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**Original article**

# Relevance and elaboration of a base of experimental data of net blood nutrient fluxes across tissues and organs

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**Abstract** — In order to optimise the storage and handling of experimental data obtained on multicatheterised animals, a database was created with Microsoft Access using the MERISE method. An experiment carried out using 6 lambs catheterised at the portal drained viscera, liver and hindlimb levels was used for this construction. First, the available data were inventoried as manuscript documents or Microsoft Excel files: the timetable, feed composition and intake, animal growth, blood flow measurements, results of blood metabolite concentrations and rumen fluid characteristics. The number of Excel equivalent worksheets amounted to nearly 3 407 and the total disk volume to 42 Mega Bytes. Subsequently, a data model was established with 10 entities and 15 relationships. Twenty-one tables were created corresponding for most of them to entities or relationships of the data model. Finally, 10 procedures calling 133 queries were realised, to especially carry out the flux calculations on blood metabolites at the levels of the portal drained viscera, the liver, the splanchnic tissues and the hindlimb. As a conception method, Merise proved to be suitable to collect, model, and handle experimental data obtained on multicatheterised animals. Compared with Excel which is often used, the database presents several advantages. First, it facilitates information storing and retrieving by reducing the number of files and worksheets, and it decreases the risks of errors. Second, it proved to be an efficient tool to apply in accordance with Quality Insurance requirements as an aid for data validation and traceability. Third, it allows all required data handling. Fourth, the utilisation of the database is simple for users and the running time on modern micro-computers is short. Finally, this type of database can be generalised to other experimental data obtained on animals.

**experimental database / blood nutrient fluxes / MERISE / ACCESS**

**Résumé** — **Intérêt et élaboration d'une base de données expérimentales sur les flux de nutriments sanguins à travers les tissus et organes.** Dans le but d'optimiser le stockage et l'exploitation des données expérimentales obtenues sur animaux multicathétérisés, une base de données a été créée sous Access à l'aide de la méthode MERISE. Une expérience conduite sur 6 agneaux multicathétérisés au niveau des tissus drainés par la veine porte, du foie et de la patte arrière a été utilisée pour cette

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construction. Initialement, l’ensemble des données disponibles sous forme de documents manuscrits ou de fichiers Excel a été inventorié: le calendrier des mesures, la composition et la consommation des aliments, la croissance des animaux, les mesures de débit sanguin, les résultats de dosages de concentrations de métabolites sanguins et de paramètres de jus de rumen. Le nombre de feuilles en équivalent Excel s’élevait à 3 407 pour un volume total sur disque de 42 M octets. Ultérieurement, un modèle de données a été élaboré avec 10 objets et 15 relations. Vingt et une tables ont été créées, correspondant dans leur majorité aux objets et relations du modèle des données. Enfin, 10 procédures appelant 133 requêtes ont été réalisées pour effectuer en particulier des calculs de flux de métabolites sanguins au niveau des tissus drainés par la veine porte, du foie, des tissus splanchniques et de la patte arrière. En tant que méthode de conception, MERISE convient au recueil, à la modélisation et au traitement des données expérimentales sur animaux multicathétérisés. Comparée à Excel qui est utilisé habituellement, l’élaboration d’une base de données présente un certain nombre d’avantages. Tout d’abord, elle facilite le stockage et la récupération de l’information en réduisant le nombre de fichiers et de feuilles, et elle réduit les risques d’erreurs. Deuxièmement, elle constitue un outil performant dans le cadre des exigences de l’Assurance Qualité comme aide à la validation et la traçabilité des données. Troisièmement, elle permet d’effectuer tous les traitements de données nécessaires. Quatrièmement, l’utilisation de la base est simple pour les utilisateurs et les temps d’exécution sur des micro-ordinateurs modernes sont courts. Enfin, ce type de base de données peut être généralisé à d’autres résultats expérimentaux obtenus sur animaux.

