UNIT 2: ENERGY

Table of Content

1.0 Introduction

In Unit I, you learned that one of the major functions of food and the nutrients in the food is to supply energy for internal body metabolisms and for physical activities. This unit discusses energy; its forms, the energy content of food, measurement of energy, the expenditure of energy, the rates of expenditure and the energy requirements of man.

2.0 Objectives

At the end of this unit, you should be able to

- List the forms of Energy
- Calculate the energy content of a given food item with know composition of nutrients
- Measure energy expended
- Discuss the energy requirements of man.

3.0 Main content

3.1 Forms of Energy

There are five forms of energy namely Solar, Chemical, Mechanical, Thermal and Electrical.

In *Unit 1*, you learned that the green living parts of plant manufacture carbohydrate from carbon dioxide and water in the presence of the sunlight energy absorbed by chlorophyll.

It is also known that the plants are able to synthesize carbohydrates, proteins and fats from inorganic substances such as CO2, I-120, NI-I3 and SO4. In food, chemical energy is stored. The chemical energy is used to do the following:

- Perform mechanical work
- F o r g r o w t h
- Maintenance of the body tissue.

There is the conversion of chemical energy to mechanical energy when there is the need to perform mechanical work — that is physical activities.

Out of the energy required for maintenance, 10% is known to be used for internal mechanical work — the beating of the heart and movement of the respiratory muscles. The rest 90% of the energy for maintenance has been found to be used for the osmotic pumps that maintain the differences in the electrolyte concentrations between i ntra and extra cellular fluids for synthesis of protein and other macromolecules (Davidson et al, 1975).

The unit of energy is given in joules, kilojoules, mgajoules and kilocalories A joule of energy is the energy required to move 1 kilogram a meter by a force of 1 Newton (N).

1000 joules equal to 1 kilojoule
100000 kilojoules is equal to 1 megajoule

Kilocalorie has become more familiar in use than joules and kilojoules. 1 kilocalorie has been found to be equal to 4.2 kilojoules.
The rate of expenditure of energy is expressed in kilowatts.
One kilowatt is equal to 1 kilojoule per second. Kilojoule is abbreviated as Kj and kilocalorie as Kcal.

Student Assessment Exercise 2.1

2.1.1 Convert the following to kilojoule,
(i) 100 Kcal *(ii) 38.5 Kcal*
2.1.2 Convert (i) 375 kilojoules to kilocalories
(ii) 10542 kilojoules to kilocalories

3.2 Energy Content of the Food

There is a need to know the energy content of food to know the amount of energy derivable from a portion of food of known composition of nutrients.

To obtain the energy content of food we use bomb calories

The food stuff is placed in a small chamber or bomb and exposed to high pressure of oxygen in the presence of a platinum catalyst. This is ignited by a small electric current. The food stuff in the bomb burns and the heat produced causes a rise in the temperature of the sun-ounding water. From this the heats of combustion of the three major nutrients carbohydrate, protein and fat can be measured.

It has been found that there are slight differences in the heats of combustion of the nutrients in different foods.

In obtaining the heat of combustion of the different nutrients the extent of the oxidation of the individual nutrients is very important. It has been found that in the animal body, the tissue is able to oxidize fat and carbohydrate completely to carbon dioxide and water. However, the oxidation of protein, has been found not to be complete because of the presence urea, uric acid and creatinine Mat are excreted in urine. Urine has been found to contain unoxidized materials. In computing the heat content of protein, there must be correction for the presence of unoxidizable materials in the urine.

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Generally, the absorption of the nutrients is not also complete. In view of this, there must be allowances made for incomplete absorption of nutrients while computing the energy content of food.

For all these corrections, in computing the energy content of food, 92% of carbohydrates are considered absorbed in the body. The rest passes on as faeces and urine.

The table 2.1 presented here show the heat of combustion and the available energy in the three proximate principles — protein, fat and carbohydrates, in a mixed diet.

Table 2.1 The Heat of Combustion and the Available Energy In the Three Proximate Principles In a Mixed Diet

Nutrients	Heat of Combustion		Loss in Urine		Availability	At Water Factors	
	Kj/gm	Kcal/gm	Kj/gm	Kcal/gni	Percentage	Kj/gm	Kcal/gm
Protein Meat			5.23	1.25	92	17	4
Egg	22.4	5.35					
	23.4	5.58					
Fat							
Butter							
Animal Fat Olive	38.2	9.12			95	37	9
oil	39.2	9.37					
	39.3	9.38					
Carbohydrate							
Starch	17.2	4.12					
Glucose	15.5	3.69	-	-	99	16	4

Source: Davidson S. et al (1975) Human Nutrition and Dietetics. Sixth edition, Longman Group Ltd., Pg. 19

Columns 1 and 2 show the heat of conlbustion of the nutrients in both kilojoules and kilocalories. Column 3 and 4 show loss of heat through urine. Column 5 shows the percentage availability of the nutrients after allowances have been made for loss in urine and loss through incomplete absorption. Columns 6 and 7 show the At Water fact(is which can be used to calculate the metabolizable energy.

