Evaluation of Energy

Dept of Animal Nutrition,
CoVSc & A.H., Jabalpur

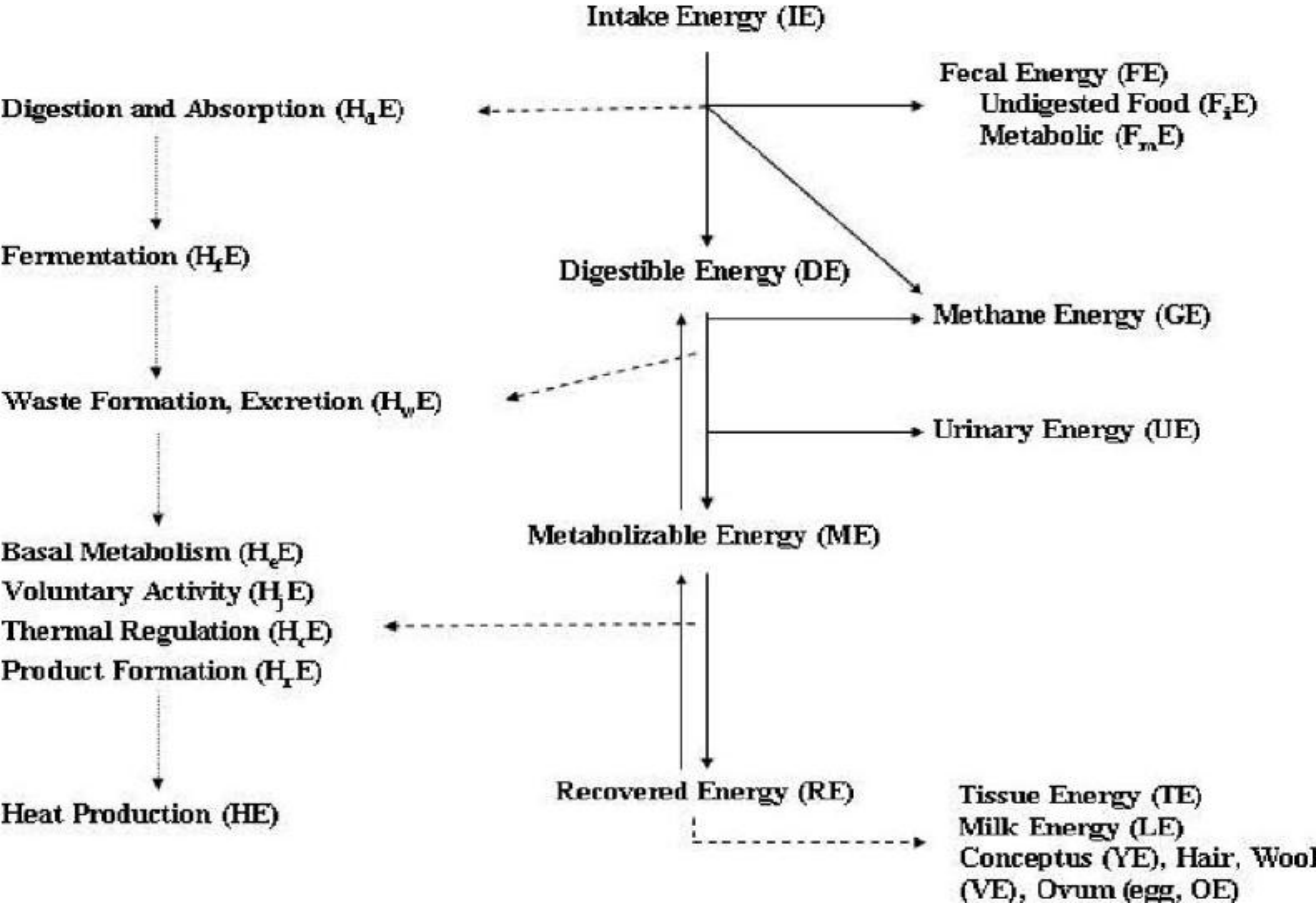
MEASURES OF FOOD ENERGY AND THEIR APPLICATION

- The force that enables to sustain life activities is energy.
- Various types of energy, such as chemical, electrical and mechanical, radiant can be converted from one form to the other.
- The plants trap energy from sun to synthesize complex constituents (chemical energy) that are broken to yield energy for maintenance of life in the animal for performance of work /production.
- Energy required for maintenance of life includes:
  - Mechanical energy for essential muscular activities like heart beat, respiration etc.,
  - Chemical energy like movement of dissolved substance against concentration gradient, synthesis of enzymes & hormones.
- Energy required for performance of work / production includes:
  - Muscular work.
  - Milk production.
  - Growth.
  - Egg production.
  - Wool production.

