# 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
- For growth
- 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.

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 kilo joules 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 surrounding 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 that 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.

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 Percentage | At Water Factors | |
|---|---|---|---|---|---|---|---|
| | Kj/gm | Kcal/gm | Kj/gm | Kcal/gni | Percentage | Kj/gm | Kcal/gm |
| Protein | | | | | | | |
| Meat | 22.4 | 5.35 | 5.23 | 1.25 | 92 | 17 | 4 |
| Egg | 23.4 | 5.58 | | | | | |
| Fat | | | | | | | |
| Butter | 38.2 | 9.12 | | | | | |
| Animal Fat | 39.2 | 9.37 | | | 95 | 37 | 9 |
| Olive oil | 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

= 20.7Kj

4.9Kcal.

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 (Zuntz. 1897)

Table 2.2 Energy Yields from Oxidation of Foodstuffs (Zu0tz1897)

| | Oxygen Required | Carbon dioxide | RQ | Energy Developed | | Energy Equivalent of $O_2$ per litre | |
|---|---|---|---|---|---|---|---|
| | | | | Kj | Kcal | Of $O_2$ Kj | Kcal |
| | Ml | Ml | | | | | |
| Starch | 828.8 | 8288 | 1.00 | 17.51 | 4.183 | 21.63 | 5.047 |
| Animal & Fat | 2019.2 | 1427.3 | 0.77 | 39.60 | 4.461 | 19.62 | 4.686 |
| Protein | 966.1 | 781.7 | 0.809 | 18.59 | 4.442 | 19.36 | 4.600 |

Source: Davidson S. et al (1975) Human Nutrition and Dietetics Sixth

## 34 Energy Expenditure by the Body

### 3.4.1 Energy Expenditure In Mechanical Work

In performing mechanical work, there is the movement of the muscular contractions — both voluntary and involuntary contractions. The voluntary contractions are used to move the different parts of the body while



•

Performing mechanical work. The involuntary contractions occur with the muscles of the internal organs of the body. This allows vital processes such as circulation and digestion. The processes occur throughout the life of a man though there is reduction of the *rate* during *sleep.*

For both the voluntary and involuntary contractions, *energy is expended.* It has been found that only 1/4 of the *energy* made available in this regard is used The rest is expended as heat.

### 3.4.2 Synthesis of Essentials

The cells do a lot of syntheses such as syntheses of fat, protein and some other organic molecules. All these require some energy.

### 3.4.3 Maintenance of Body Temperature

For the maintenance of the body temperature, some energy is required. During physical activities, the heat produced is used to maintain the body temperature. Since the normal body temperature (37˚C) is higher than the normal environmental temperature, those who could not properly maintain their body temperature (babies and old people) should not be exposed to low environmental temperature while at rest.

### 3.4.4 Energy Expenditure at Rest

It has been found that when a person is resting and when there is no voluntary

muscular contractions going on, the body still expends energy fro the involuntary contractions of the muscles of the internal organs for cell and nerve activity. During the resting period, the heart still pumps blood, respiration still takes place, and there is a lot of the involuntary muscular actions. All these consume energy. The *energy* required at the rest is called basal metabolism. Basal Metabolic Rate (BMR) is determined experimentally and it is the energy below which energy expenditure should not fall throughout the 24 hours of a day. It is the minimum energy requires d by the body. This is measured some 12 hours after *the* last meal while an individual is lying down wearing a light cloth in a comfortably warm room.

There are tables for *the* basal metabolic rates showing standard values for *people* of both sexes and of all ages. However, there are variations betvveen different people of both sexes and of all ages. The basal metabolic rate of a person can *he related* to *the* surface area of that person. It has *been found* to be more related to the lean body mass of a person. The lean body mass of a person is the *weight* of the carcass of the person minus weight of the fatty substances *in* the carcass. The weight of the carcass is the weight of the person minus the metabolic rate. People living in the tropics have been found to have BMR above 10 percent but below the standards. Age also has effect on the BMR. The BMR has been found to be higher in actively growing children than in the older people.

### 3.4.5 Specific Dynamic Action

When food is eaten, there is always the release of some heat. The term used to describe this effect of rise in the metabolic rate above the value found when fasting is called Specific Dynamic Action (SDA). SDA is also described as the effect of food which increases the metabolism over the basal level. When food is taken in excess of what is required for immediate energy needs, there will be SDA. With the consumption of protein the rate of metabolism increases by 30 to 40 percent, with fat 4 to 14 percent and with carbohydrates 5 to 7 percent. The heat produced by the SDA of protein has been found to contribute to the maintenance of the body temperature. As a result of the SDA of protein, some people have argued whether those in hot climates should consume less protein, however, it is also discovered that excess protein does not have deleterious effect on the body and in the capacity to perform work at these hot climates.