**base de données expérimentales / flux de nutriments sanguins / MERISE / ACCESS**

## 1. INTRODUCTION

Some experimental protocols call for the use of a small number of experimental units which are each subjected to a heavy experimental pressure in terms of the number of measured variables. In this respect, in vivo metabolism studies conducted in multicatheterised animals in order to measure net nutrient fluxes at the level of tissues and organs [23] are great time and work consumers, and may yield, when exhaustively conducted and analysed, a huge mass of data. These data include a wide variety of variables covering all the experimental steps, such as information on the surgical preparations, on diets, feeding and intake, on live-weight gains, on blood flow across various tissues and organs, on animal behaviour during sampling periods, or on blood concentrations of metabolites in different blood vessels. They may be collected by different operators, in different geographical sites and at different periods of time. Usually, the records are manuscript or computerised generated files, mostly under Excel [18]. For each measurement, experimental data are subsequently individually validated. Ultimately, the validated values are used in series of calculations implying several steps before producing the final results.

The use of spreadsheets (such as Excel) on individual computers has introduced great progress in the handling of data but are now showing their limits. For example, a complex experiment may yield a large number of files, each existing in several versions. Redundancy of raw information may also appear when different files are used for different calculations. Their handling requires an absolute rigour and the risk of error increases with the number of data and data files as well as with the number of operators.

The storage of experimental data and notes taken in the course of an experiment is rarely realised according to a systematic and reproducible way. With the development of Assurance Quality procedures in Research Laboratories, the traceability of the results will have to be assured. In this context, and to limit the risk of introducing errors in experimental data, systematic and clear storage procedures have to be elaborated.

The relevance and the benefits which can be drawn from the utilisation of computerised databases has already been demonstrated, in particular for the analysis of production and health monitoring systems for dairy herds [12]. Computerised databases constitute powerful tools to handle a wide number of information. Theoretically, the size of the databases is limited only by the storage capacity of the available computer system [17]. Risks of errors are reduced because all the elementary information is unique, not duplicated, easily updated and annotated, and is included in a database which is unique. This elementary information can be easily accessed for any further data handling. Finally data treatment is facilitated by the fact that complete data sets can be easily selected and used for further calculations. Elaboration of computerised databases may answer some of the requirements of Assurance Quality procedures [7] in that original data may be easily both stored intact over years as well as retrieved. All data from one experiment may be grouped in only one file, and data identification has to be rigorously applied.

Numerous database managing systems exist. Given the tremendous improvements brought to machines and operating systems, powerful database managing softwares are now run on personal microcomputers [26]. In particular, improvements in storage volume, processing performance and easiness of use are of interest. Response times for a computer work involving a large number of data and several processing steps vary from a few seconds to a few minutes.

Consequently the objective of the present work was to elaborate a database with Access in order to record and handle all data and information obtained in an experiment conducted using multicatheterised animals aimed at measuring net nutrient fluxes at the levels of the portal-drained viscera, the liver and the hindlimb [16, 27].

## 2. MATERIALS AND METHODS

### 2.1. Animal study used for database modelling

The animal study which was at the origin of this database modelling was aimed at determining the partition of metabolisable energy (ME) among tissues and organs in growing ruminants, and especially the proportion of supplementary ME which is effectively available to peripheral tissues for growth [27]. A special interest was also paid to the nature of the ME by studying the balance among the major blood nutrients as in [16].

A brief summary of the experimental procedures is given here. A complete description may be found elsewhere [16]. Six male lambs were surgically equipped with chronic blood catheters in the mesenteric artery, the portal vein, a hepatic vein and an external iliac vein, with blood flow probes around the portal vein and an external iliac artery as well as with a rumen cannula. The post-surgical recovery period lasted several weeks during which the animals were closely looked after and received veterinary treatment. All animals were then offered a basal diet composed of frozen stored grass in 12 equal daily meals. They were subjected to two treatments (rye-grass alone and rye-grass supplemented with whole grain barley) according to a triplicate 2 × 2 Latin Square design, with each treatment lasting two weeks. The animals were systematically weighed twice weekly. Individual feed intake was recorded daily. Chemical composition of feeds was determined on daily (dry matter) or weekly (crude fibre, total nitrogen, etc.) samples. On the last day of treatment, blood flows were measured continuously using a flowmeter connected to a microcomputer which integrated blood flow values over 1 min periods. Visual observations of animal behaviour were made as a tool to interpret hindlimb blood flows. Additionally eight spot sampling were carried out at 30 min intervals at the portal, hepatic and iliac veins as well as at the arterial levels, over two feeding cycles (i.e. 4 hours). Blood samples were stored for subsequent analysis of hematocrit level and blood oxygen, glucose, L-lactate, ketone bodies, volatile fatty acids, or plasma free fatty acids, total glycerol, and individual amino acids. Finally, three rumen fluid samples were taken at 30 min intervals for determination of rumen fluid parameters (pH, volatile fatty acids). At the end of the experiment, the animals were humanely killed for necropsy. Subsequently, chemical determinations were carried out on the feed, blood, plasma or rumen fluid samples based mainly on spectrophotometric and chromatographic methods, where the measuring equipment could be connected to a microcomputer for signal recording and calculation of metabolite concentrations using Excel.

