates; ^{13}C leucine, ^{15}N glycine or ^{3}H-tyrosine for investigations on whole body protein turnover. These investigations provided a solid base to the present-day animal nutrition and to the development of feeding strategies based on sound animal nutrition concepts. Details of these studies are available in (IAEA, 1975, 1976, 1982, 1986, 1987). During the last decade, several new nuclear techniques have emerged and also new uses of several old isotopic and nuclear techniques have been put forwarded. The purpose of this paper is to highlight the nuclear techniques that are being used in the