## 3•5 Energy Requirements of Man

### 3.5.1 Dietary Survey

You have learned that man requires energy for physical activities, basal metabolism, and synthesis of some micro molecules in the body and maintenance of body temperature. The energy requirement of the body could be assessed through dietary surveys. From the food intakes he can calculate the energy supplied. The dietary surveys provide good estimates of the energy requirements of the individuals. The dietary survey has these major drawbacks.

a) There could be more food than required and people may tend to eat more than necessary

b) There could also be less food than required and people may not get enough to eat.

With these, dietary surveys may not provide the accurate estimated of the energy requirements of the individuals.

### 3.5.2 Recommended Intakes of Energy

Many associations and bodies have developed recommended intakes of energy for *people* of both sexes and different age groups in various occupations *depending* on the *levels* of physical activities. There *are* tables of recommended intakes by USA Foods and Nutritional Board of National Academy of Sciences since 1943 and UK Department of Health and Social Security. There are also recommended intakes for energy by Food and Agricultural Organization and the Department of Health and Social Security (DHSS) United Kingdom.

From the tables, one could have an estimate of the energy required of an individual, though with allowances for some variations.

### 3.5.2 Variations in the Energy Requirement

Physical The energy requirements of individuals have been found to be dependent on physical activity, body size and composition, *age* and climate and environment (Davidson S. et al, 1975).

a) Activity

Occupations have been classified as sedentary, moderately active and very active occupations. You have learned that energy is required for both basal metabolism and physical activities. For moderately active occupzttions, it has been found that above half of the energy requirement is for basal metabolism and the other half for physical activity.

b) Body Size and Composition

Since energy intake is used for maintaining body temperature and synthesis of tissue, it is wise to say that the larger the body size the greater the energy requiretnents. Since the body weight is taken as a measure of the body size, the greater the weight the greater the energy required to move the body.

The energy requirement has more relationship with the lean weight. The more the lean weight the greater the energy required. Women tend to have more of fatty body than men. That is, men have more lean weight than women and require more energy than women of the same body weight.

c) Age

Energy Is Required For Growth and for Synthesis of tissues. The energy requirement has *been found* to rise from a minimum in young children to a maximum in adolescents. Thereafter, there will be a gradual fall. The energy requirement is related to body weight during growth. At old age, there is reduction in the metabolic rate hence causing a reduction in the energy requirement.

d) Climate

It appears as if individuals tend to eat more in cold weather than in hot weather. This is probably to maintain the body temperature during the cold weather. In exceptionally hot and cold conditions, physical activities tend to reduce causing a reduction in the energy requirements. Within the tropics, the energy requirements of an individual are above 5 to I() percent lower than the standards, given for places where the mean temperature exceeds 25˚C.

e) Pregnancy and Lactation

During pregnancy, there is the need for increase in the energy intake for the growth of the developing embryo. This is also applicable to lactating mothers who will require additional calories intake for the production of milk. During these physiological stages, the mothers require additional caloric intake which invariably increases the requirements of the mothers.

*Student Assessment Exercise 2.2*

*2.2.1 if a food item contains 500gins of carbohydrates, 300gms of protein and 200gms of fat, what is the energy content of the food item to the body if allowances are provided for loss through urine and incomplete absorption of nutrients?*

*2.2.2 List the factors that cause variations in the energy requirements of individuals.*

## 4.0 Conclusion

This unit discusses the forms of energy, the energy content of food, the measurement of energy expenditure and the energy requirements of the body. The unit gives the basis of obtaining the values of energy requirements of the individuals.

## 5.0 Summary

The unit gives, chemical, mechanical, solar, thermal and electrical energies as the forms of energy. The unit also slates that the energy content of food can be measured by calorimeter.

The body can be estimated by dietary surveys. The unit finally gives that energy requirements of the individuals are influenced by the level of physical activity, age, body size and composition, climate and environment. Subsequent units will discuss the various nutrients in the food.

## 6.0 Tutor Marked Assignment

Discuss the ways in which energy is expended in the body.

Answers to Student Assessment Exercises

2.1.1 (1) 420kj (ii) 161.7kj

2.1.2 (i) 85Kcal (ii) 2510Kcal

2.2.1 500gms of carbohydrate

Availability $= \frac{99 \times 500}{100}$

Energy Content = 495 x 4Kcals = 1980Kcal

300gms of Protein

Availability $= \frac{100}{100} \times 95 = 276$gms

Energy Content = 276 x 4 = 1104Kcal

200gms of Fat

Availability $= \frac{200}{100} \times 95 = 190$gms

Energy Content = 190 x 9 = 1710Kcal

Total Energy Content = 1980 + 1104 + 1710 = 4794Kcal

2.2.2 Age, body, size and composition, climate, physical activity, lactation and pregnancy.

## 7.0 References and Other Sources

Davidson S. et al (1975) Human Nutrition and Dietetics Sixth edition Longman Group Ltd.

Fleck H. (1976) Introduction To Nutrition. Third edition, Macmillan Pub. Co., Inc., New York

Lake B and Inlaternurte M. (1980) Food and Nutrition 1.3u edition, Mills and Boon Ltd., London