BIHAR ANIMAL SCIENCES UNIVERSITY, PATNA

Animal Nutrition

UNIT-1 : Principles of Animal Nutrition and Feed Technology

UG Lecture on

Direct and Indirect Calorimetry, Carbon & Nitrogen Balance Studies

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Point to be discuss……………………….

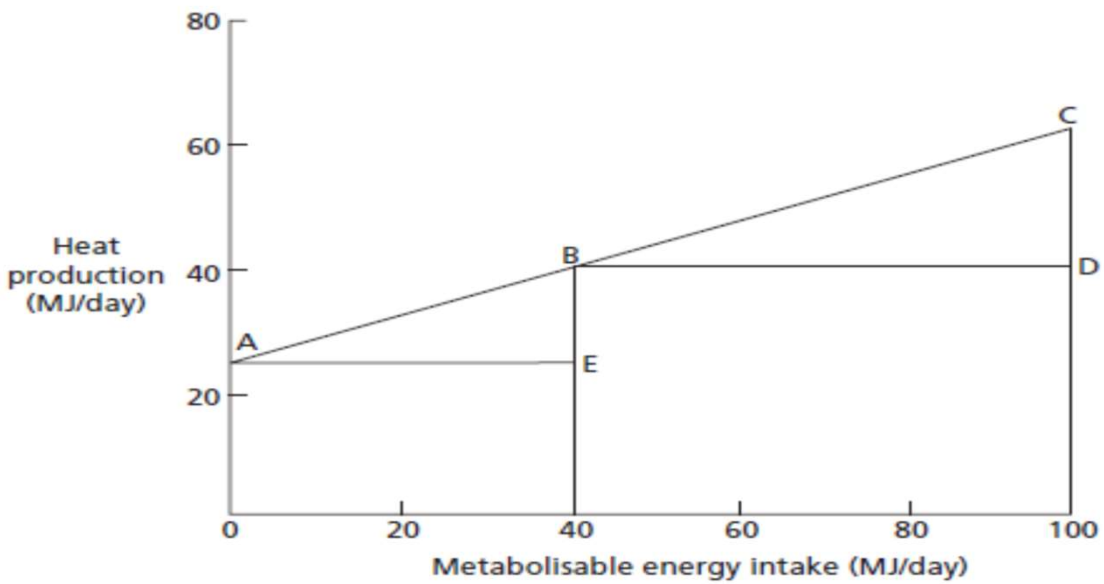
- ✓ Animal calorimetry
- ✓ Methods for measuring heat production and energy retention
- ✓ Direct calorimetry
- ✓ Indirect calorimetry
- ✓ Measurement of respiratory exchange using respiration chambers
- ✓ Close circuit type
- ✓ Open circuit type
- ✓ Measurement of respiratory exchange in unconfined animals
- ✓ Measurement of energy retention by carbon & nitrogen balance technique
- ✓ Measuring energy retention by comparative slaughter technique

ANIMAL CALORIMETRY: METHODS FOR MEASURING HEAT PRODUCTION AND ENERGY RETENTION

- **Calorimetry means the measurement of heat.**
- **Measurement of heat production & energy retention in animals can be quite complicated, both in principle and in practice.**
- **Heat production of animals can be measured physically, i.e. direct calorimetry.**
- **Alternatively, heat production can be estimated from the respiratory exchange of the animal, i.e. indirect calorimetry.**
- **Respiration chambers can also be used to estimate energy retention rather than heat production, i.e. carbon and nitrogen balance technique**

Animal calorimeter

- **Animals do not store heat, except for relatively short periods of time.**
- **Measurements are made over periods of 24 hours or longer it assume that the quantity of heat lost from the animal is equal to the quantity produced.**



(A is the basal metabolism & B & C represent heat production at metabolizable energy intakes of 40 MJ and 100 MJ, respectively)

Direct Calorimetry

- **Heat is lost from body principally by radiation, conduction & convection from body surfaces & by evaporation of water from the skin & lungs.**
- **Animal calorimeter is essentially an airtight, insulated chamber.**
- **In early calorimeters, sensible heat losses measured in water circulated through coils within the chamber & the quantity of heat removed from the chamber then calculated from the flow rate of water & the difference between its entry and exit temperature.**
- **Evaporative heat losses measured by recording the volume of air drawn through the chamber and its moisture content on entry and exit.**

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- In a more recent type of calorimeter - gradient layer calorimeter used.
- Quantity of heat is measured electrically as it passes through chamber wall.
- In this calorimeter, both sensible & evaporative heat losses can be recorded automatically.