Solution

Nutrients	Amount gm s	Availability Percent	Energy Content (Kcal) Kcal
Carbohydrate	350	346.5	1386
Fat	150	142.5	1282.5
Protein	200	184	736
Total			3404.5

For availability, the weights of protein, fat and carbohydrate and multiplied by 0.92, 0.95 and 0.99 respectively. The availability, was multiplied by 4, 9 and 4 respectively for protein, fat and carbohydrate to obtain energy content of the carbohydrate respectively are the At Water factors.

In obtaining the proximate weight of protein in any food the nitrogen content of the food is usually evaluated. Nitrogen content is about 16% of the protein in the food. If the nitrogen content is obtained, the value is usually multiplied by 6.25 to obtain the value of the protein in the food. The value may appear too low fro milk and milk products, and too high for cereals. For milk 6.4 is used and for cereal 5.7 is used to multiply the nitrogen value in order to obtain the protein content.

In order to obtain the carbohydrate content, we subtract the sum of the weight of water, from protein and mineral salts that the contents of the water, protein, fat and mineral salt will be obtained first before that of carbohydrates. In modern tables of heat of combustion, the content of the monosaccharide is used to express the carbohydrate content. Monosaccharides are the smallest units of the substances that form the carbohydrate. This will be discussed in some subsequent units.

The differences in the composition of different samples of the same food items can lead to differences in the heat content of food items of the same weights. Even with the differences, the tables of food composition are still very useful in dexterities.

Alcohol can also be another source of energy to man (7Kcal/gm). It has been found that all the energy released from alcohol, ethyl alcohol, could be utilized by man.

Cellulose has been found to be a good source of energy to the ruminants for example sheep. The cellulose is broken down by bacteria into simpler form which are transported and metabolized in the cells of the ruminants to release considerable amount of energy. Since man does not possess cellulose, he

cannot derive energy from cellulose.

3.3 Measurement of Energy Expenditure

3.3.1 Direct Calorimetry

This is done by putting a man in a chamber in which the total heat evolved can be measured. The measurement was developed by At water and Rose and the At water and Rosa respiratory calorimeter was used for the measurement. The total *energy* expenditure is given as the amount of heat evolved plus the mechanical work performed. Since there is conservation of energy, the total energy expenditure that is the sum of heat produced plus the mechanical work done is equal to the net energy from the food intake that is the total chemical energy in the food minus the energy lost faeces and urine (Davidson S. et al, 1975). You learned that there should be allowance for energy loss through urine and *energy* loss as a result of incomplete absorption of the nutrients. The loss through incomplete absorption of the nutrients is to

the faeces.

Since respiration which is the process by which the food or the nutrients are oxidized to release *energy*, the *energy* expenditure of the body has been found to be quantitatively related to the oxygen consumpt;on.

The process of direct calorimetric appears simple in theory. However, it is very difficult and expensive in practice.

3.3.2 Indirect Calorimetry

In this method the oxygen consumption is measured. During respiration, the nutrients are oxidized to release energy. If there is total combustion of the nutrients, then the amount of energy produced either in the body or in the calorimeter must be quantitatively related to oxygen consumption. There is a chemical equation for this. The law of conservation of mass and energy must be obeyed.

From the equation of respiration

Sugar (Glucose) + Oxygen = Carbohydrate + Water + Heat

Chl^{-}Ip06 + 60_2 = 6CO3 + 6H10 = Heat

From the equation, 180gms of sugar will be combusted by 6 x 22.4 litres of oxygen to produce 6 x 22.4 litres of carbon dioxide and 6 x ISgsin of water. You should realize that the molar volume el any gas is the volume occupied by one mole of gas at normal temperature and pressure hence for 6 moles of the gas at the volume of oxygen will be 6 x 22.4 litres.

The heat generated during the reaction has been found to be equivalent to 2.78m.j.

lgm of sugar will then produce
2.78 x 1000000 joules 15444 joules
= 15.4 Kj
3.69Kcal

Also 1 litre of oxygen gives = 2.78 x 1000Kj
6 x 22.4
=

2
0
.
7
K
j

4
.
9
K
c

a
l
.

the ratio of the carbon dioxide produced to the oxygen consumed is known as respiratory quotient (RQ). The value of RQ for the oxidation of glucose presented above is 1. The RQ is CO/ Expired
02 Consumed

This enables us to determine whether carbohydrate, fat or protein is burnt or not.

This is very useful in certain clinical situations.

The table 2.2 below shows the energy yields forms oxidation of foodstuffs