THE DIET-MEAT AND DIET-MILK TRANSFER OF ^{137}Cs IN THE CATTLE: VALUES OF A DYNAMIC MODEL AND VALUES OBTAINED IN FIELD

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Introduction

In conditions of environmental radiocontamination, the vegetable-animal products-man food chain becomes particularly critical for the determination of population equivalent doses (1). Such doses may be predicted using contaminant transfer models such as NUCRAC-SAI (2), DOSDIM (3), NRPB (4), PATHWAY (5) and others.

These are principally founded on dynamic compartmental systems and they have in common the use of first degree kinetics, which lead to the formulation of a system of differential equations, the solution of which shows the trend of radionuclide concentration in time, in the various environmental and animal matrices. Efficacy verification of these analytical instruments is performed at its best in real situations of radioactive spill in the environment, such as the incident which interested Italy in 1986.

In the latter occasion we applied a modulus belonging to a more complex model described below, and which uses the daily dietary intake of ^{137}Cs , to predict the meat and milk contamination variation in time, in the adult bovine.

To verify the efficacy of this model we compared calculated values against those measured directly by radiometry of meat and milk samples of the same bovines.

Materials and Methods

a) - The Model

The model used is represented by a complex modulus belonging to a general dynamic model developed at NRPB (4) to predict radionuclide transfer through the food chain. The pasture/fodder (diet)-bovine-milk/meat pathway is represented by two connected models for the soil-fodder chain and for the bovine metabolism.The first model was ignored. Using the diet contamination data as primary source of information, the animal metabolism model referred to ^{137}Cs, was fully utilized.

The block diagram (fig.l), presents the outline of the model used, limited to the ingestion route of contamination. For ^{137}Cs, apart from the digestive tract and transfer compartments, the model uses the muscular, liver, mammary and two soft tissue compartments. The activity is removed through excretion (urine and feces) and through milk secretion, with the kinetic transfer constants reported in the paper of Sumerling (4). The gastro-intestinal absorption fraction is assumed equal to 70 %.

b) - Radiometric Analysis

During two subsequent samplings (6), analysis were made of the γ spectra from muscle and milk samples taken from 19 fresian cows from two herds. Five cows came from one herd, and from their muscle samples were taken upon slaughter on May 26, 1986 (two heads) and October 6, 1986 (three heads). Milk samplinq was incomplete.

In the second herd 10 heifers and 4 cows were studied. Muscle samples and 3 milk samples were analysed.

For the preparation of the milk samples for radiometric analysis, various counting containers from 50 to 250 ml, immersed in well type NaI(Tl) detectors of

appropriate size, were used. The samples with weights of roughly lOO g were treated by wet ashing (7) making sure that the recuperated activity of the radioisotopes present was equal to 100 %. The counting time was raised to 80.000 s in order to obtain significant results. The fodder samples were counted in Marinelly geometry in presence of an NaI(Tl) crystal. All fodder results are expressed in Bq/kg dry weight. The internal coherence of the measured activity was checked by verifying the $^{137}Cs/^{134}Cs$ ratio, know and a function of the time passed between fall-out and counting date.

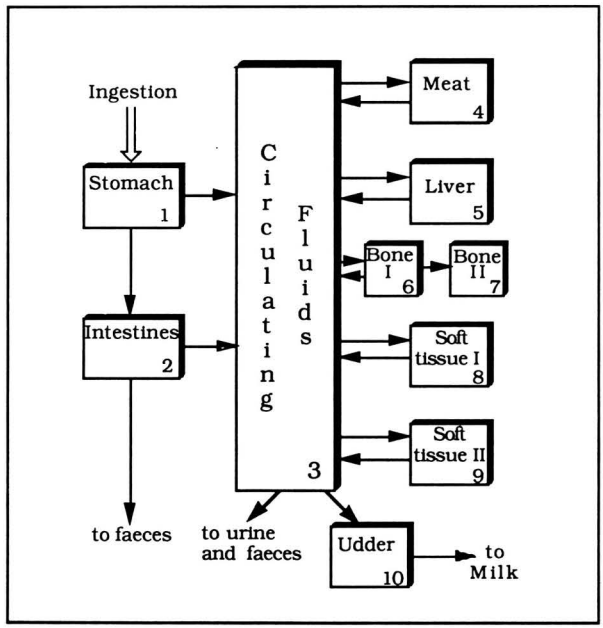

Figure 1. The model for transfer in the cow.

All activities measured in the biological samples were divided by the original weight, in order to express the concentrations in Bq/kg fresh weight.

c) - Diet

The input datum for the model was the introduction of daily activity value. Therefore, in addition to the ^{137}Cs measure in the samples of different fodders and concentrates used for feeding the cattle during the testing period, a research on weight and composition of the daily dietary intake was also made.