Individual data on blood metabolite concentrations have to be validated before being used in subsequent calculations. The values are then accepted or rejected on the basis of criteria specific to each variable [9]. Two types of criteria are used. The first ones are purely analytical, they relate to the validation of laboratory methods or equipment. When the values are rejected, generation of new data is expected when possible, e.g. by duplicating the laboratory analysis; two values may then exist for the same sample. The other criteria are more generally related to the net nutrient flux measurement method. They question the representativity of the measurement (e.g. hindlimb blood flow in agitated animals) or of the available samples which can only be appreciated subjectively. To appreciate this representativity, calculations of arterio-venous concentration differences, fractional extraction and net nutrient fluxes were carried out for each sampling time using individual results. The decision of a lack of representativity may have led to values being eliminated and considered as missing. In some cases, when the lack of data may compromise the use of complete sets of other data, an estimated value may be used (e.g. hindlimb blood flow in quietly standing animals [9]).

Subsequently, validated blood flow data were used to calculate average portal blood flows and to estimate arterial and hepatic blood flows [16] as well as hindlimb blood flows in quietly standing animals after accounting for animal behaviour [9]. Validated blood and plasma concentration were averaged over time for each animal and each treatment, and used to calculate the final results, i.e. arterio-venous concentration differences, in- and outflows, as well as net nutrient fluxes and fractional extraction across the different organs and tissues, as given in [2, 10, 22]. Tissue energy expenditures were obtained as described by Vernet et al. [27].

## 2.2. Constraints applied to the database

Several constraints were defined for the database. The first requirement was to gather all the information obtained in such experiments. This information concerned the animals, treatments, feed, measurements of blood flows and determinations of blood metabolites. The specific information of blood metabolite determination such as optical densities of spectrophotometric measurements, or regression equations used for the calculation of metabolite concentration were not included in the database. The second one was to allow an easy interface with other software (e.g. Excel) which are often used during data acquisition processes and which are better known by a large number of operators (technicians and researchers). The third one was to allow storage of initial and revisited values accounting for the steps of data validation [9], accompanied by the reasoning applied for accepting, rejecting or eventually estimating each individual data. The final requirement was to realise all the pre-established calculations on blood or plasma nutrient fluxes at the level of different organs and tissues and all new calculations (within or among experiments) which could appear as necessary for the scientific interpretation of the data. For this experimental database, data processing was limited to a conventional work of scientific calculation and did not include data exploration or mathematical modelling.

### 2.3. Data modelling

The elaboration of a database consists of organising basic data items in a complex way in order to accommodate all data to be recorded and all data processing to be carried out [6, 11]. The structure of the information is of paramount importance and is referred to as the conceptual data model. The modelling method which was chosen was MERISE which has only recently been used in agriculture and agricultural research [12]. The appropriate terminology and the rules which allow to secure the construction of databases associated to the MERISE method have already been described [5, 12, 24].

The present database was elaborated on a personal computer equipped with a Pentium III processor with 256 MB RAM. The running was carried out on the previous computer and another one of similar performance. Microsoft Access 97 version 7 [17] was used for both creating and running the database.

## 3. RESULTS

### 3.1. Identification of existing data and processing requirements

Inventorying the existing data requires to account for the specificities of studies using multicatheterised animals [1, 14, 15, 23].

Initially, the recording of timetables and of their changes is an important prerequisite.

Indeed a precise timetable is set up. However, changes may occur because of lag time between the different experimental periods or experimental mishaps.

Careful recording of feed intake, sampling and composition, weight changes, animal health status and possible veterinary treatments, as well as conditions during measurement and periods of animal blood sampling is an important tool in the subsequent evaluation of the validity of the measured data. Indeed, treatment effects are often of low magnitude and may be easily biased by non rigorous experimentation or be cancelled by uncertainties of measurements. Consequently, a very close follow up of those animals is required.