SYSTEMS OF EXPRESSING ENERGY VALUE OF FEEDSTUFFS

- Food evaluation systems are based on digestible, metabolic and net energy.
- The various systems in vogue are DE, ME, NE, physiological fuel value, total digestible nutrients, starch equivalent, Armsby NE system and Scandinavian food unit system.
- Actually, the only useful form of energy is Net energy.
- Although the experimental determination is somewhat tedious, in most of the developed countries, most systems of feed evaluation at present is based on net energy.

Figure . Schematic partition of energy in the animal (NRC, 1981).



Intake Energy (IE)

Fecal Energy (FE)
Undigested Food (F_iE)
Metabolic (F_mE)

Digestion and Absorption (H_dE)

Fermentation (H_fE)

Digestible Energy (DE)

Methane Energy (GE)

Waste Formation, Excretion (H_wE)

Urinary Energy (UE)

Metabolizable Energy (ME)

Basal Metabolism (H_eE)
Voluntary Activity (H_jE)
Thermal Regulation (H_cE)
Product Formation (H_rE)

Heat Production (HE)

Recovered Energy (RE)

Tissue Energy (TE)
Milk Energy (LE)
Conceptus (YE), Hair, Wool
(VE), Ovum (egg, OE)

TOTAL DIGESTIBLE NUTRIENTS

- This is the simplest form of energy evaluation & indicates the relative energy value of a feed.
- The digestibility of nutrients is determined by digestibility trials.
- Expressed in Kg or %

- **TDN (%) = % DCP + % DCF + % DNFE +(2.25 x % DEE)**

- The digestible ether extract is multiplied by 2.25 because on oxidation fat provides 2.25 times more energy as compared to carbohydrates.
- The digestible protein is included in this equation because of the fact that excess of protein eaten by the animals serve as a source of energy to the body.

- The feed and faeces are subjected to the proximate analysis namely, CP, EE, CF and NFE.

- The amounts of these nutrients not recovered in the faeces are considered to be digested.

FACTORS AFFECTING TDN VALUE OF FEED

- % Dry matter:
  - In high moisture feed the nutrient concentration is less and so the TDN value on fresh matter basis will be less.
- % Digestibility of dry matter:
  - The presence of indigestible substances like lignin, acid insoluble ash will interfere the digestibility of other useful nutrients.
  - Hence feeds with high lignin and/or acid insoluble ash will have low TDN values.
- Presence of minerals:
  - Since minerals as such contribute no energy, high mineral containing feeds will have low TDN.
- % Digestible fat in the feeds:
  - The feeds containing high digestible fat will have high TDN value because due weightage is given for its high energy content in TDN system.
  - For feeds containing more digestible fat the TDN value sometime exceeds 100%.

MERITS AND LIMITATIONS OF TDN SYSTEM

Merits:

- It is easiest to determine the digestible values through digestive trials unlike the ME and NE, which require complicated procedures.

Limitations:

- Only the loss in faeces is accounted for in this method, but losses in combustible gases, heat of fermentation and urine are not considered. This is a strong limitation to the usefulness of TDN for evaluating feeds for ruminants.

- It over estimates the value of roughages: losses in methane and heat are relatively larger per unit TDN for roughages than for concentrate.

- If feeds are high in fat content, the TDN value some time exceed 100 in percentage (Eg.) Pure fat which has 100% digestibility would theoretically have a TDN value of 225% (100 x 2.25 = 225). Animal fat – 175%, maize oil – 172%.

- The term total digestible nutrients consider only the energy giving nutrients whereas the micronutrients like minerals have not been included.

KELLNER'S STARCH EQUIVALENT

- The classical method developed by Kellner in 1907 in Germany is a net energy system,
- Kellner expressed the energy value of feedstuff by its fat producing ability relative to that of pure starch
- Kellner’s system was based on the determination of carbon nitrogen balance by respiration experiments.
- **Definition:**
- SE is defined as the number of Kg of starch that produces the same amount of fat as 100 kg of the respective feed.
- **SE = (Weight of fat stored per unit of food/ Weight of fat stored per unit weight of starch) X 100.**

- (Eg.) When we say that the SE of wheat bran is 45, it means that 100 kg of wheat bran can produce as much animal fat as 45 kg of pure starch when fed in addition to maintenance ration or in other words 100 kg of wheat bran contains as much net/productive energy as 45 kg of the starch.