- However, Animal calorimeters are expensive to build and earlier types required much labour to operate them, so, presently indirect method in practice.

Measurement of respiratory exchange using respiration chambers

- The simplest type of chamber- closed-circuit type - airtight chamber for the animal together with vessels holding absorbents for CO_2 and water vapour.
- The chamber having devices for feeding, watering & milking of animal.
- The oxygen used by the animal is replaced from a metered supply.
- End of trial period (24 hrs), CO_2 produced measured by weighing absorbent & any CH_4 produced measured by sampling & analysing the air of chamber.
- The main disadvantage of closed-circuit chamber- large quantities of absorbents are required i.e. for a cow, 100 kg of soda lime needed/day to absorb carbon dioxide & 250 kg of silica gel to absorb water vapour.

(a) Closed circuit

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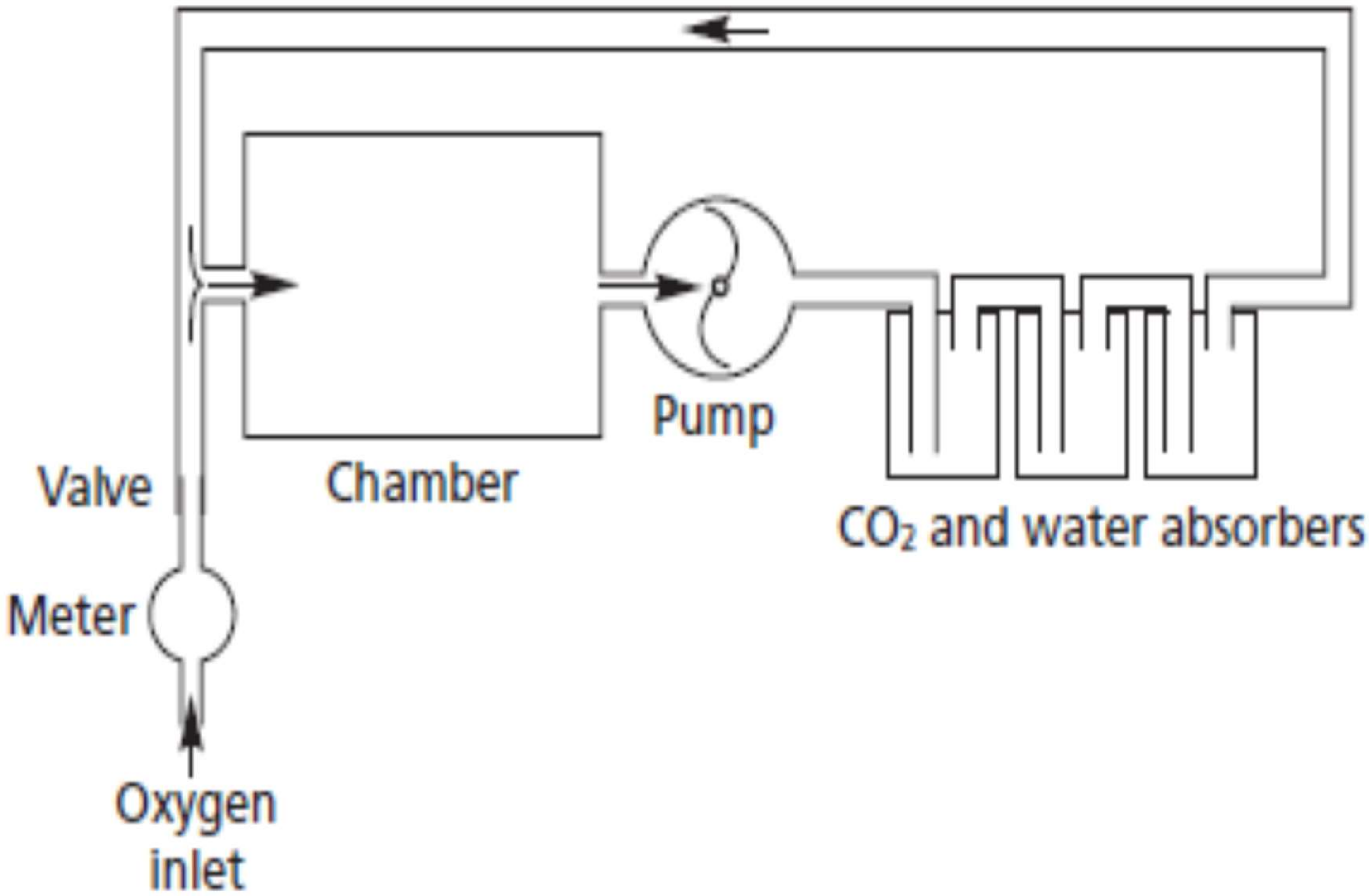