Considering the variety of information, the number of blood metabolites studied (n = 50) and the number of blood vessels sampled (n = 4), a large number of documents is generated from such an experiment. They may be in a manuscript or computerised form. With six animals submitted each to two treatments, the number of equivalent files and worksheets of raw data amount to 693 and 3407, respectively, which represents a total of 42.4 Mega Bytes. Expressed as a percentage of the total data volume, data on blood metabolite concentrations, rumen fluid characteristics and blood flows represented 86.3, 8.6 and 3.6% respectively.

The number of worksheets increases after data validation. All information concerning data validation (acceptation, rejection or exceptionally estimation) has to be carefully and exhaustively recorded including comments explaining the reasons of the choice. The final results are calculated using accepted or estimated values averaged over time for each animal and each treatment. Consequently the total number of equivalent worksheets rises up to nearly 4 600 because of the frequent data redundancy required for the intermediate calculations and data validation steps.

These documents may be generated over periods of several months (up to 24), and by several operators. In our research conditions, where specialised research staff, in particular technical staff (animal work, laboratory analyses, statistical analysis...), may be involved, an experimental study may require a minimum of 8 different operators who will have to coordinate their action and their records.

### 3.2. Elaboration of the conceptual database model

The conceptual data model must be large enough to describe all the components of an experiment and precise enough to depict in detail all the existing characteristics.

The main entity [12] of the model is the ANIMAL which includes all the experimental animals and which is identified by the animal number (Figs. 1, 2, 3). It contains properties [12] which are 'name', 'sex' and 'breed'. For this entity, the first three MERISE normal forms were verified [3, 4, 12].

The first part of the model described experimental treatments, growth and health status (Fig. 1). The succession of treatments to which each animal was subjected was modelled thanks to two entities TREATMENT and PERIOD and a relationship 'undergoes a treatment between given dates'. Other characteristics of the animals, in particular their growth and health status were associated to specific dates (Fig. 1). So, the entity DATE was created. Subsequently, the growth pattern of the animals was described thanks to a relationship 'has for weight at a given date' which carries the property 'weight'. Similarly, a relationship 'has a veterinary monitoring at a given date' links the entity ANIMAL to the entity DATE and bears the property 'comment'.

The second part of the model described the experimental feeds and intake (Fig. 2).

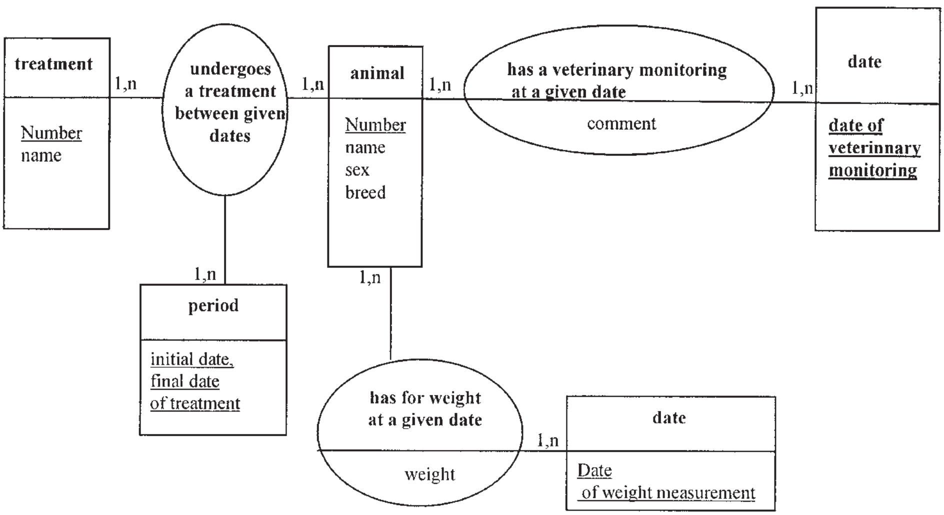


**Figure 1.** Représentation of experimental treatment sequences, growth and health status of animals in the conceptual data model for experiments on multicatheterised animals (□: an entity, ○: a relationship). The identifier is underlined; cardinalities (l, n) indicate the number of information lines.