Kellner determined the actual fat producing power of isolated nutrients typical of the proximate constituents of feedstuffs

Digestible nutrients	Fat deposited (g)	Starch equivalent factor
Starch	250/250	=1.0
Crude fibre	250/250	=1.0
Ether extract		
• From oil seeds	600/250	=2.4
• From cereals	525/250	=2.1
• From roughages	474/250	=1.9
Protein	235/250	=0.9

- The percentages of the digestible nutrients are multiplied by the respective starch equivalent factors.
- The arithmetic sum of these products is called as production value/starch value.
- As the calculated production values differed with the actual values Kellner used a standard for concentrates called as golden number and correction factor for roughages.

Concentrate – Golden number (0.95):

- For concentrates the actual starch value is obtained from the production value by multiplying with the ‘ golden number’ or ‘value number’.
- The value number expresses the ratio between the starch value of a feedstuff and that of the pure nutrients contained in the feedstuff.

Actual SE of concentrates =

- **Calculated production value x 0.95 Golden number**

Roughages (Correction factor):

- The production value of a roughage would be reduced by 0.58 units for every 1 per cent crude fibre present in the roughages.

Actual SE of roughages =

- **Calculated production value x (CF% x 0.58) Correction factor**

Calculation of SE of Feedstuffs

- Calculation the Starch Equivalent of barley for the following data (value no. of barley is 98).
- 100 kg barely contains 7.6 kg DCP, 1.2 kg DEE, 60.9 kg DNFE and 2-5 kg DCF.

Solution

Nutrition	%Factor		SE
DCP	7.6 x 0.94	=	7.14
DEE	1.2 x 2.10	=	2.52
DNFE	60.9 x 1.00	=	60.90
DCF	2.5 x 1.00	=	2.50
			73.06

- Calculated SE = 73.06
- Value No. of barley =98

- **Corrected SE of barley =73.07 x 98/100= 71.60**

PHYSIOLOGICAL FUEL VALUE

- Based on the composition of carbohydrate, fat and protein the heat of combustion of the feed sample can be worked out using appropriate factors.
- From the gross chemical composition of the feed samples the amount of energy yielding nutrients namely carbohydrate, fat and protein are estimated.
- If the amount of each is known it is easy to workout the heat of combustion of the feed sample using appropriate factors.
- The heat of combustion of individual carbohydrates, proteins and fats differ with their composition. (Eg.) As determined by Atwater GE of sucrose is 3.96 Kcal/gram and that of starch is 4.23 Kcal/gram.
- Energy yield of butterfat was found to be 9.21 Kcal/gram and that of lard, 9.48 Kcal/gram.
- For practical use individual figures were averaged to apply to the major food stuffs (carbohydrate, fat and protein) as gross energy of food.

ATWATER PHYSIOLOGICAL FUEL VALUES

- While carbohydrates and fats are completely oxidized to CO_2 and water in body cells after digestion and absorption, proteins are not completely oxidized by the cell.
- Unoxidised protein matter is equivalent =7.9 Kcal/gram of nitrogen, which in terms of protein is 1.25 Kcal/g of protein: This energy represents metabolic loss and must be subtracted from the 'digestible protein'.
- After considering this Atwater has given factors for ME, which is also known as physiological fuel values.

Atwater physiological fuel value factors

Carbohydrate – 4.15 x 0.98 = 4 Kcal/g

Fat – 9.40 x 0.95 = 9 Kcal/g

Protein – (5.65 – 1.25) x 0.92 = 4 Kcal/g

- In ruminants gaseous loss also costs much of energy thus these physiological fuel values are not applicable in the case of ruminants.
- These values have been used in calculating the TDN of feedstuffs, but it is a crude procedure for ruminants.

DIRECT CALORIMETRY

- Calorimetry means the measurement of heat.
- The heat production of animals can be measured physically using a procedure known as direct calorimetry.
- Heat is lost from an animal body principally by radiation, conduction and convection from body surfaces Sensible HL
- and by evaporation of water from the skin and lungs. Insensible HL
- An animal calorimeter is essentially an airtight, insulated chamber.
- SHL & IHL in animal body can be measured with two general types of calorimeters:
  - Adiabatic calorimeter
  - Gradient calorimeter

INDIRECT CALORIMETRY

- Animal body derives all of its energy from oxidation, the magnitude of energy metabolism can be estimated from the exchange of respiratory gases.
- Such measurements of heat production are more readily accomplished than are measurements of heat dissipation by direct calorimetry.
- A variety of techniques are available for measuring the respiratory exchange; all ultimately seek to measure oxygen consumption and CO_2 production per unit of time.