Open-circuit type of chamber

- **Air drawn through the chamber at a metered rate & sampled for analysis on entry & exit.**

- **Thus, CO_2 production, CH_4 production & O_2 consumption can be estimated.**

- **If conditions for the animal are to be kept normal, very accurate measures of gas flow and composition are required.**

- **Modern equipment, based on infrared analysers, open-circuit chambers have now largely replaced closed-circuit chambers.**

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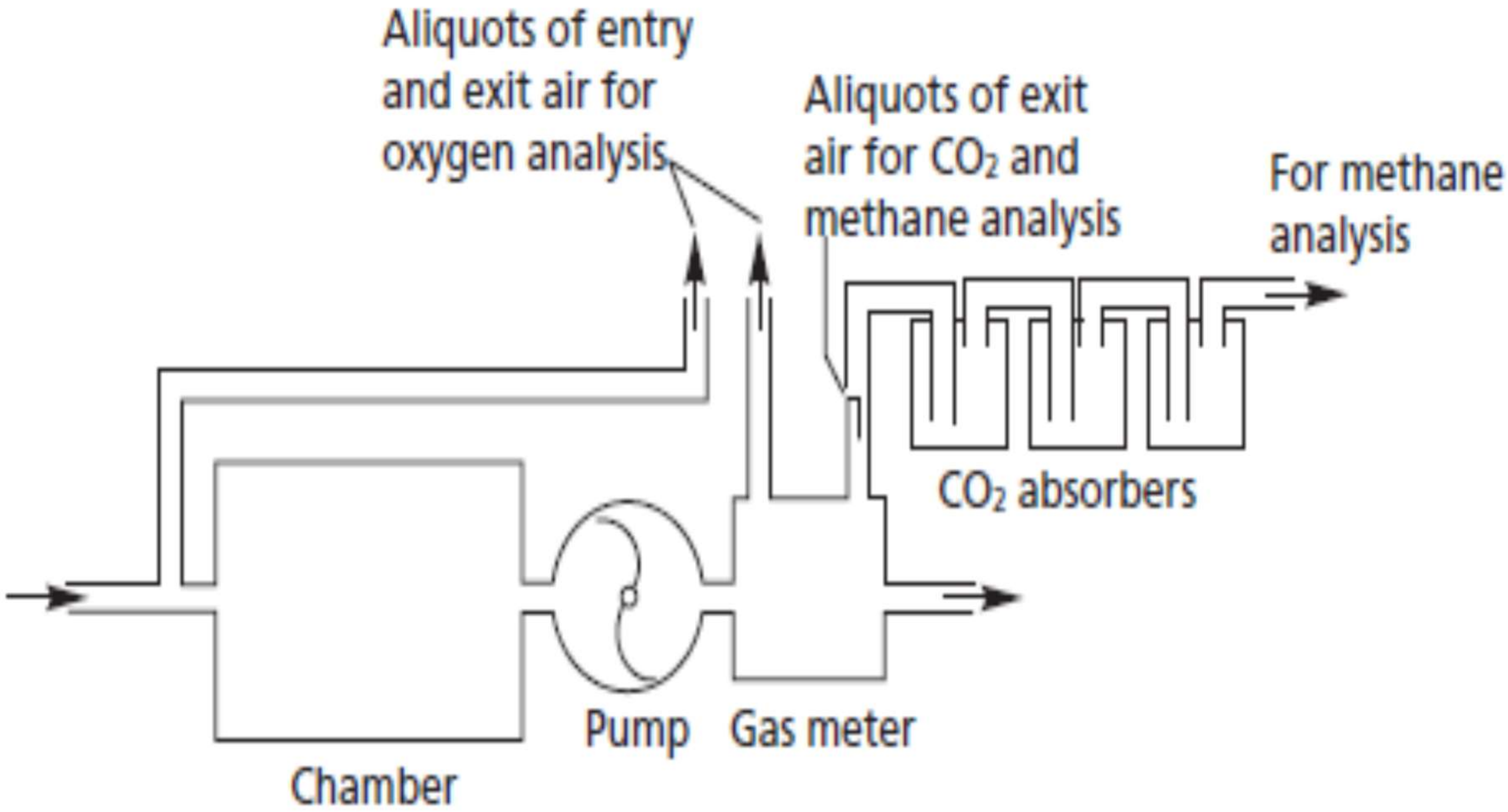
(b) Open circuit