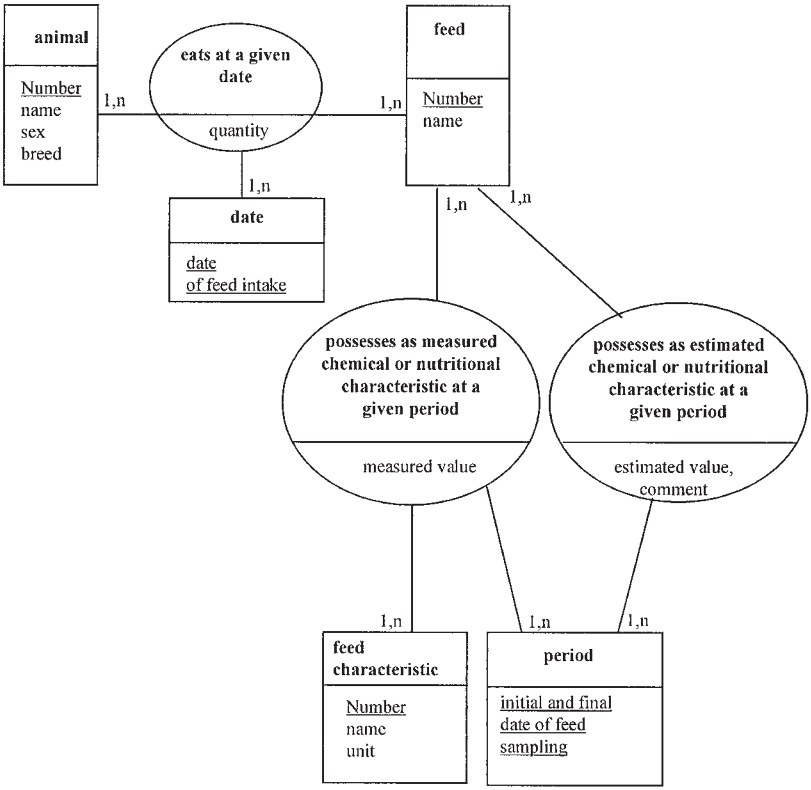


**Figure 2.** Representation of feed characteristics and intake in the conceptual data model for experiments on multicatheterised animals (□: an entity, ○: a relationship). The identifier is underlined; cardinalities (l, n) indicate the number of information lines.

A first entity FEED included all the feedstuffs offered to the animals such as the experimental grass, the supplementary concentrate and the mineral and vitamin supplements, which constituted the different occurrences. All characteristics pertaining to the chemical composition or the nutritional value of the feedstuffs were included in an entity FEED CHARACTERISTIC. Subsequently, a relationship 'possesses as measured chemical or nutritional characteristic at a given period' links the entities FEED, FEED CHARACTERISTIC and PERIOD. This relationship bears as a property the measured value of the feed characteristic for a given period (e.g., % of nitrogen on a dry matter basis). When elaborating this relationship, an account was taken of the fact that not all feed characteristics were measured; some were estimated such as the metabolisable energy content which came from the INRA tables of nutritional value of feeds [8]. Because missing data are not acceptable under MERISE [12], it was not possible to include two occurrences ('measured', 'estimated') in the same relationship and a second relationship 'possesses as estimated characteristic at a given period' was created. Finally, a relationship 'eats at a given date' links ANIMAL to FEED and DATE, in order to describe the quantity of feeds, on a fresh matter basis, which the animal eats at a given date.