Indirect Calorimetry: HP measurement of respiratory exchange

- Alternatively, heat production can be estimated from the respiratory exchange of the animal.

- For this, a respiration chamber is normally used and the approach is one of indirect calorimetry.

- Respiration chambers can also be used to estimate energy retention rather than heat production, by a procedure known as the carbon and nitrogen balance technique.

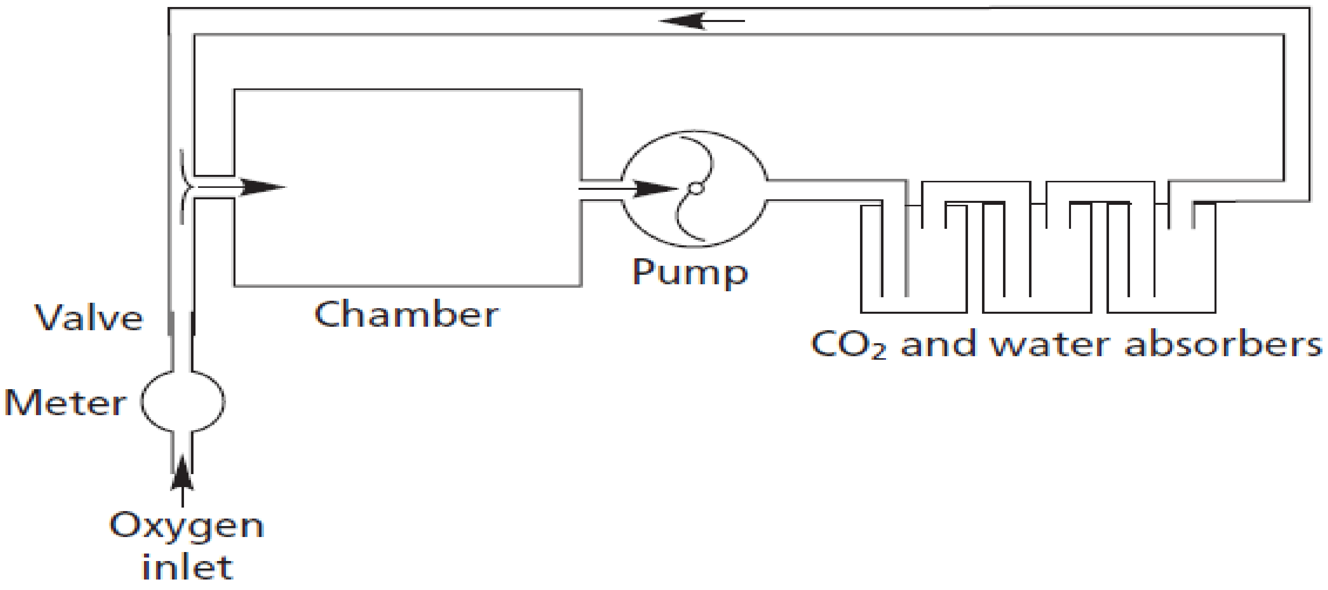
Closed-circuit type respiration chamber

- consists of an airtight chamber for the animal together with vessels holding absorbents for CO2 and water vapour.
- The chamber incorporates devices for feeding, watering and even milking the animal.
- The oxygen used by the animal is replaced from a metered supply.
- At the end of a trial period (24 hours), the carbon dioxide produced can be measured by weighing the absorbent.
- Methane produced can be measured by sampling and analysing the air in the chamber.
- The main disadvantage of the closed-circuit chamber is that large quantities of absorbents are required;
- A cow, 100 kg of soda lime would be needed each day to absorb carbon dioxide and 250 kg of silica gel to absorb water vapour.

Open-circuit type of reparatory chamber

Air is drawn through the chamber at a metered rate and sampled for analysis on entry and exit. Thus, carbon dioxide production, methane production and oxygen consumption can be estimated.