In the herd with the first 5 cows, even though the dates of administration of the various cuts were sufficiently well known, it was decided to vary the weight of the administered diet from 12 kg/day to 18 kg/day, with the purpose of taking into account mixtures of fodders of various origin and/or radioactivity, not ascertained upon sampling. In the second herd, the diet was differentiated: two diets were used for the cows: for the heifers, the diet indicated by the breeder was used.

Results

The problem of autovectors and autovalues of the differential equations system, formed on the basis of the biokinetic model considered, was resolved using a Harwell software available at the "E.Clementel" ENEA Center (8). By using those values (9), the retention function for each compartment was evaluated through a program developed in our laboratory.

Fig.2 shows the trend of muscle retention and of the contamination of milk produced daily, for the animals of the first herd. A hypothetical daily milk production varying between 10 l and 20 l per head was considered. In terms of graphic representation, in fig.2 the error bar for milk represents the range of possible values for total excretion per day through milk, for a production varying between 10 l and 20 l. The variation of the mean ^{137}Cs concentration present in the diet is also indicated.

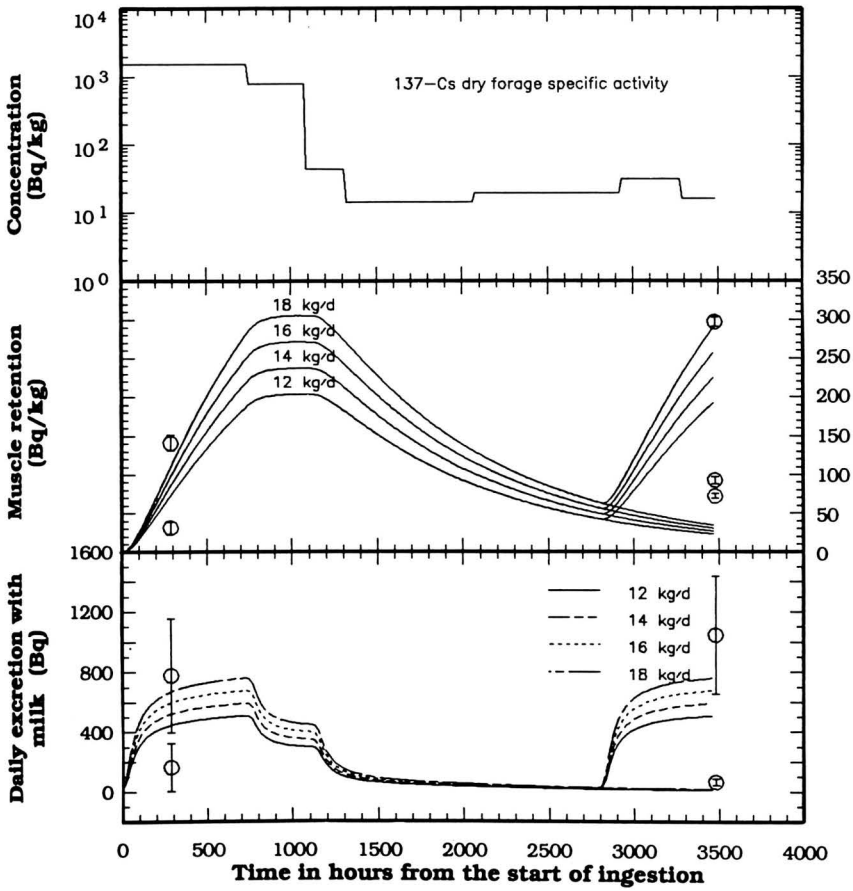

Figure 2. Comparison between observed values of ^{137}Cs concentration in the main bovine by-products and the expected values, using the model on the group of cows from the first herd.

For the muscle retention of ^{137}Cs, the mean values measured in the field corresponded well to those of obtained using the model. The same was true for milk. From the same figure one can deduce a remarkable degree of correlation between the contamination of the animal and the degree of fodder contamination. In fact, the effects connected to daily consumption are most evident at the end of the first month, with values decreasing up to the sixty-second day.

Also in accordance with the model predictions, are the ^{137}Cs values found in the meat and milk of a cow fed for the four weeks prior to slaughter, on fodder of the first cut, which was markedly more contamined than that fed to another two cows slaughtered in the same period.