Respiratory exchange measurement by Indirect calorimetry

- **The substances oxidised in an animal's body, and whose energy is therefore converted into heat, consist mainly of carbohydrates, fats & proteins.**

- **The overall reaction for the oxidation of a carbohydrate such as glucose is:**

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + 2820\ kJ$$

- **oxidation of the typical fat such as tripalmitin is:**

$$C_3H_5(OOC.C_{15}H_{31})_3 + 72.5O_2 \longrightarrow 51CO_2 + 49H_2O + 3202\ kJ$$

- **One gram-molecule of O_2 occupies 22.4 L at NPT.**
- **Thus, if animal obtaining all its energy from the oxidation of glucose, then the utilisation of one litre of O_2 would lead to the production of;**

  2820/(6 * 22.4) = 20.98 kJ of heat &

  for mixtures of CHO, an average value is 21.12 kJ/l

- **Such values are k/a thermal equivalents of O_2 & are used in indirect calorimetry to estimate heat production from oxygen consumption.**
- **For animals catabolising mixtures of fats, the thermal equivalent of O_2 is 19.61 kJ/l.**

- **Animals do not normally obtain energy exclusively from either CHO or fat, as they oxidise a mixture of these & protein.**

- **So, in order to apply the appropriate thermal equivalent, it is necessary to know how much of the oxygen is used for oxidation of each nutrient.**

- **The proportions are calculated from respiratory quotient (RQ).**

- **RQ is ratio b/w volume of CO_2 produced by animal & volume of O_2 used.**

- **RQ for carbohydrate is calculated as $6CO_2/6O_2 = 1.0$**

- **RQ of the fat (tripalmitin) is calculated as $51CO_2/72.5O_2 = 0.70$**

- **However, protein is incompletely oxidised in animals body because they cannot oxidise nitrogen & average amount of heat produced by the catabolism of protein is 18.0 kJ/g.**

- **Oxidation of each gram of protein, produced 0.77 L Co_2 & used 0.96 L O_2, giving an RQ of 0.80.**