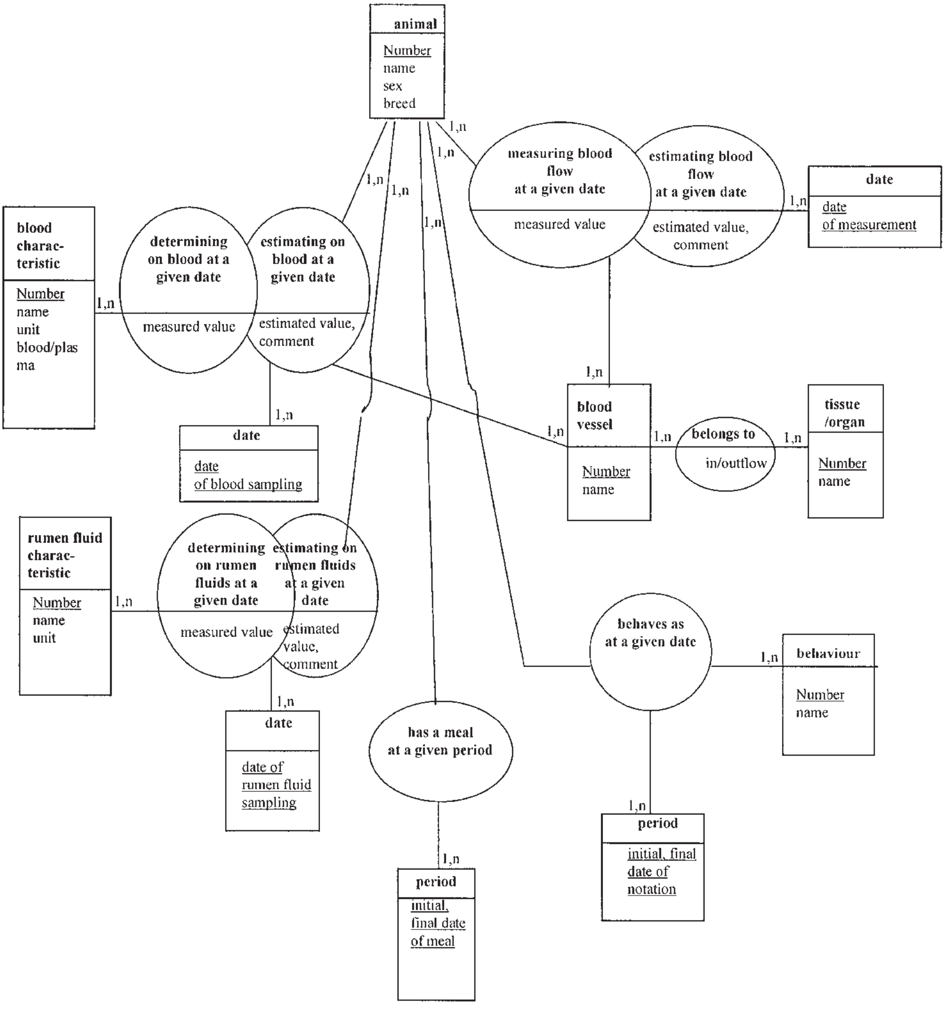


**Figure 3.** Representaiton of meal periods, blood flows, animal behaviour, chemical analysis of blood metabolites and chemical determinations in rumen fluids in the conceptual data model for experiments on multicatheterised animals (□: an entity, ○: a relationship). The identifier is underlined; cardinalities (l, n) indicate the number of information lines.

The third part of the model describes the anatomical sites and the nature of the different measurements (Fig. 3). The identification of the different organs and tissues (portal-drained viscera, liver, hindquarters) to which net nutrient fluxes will relate, is important just as the identification of the blood vessels on which blood flows will be measured and blood sampled. The two enti- ties TISSUE / ORGAN and BLOOD VESSEL were created and linked together by a relationship 'belongs to' which identifies whether a given blood vessel belongs to a given tissue or organ. This relationship bears one property 'in/outflow' which describes the afferent or efferent flux to a given tissue or organ. For example, measurements on the artery belong to all tissues and organs studied here and were used to characterise the inflow of metabolites.

Measurements carried out on the last day of the treatment pertain to one of three main categories: measurement of blood flows, chemical analysis of blood metabolites and chemical determinations in rumen fluid.

As far as measurements of blood flows are concerned, the issue of eliminating and estimating data applies. For example, the changes of the position of the animal, experimental mishaps (accidental disconnection of the probes; electronic dysfunctionning in the flowmeters...) may be responsible for wrong values. Missing values were then estimated on the basis of the other measured values in order to avoid losing all other information collected on that animal. Similarly to the modelling solution adopted for the description of the chemical and nutritional characteristics of feeds, two distinct relationships 'measuring blood flow at a given date' and 'estimating blood flow at a given date' were developed to link the entities ANIMAL and BLOOD VESSEL at a given DATE. These two relationships bear the properties 'measured value' and 'estimated value' and 'comment', respectively.

Because of the influence of animal behaviour and especially of its spontaneous physical activity on hindlimb blood flows, an entity BEHAVIOUR and a relationship 'behaves as, at a given date' which linked the entities ANIMAL, BEHAVIOUR and PERIOD were created.

Data obtained on blood samples were also modelled by means of an entity BLOOD CHARACTERISTIC and two relationships 'determining on blood at a given date' linked the three entities ANIMAL, BLOOD CHARACTERISTIC and DATE. These relationships bore the properties 'measured value' and the 'final measured value (for example, after replication of the analytical determination) or the estimated value' and a 'comment', respectively.