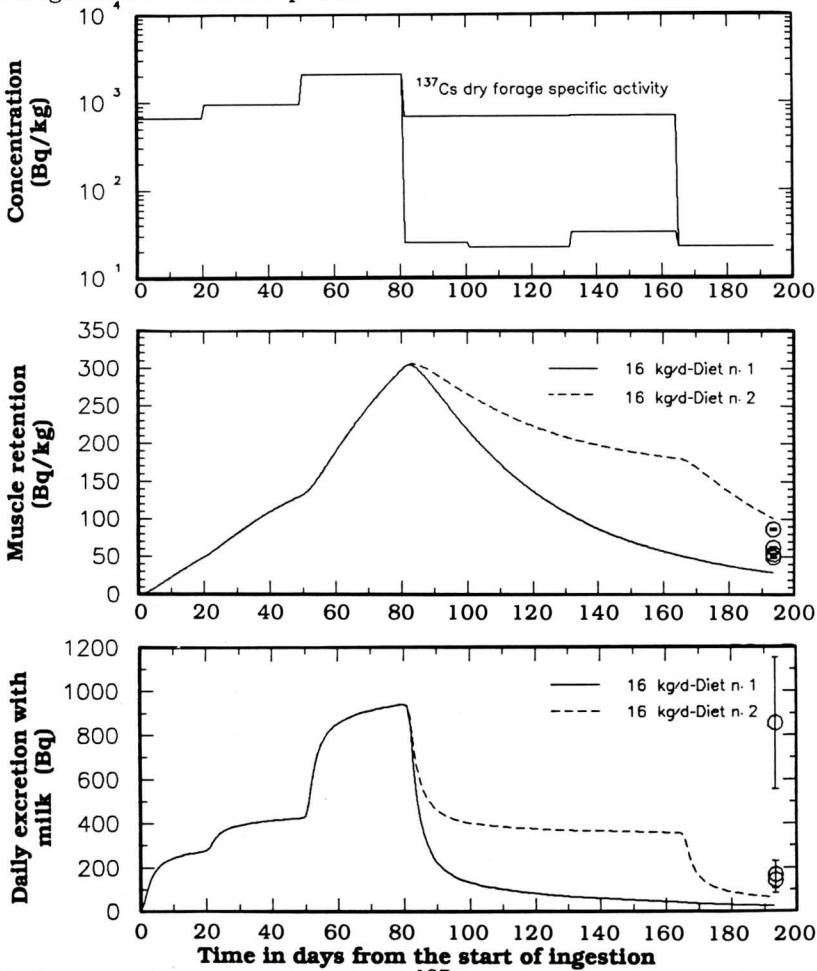

Figure 3. Comparison between observed values of ^{137}Cs concentration in the main bovine by-products and the expected values obtained through the application of the model to the group of cows from the second herd and using two different diets.

The graphs in fig.3 show the same variations of the ^{137}Cs concentrations in the four cows from the second herd, obtained using the two hypothetical diets as a reference of minimal (diet n. 1) and maximal (diet n. 2) incorporation. The experimental points refer to the date of slaughter, which was 194 days after commencement of administration of the ^{137}Cs contamined diets. The graphs highlight the anomalous behavior of one of the four animals, which showed a much higher ^{137}Cs milk concentration than predictable by using the model.

From this result one must presume that the animal was fed on a diet with a composition similar to that of the 10 heifers, characterized by a prolonged administration of highly contamined fodder (3024 Bq/kg), up to the day of slaughter. If one takes this dietary variation into account, then the model can confirm also the values for the latter cow.

For demonstrative purposes the NRPB model was applied to the group of heifers from the second herd also. A muscle mass of 220 kg was considered. As expected (see fig.4), since the model was preset for dairy cows, it did not predict the values for meat contamination with sufficient accuracy, even so, it still showed to be conservative in the case we analysed.