(a) Closed circuit



(b) Open circuit

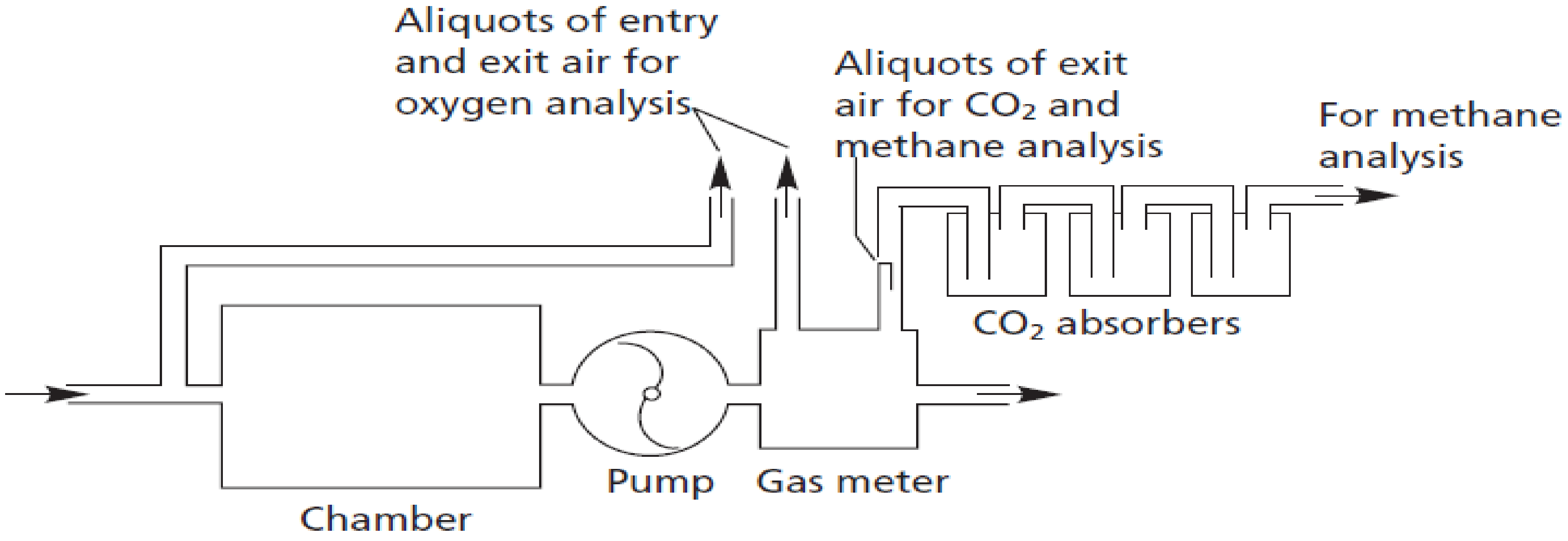


Fig. 11.4 Diagrams of respiration chambers.

Calculation of HP of a Calf from Respiratory Exchange and Urinary N Excretion.

Oxygen consumed	392 L	
CO_2 produced	310.7 L	
Urinary N excreted	14.8 g	
Heat from protein metabolism*		
Protein oxidized	14.8 x 6.25	92.5 g
Heat Produced	92.5 x 4.3 Kcal	398.8 Kcal
Oxygen used	92.5 x 0.96	88.8 L
CO_2 produced	92.5 x 0.77	71.2 L
Heat from carbohydrate and fat metabolism*		
Oxygen used	392-88.8	303.2 L
CO_2 produced	310.7-71.2	239.5 L
Non-protein RQ	-	0.79
Thermal equivalent of O2 at RQ (From table)	0.79	4.789 Kcal/L
Heat produced	303.2 x 4.789	1452 Kcal
Total Heat produced	398.8 + 1452=	1850.8 Kcal

Measurement of energy retention by the carbon and nitrogen balance technique

Amount		*Nitrogen (g)*		*Carbon (g)*	
		Intake	**Outgo**	**Intake**	**Outgo**
Feed :	6.988 kg hay	56.4	-	2831.7	-
	0.400 kg linseed meal	21.9	-	172.6	-
Excreta :					
	16.619 kg faeces	-	33.5	-	1428.7
	4.357 kg urine	-	32.4	-	124.2
	37 g brushings	-	1.3	-	8.0
	4.730 kg CO_2	-	-	-	1290.2
	142 g CH_4	-	-	-	106.6
	Total	78.3	67.2	3004.3	2957.7
	Gain in carbon	46.6 g :		Gain in nitrogen	11.1 g

- The animal gained 11.1 g N2
- Gain of protein is 11.1 x 6.25= 66.6 g
- Protein contain= 52.54% carbon
- Carbon used for this protein is 66.6 x 52.54÷ 100=35 g.
- Total gain of C was 46.6g.
- Amount C available for fat formation is 46.6-35=11.6 g.
- Fat contains 76.5% carbon,
- The gain of fat is 11.6 x100÷76.5 = 15.2 g.
- C and N balance data: 66.6 g of protein and 15.2 g of fat are formed in the body.
- Energy retention can be calculated:

  (66.6 x 5.64) + (15.2 x 9.39) =518 Kcal.
- If ME intake is known, subtraction of energy retention from ME gives heat production of the animal.

  HP=MEi-EB