Data obtained on rumen fluid were modelled on the same principles (Fig. 3).

### 3.3. Elaboration of the relational database

The translation of the conceptual database into a relational database was carried out as in Lescourret et al. [12, 13]. Entities and relationships were translated into tables which are computer structures used to store information.

The entity ANIMAL was translated into a table ANIMAL. The 'animal number' became the primary key of the table. The properties 'name', 'sex' and 'breed' became ordinary fields (columns) of the table. Nearly all the entities were translated into tables according to the same principles. Dates, which were entities in the data model, did not give rise to tables; they were translated as primary keys in tables derived from relationships.

The relationship 'undergoes a treatment between given dates' was translated into the table UNDERGOING A TREATMENT with as the primary key 'animal number + treatment number + date1 + date2'. Other relationships were translated into tables according to the same principles.

In order to allow traceability and possible work with missing data, to facilitate reading of data, and to save space, all the twin relationships such as 'possesses as measured chemical or nutritional characteristic at a given period' and 'possesses as estimated chemical or nutritional characteristic at a given period' have been translated into single tables such as FEED COMPOSITION. Consequently, the table FEED COMPOSITION contained as ordinary fields 'measured value', 'criteria', 'estimated value' and 'comment'. 'Criteria' was included to explicit whether the value was 'measured' or 'estimated'.

At last, the sample number was added as the ordinary field in the table BLOOD DETERMINATION to easily connect blood flows and blood characteristic determinations and to be able to use it in the statistical analyses.

Other entities and relationships were translated without any changes regarding the data model structure.

### 3.4. Data processing

A relative moderate number of calculation procedures (ten) were elaborated, each constituted of one or several queries. Not all of them will be commented upon here since their principles do not vary greatly from the description in Section 2.1. To illustrate the elaboration of data processing, the calculation of net nutrient fluxes across the portal-drained viscera will be presented.

Intrinsically, this procedure includes different steps to account for intermediary data validation as described by Ortigues and Durand [19] and Isserty and Ortigues [9]. The first step consisted of controlling the physiological validity of recorded portal blood flow measurements and searching for experimental mishaps. This step led to a revised version of the table BLOOD FLOW MEASUREMENT which does not erase the initial BLOOD FLOW MEASUREMENT table. It shows the interest of the database as a tool of data control.

The second and third steps were aimed at controlling the validity of measured concentrations of blood metabolites in each individual sample. Initially (second step) the following variables: concentrations, arterio-venous concentration differences, influx, outflux, net flux, fractional extraction of nutrients were calculated using raw values of blood metabolites. An output of raw results was produced per blood parameter, animal, treatment and set of blood sampling. Subsequently (third step) a search for non physiological values was operated by examining the means and coefficients of variation calculated per animal and per treatment, and by interpreting them using the validation results of laboratory procedures [20], all notes recorded during the experimental periods and especially those taken during sampling, as well as basal knowledge in physiology and metabolism. This third step led to a revised version of the table BLOOD DETERMINATION. When a decision was made to eliminate or estimate a value, the fields 'criteria' and 'estimated value' of this revised table were updated correspondingly and justifications of those changes were included as comments. It is important to note that Access can manage missing values. At the creation of a table which may contain missing values the 'null' characteristic can be authorised for one or several fields. Subsequently, during data handling, crossing any value with a null one will produce a null result. These steps may be reiterated as often as necessary, in order to test the consequences of the different choices of data validation. The interest of the database is obvious here as a tool for rapid calculation to facilitate human decision to achieve data validation.

Ultimately, blood flow and blood metabolite concentrations were averaged over time, per animal and per treatment, and used in the final calculations of the net nutrient fluxes.

In order to perform the whole data processing, a total of 133 queries were created. In accordance with the objectives of the database, the main roles of the queries were to select data and to perform calculations. Queries were often chained as far as five different levels, which allowed quite complex processing constructions. After completion of the queries, tests were performed to ensure that the right results were produced. The majority of the results of the calculations were temporary, in the sense that they were not stored in a resident table on the computer disk. So, any time results are required, running the last query involved in a procedure is sufficient to automatically trigger the successive upstream queries.

## 4. DISCUSSION

This database on experimental data of net nutrient fluxes across tissues and organs represents an original and efficient way of storing and processing experimental data.