- **Heat is produced not only when nutrients are oxidised but also when they are used for the synthesis of animal tissues & bear the same relationship to respiratory exchange.**
- **The relationship between respiratory exchange and heat production is disturbed if the oxidation of CHO & fat is incomplete.**
- **Metabolic disorder may arises k/a ketosis, in which FA are not completely oxidized to Co2 & H2O, whereas, C and H2 leave the body as ketones bodies.**
- **Incomplete oxidation also occurs under normal conditions in ruminants, because an end product of CHO fermentation in the rumen is CH4.**
- **So, heat production calculated from respiratory exchange in ruminants is corrected for this effect by deduction of 2.42 kJ for each litre of CH4 produced.**

- **Calculations explained above may be combined into a single equation k/a the Brouwer equation (Dutch scientist E Brouwer):**

  $HP = 16.18\ VO_2 + 5.16\ VCO_2 - 5.90\ N - 2.42\ CH_4$

  Where, HP = heat production (kJ), VO_2 = O_2 consumption (litres), VCO_2 = CO_2 production (litres), N = urinary nitrogen excretion (g) & CH_4 = methane production (litres).

- **However, in poultry the N coefficient is 1.20 (instead of 5.90), because poultry excrete nitrogen in the form of uric acid, which is more oxidisable than urea.**

Measurement of respiratory exchange in unconfined animals

- RE can be measured without an animal chamber if the subject is fitted with a face mask, connected to either a closed or open circuit for determining either O_2 consumption alone or both O_2 consumption and CO_2 production.
- This method is suitable for short periods of measurement but cannot be used to estimate heat production when the animal is eating.
- For longer period measurements of energy metabolism in unconfined animals, HP can be estimated with reasonable accuracy from CO_2 production alone.
- The latter is measured by infusing the radio-labelled CO_2 (^{14}C $NaHCO_3$) into body fluids and sampling body fluids to determine the degree to which the labelled CO_2 is diluted by that produced by the animal.

Measurement of energy retention by carbon & nitrogen balance technique

- Alternative approach is to estimate energy retention directly & to calculate HP by difference.
- Energy stored by the growing & fattening animals mainly in the form of protein & fat, as CHO reserves of the body are small & relatively constant.
- So, quantity of protein & fat stored can be estimated by carrying out a C & N balance trial – i.e. by measuring the amounts of these elements entering & leaving the body & so, by difference, the amounts retained.
- The energy retained can be calculated by multiplying the quantities of nutrients stored by their calorific values.

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- **Both C & N enters in the body through food & N leaves it in faeces & urine, however, C also leaves the body as CH_4 & CO_2.**
- **Therefore, balance trial must be carried out in a respiration chamber.**
- **Procedure for calculating the energy retention from C & N balance data is best illustrated by considering an animal in which storage of both fat & protein is taking place.**
- **In such an animal, intakes of C & N will be greater than the quantities excreted & animal is said to be in positive balance w.r.t. these elements.**

- **The quantity of protein stored is calculated by multiplying the N balance by (1000/160 = 6.25), as body protein is assumed to contain 160 g N/kg.**

- **It also contains 512 g C/kg & the amount of C stored as protein can be calculated. The remaining carbon is stored as fat, which contains 746 g C/kg.**

- **The energy present in the protein and fat stored is then calculated by using average calorific values for body tissue.**

- **The advantages of the C & N balance technique are that no measure of O_2 consumption (or RQ) is required.**

Measuring energy retention by comparative slaughter technique

- **Energy retention can be measured in feeding trials by estimating the energy content of the animal at the beginning & end of the experiment.**

- **In this method- dividing the animals into two groups & slaughtering one group of animals at the beginning of the trial.**

- **The energy content of the slaughtered animals is then determined by bomb calorimetry (samples taken either whole, minced or body tissues).**

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- **A relationship is obtained b/w the liveweight of animals & their energy content & used to predict the initial energy content of animals in the second group.**

- **The latter are slaughtered at the end of trial & treated in the same manner as those in initial slaughter group & energy gained calculated by difference.**

- **The comparative slaughter method requires no elaborate apparatus but is expensive and laborious when applied to larger animal species.**

Discussions……………………………..

Questions, if any…………………..??

THANKS