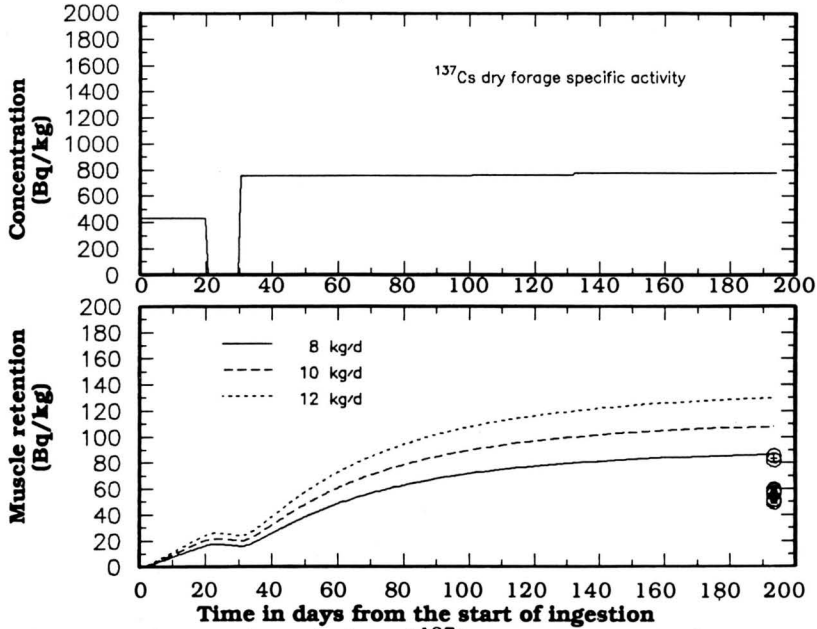

Figure 4. Comparison between observed values of ^{137}Cs concentration in the bovine meat and model previsions from the heifers from the second analysed herd. Three different diet hypotheses based on variations in the ponderal mass ingested daily are presented.

Conclusions

The indications which emerged from comparison of the predictions of the biokinetic model with the in field observed contamination values for milk and meat, permit us to underline as follows:

1 - the ^{137}Cs values predicted by the model for meat and milk from the 9 cows are

sufficiently accurate and in any case conservative with respect to those measured through γ spectometry on the same animal matrices;
2 - the meat contamination values provided by the model for the ten heifers, show greater error margins than those obtained by radiometric measurement.

These two points confirm the value of the model used for this research to predict the degree of ^{137}Cs contamination of meat and milk in the cow. On the other hand, due to the inactivity of the mammary compartment, some diet-meat transfer constants need to be corrected to increase the reliability of the model in heifers.

In conclusion, we point out that previsional models, even if continually improved and corrected are not able to evaluate the trend of the phenomena which were the object of our research as precisely as through direct measurements. Therefore the model is not to be considered an alternative, but rather an integration of the veterinarian measurement activities, to optimize the radioprotection of the consumer.

References

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Summary

The authors have applied a dynamic model that considers intake of ^{137}Cs by ingesion (diet), transfer to the meat and removal through the milk. They conducted the study on 19 cattle (9 cows and 10 heifers) which in the semester preceeding the slaughter had been fed rations composed of forage and concentrates on which the concentrations of ^{137}Cs was determined. The values of ^{137}Cs supplied by this model were compared with those obtained from the radiometric analysis of meat and milk samples collected at the site of slaughter. The average values of ^{137}Cs from the model for meat and milk for the 9 cows resulted in good agreement, in regard to those of radiometric analysis: the values supplied by the same model for the 10 heifers presented more considerable margins of error. The authors in conclusion have proposed the opportunity of changing the values of some transfer constants for the heifers.

Resumé

Les auteurs ont appliqué un modèle dynamique qui considere la voie d'incorporation du ^{137}Cs par ingestion (diète), le transfert au muscle et l'élimination par le lait. Ils ont effectué leur etude sur 19 bovins (9 vaches-10 génisses) nourris pendant le semestre precédent l'abattage avec une alimentation composée de fourages et de concentrés sur lesquels a ètè mesurè le ^{137}Cs. La confrontation des valeurs du ^{137}Cs fournies par le modele pour la viande et pour le lait avec celles mesurées au moment de l'abattage a mis en evidence la validité substancielle du module pour la prevision du transfert aliment-viande et aliment-lait du ^{137}Cs chez les 9 vaches et des erreurs plus consistantes pour l'estimation du transfert aliment-

viande chez les 10 génisses.Les auteurs concluent suggérant de changer les valeurs de certaines constantes de transfert du ^{137}Cs chez la génisse pour ameliorer la validité du module pour les prévisions.

Zusammenfassung

Die Autoren haben ein dynamisches Modell appliziert, welches die Aufnahme des ^{137}Cs durch orale Verabreichung (Diät), die Eingliederung in die Muskulatur und die Entfernunq durch die Milch in Betracht zieht. Die Studie wurde mit 19 Rindern (9 Kühe und 10 Färsen) durchgeführt, die uber ein ganzes Semester vor der Schlachtung mit Futter ernährt worden sind, das auf ^{137}Cs Gehalt gepruft worden war. Der Vergleich zwischen den ^{137}Cs-Erwartungswerten mit den nach der Schlachtung gemeserten hat ergeben, dass das Modell für die Schätzunq der Ubertragung den ^{137}Cs Diät-Fleisch, Diät-Milch seine Gültigheit bei Kühen behält,wahrend es bei Färsen zu grösseren Fehler führt. Die Autoren schlagen , vor einige Konstanten in der Schätzung der übertragung des ^{137}Cs zu ändern um die Gültigheit des Modells zu verbessern.