The MERISE modelling method has already been widely used in other fields of activity [24]. The present work represents the first application of this method to experimental data obtained with a small number of experimental units and complex experimental approaches. The MERISE method allowed to formally model our data using 10 entities and 15 relationships and in the respect of the first three normal forms [3, 4]. The elaboration of relational database tables has proven to be relatively easy. The limited failure to MERISE rules which is tolerated at this step [12] allowed to group data originating from different relationships. This was the case for the measured and the estimated data which were grouped in the same table, thereby reducing the required number of tables and queries.

The number of computer files used for the calculation of net nutrient fluxes was reduced from 693 to only one corresponding to the database. Nevertheless, the elementary results obtained for each chemical determination, such as the optical density of the standard curve and samples obtained from a spectrophotometric method, and the calculated concentrations are still stored in Excel files. The latter are numerous (up to 600 for an experiment) and must still be carefully archived. So far, the choice has been made not to include this information in the database that would imply a network connection for all measuring instruments, a programmed link between the files from measuring instruments and Access tables, and much more complex data processing.

Thanks to the use of the database, redundancy of information was avoided. Consequently the risk of errors was tremendously reduced and the liability of work considerably improved. This in itself is an important progress.

In the context of Assurance Quality, the validity of the results has to be critically analysed and traceability of the results should be ascertained. Any modification (elimination, estimation, etc.) in the raw data should be formally recorded and of easy access. All experimental data should be stored for several years following publication of the results. The present database answers to these constraints. Firstly, the grouping of such a large number of information allows the operator to control the validity of data after having set quantitative criteria (such as those obtained in the validation of a laboratory method), or by cross checking a variety of results obtained either in the same animal or in the same treatment. The consequences of data elimination or estimation on the final results can be easily calculated. At the moment, criteria used to assess the validity of the results were not included in the database since they were not all quantitative, but improvements should ultimately be made to the database to cover this aspect. Secondly, the rigorous identification of data and the fact that each measured datum is associated to a 'validation criteria' that will indicate its validity and to possible comments that will explicit any modification in raw data can guaranty traceability. Easy access to raw data will be preserved. A key aspect for the utilisation of databases is the secure storage of data which can be easily carried out by burning CD-Roms.

In terms of experimental data processing, the elaboration of individual queries has not raised any difficulties which could not be solved, despite the fact that MERISE has not been specifically developed for data processing [21]. All the necessary data handling has proved possible, even data processing which had not been pre-established. On the contrary, the large number of queries (133) constituted the first major difficulty met, and outlined the necessity of pre-planning each data process, including the role and the succession of the different steps, as much as possible [5]. The second major difficulty met was associated to the limit of the number of hierarchical levels in queries. Indeed, when more than five hierarchical levels are necessary, temporary tables have to be created to store intermediary results. This increases the difficulty of data processing. Finally, the inclusion of raw and estimated data in the same table, which presents a great interest as discussed earlier, has also raised a third difficulty. Indeed, the introduction in all mathematical formulae of a condition to test the existence of estimated data has considerably enlarged the size of the formulae to an extent that was not compatible with the expression generator of Access. To solve this problem, the Word work package was used as the formula editor.

As for the routine user of the database, no specific difficulty has been met. Once data processing has been clearly defined and the corresponding queries have been created, the user does not need to know the MERISE method, nor all the details of the database, nor any query language. To carry out a predefined calculation, it is sufficient to run the last relevant query. Additionally, the exchange of data between Access and Excel is simple and constitutes an important advantage of the system [17]. Indeed in the near future, the exchange of data with Excel will not be totally eliminated because Access is too weak in its calculation and graphical possibilities, even in more recent versions of the software.

The speed of execution is also advantageous to the user. It depends on a number of factors [25]. In the present case, the calculation of all net portal-drained viscera fluxes for 10 metabolites may take from a few seconds with a microcomputer equipped with a Pentium III processor (850 MHz, 256 MB of RAM) to 10 minutes with a less efficient microcomputer.

Finally, the present database can be easily duplicated and used for any experiment conducted with multicatheterised animals. The database accepts an unlimited number of blood parameters, experimental treatments, animals or daily sampling. Additionally, this database presents a sound structure that can be used to elaborate new databases dealing with experimental data obtained on individual animals using other experimental approaches and methods. It can also be used to combine or compare results obtained in different experiments.

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