Chapter 3

Energy Value of Food Stuffs

3.0.1 The Energy-Yielding Food Factors

The energy yielding food factors are

1. Carbohydrates.

2. Fats ; and

3. Proteins.

Within the body, these units are oxidised in the cells. The process is one of the continuous utilisation of oxygen and production of CO_2, water and heat.

$$\text{Carbohydrates and Fats} \xrightarrow{Oxidation} CO_2 + \text{Water} + \text{Heat}$$
$$\text{Proteins} \xrightarrow{Oxidation} CO_2 + \text{Water} + \text{Urea}$$

3.1 Calorific Value

Energy value of food stuffs are usually expressed in terms of a term known as calorific value.

The calorific value is defined as the quantity of heat liberated in calories by the complete combustion of a unit mass of the food stuff in excess air or oxygen under specified standard conditions. The calorific value depends on the nature of the food and relative proportion of proteins,fats and carbohydrates present in that food. It is usually expressed in kilo calories and the standard mass taken is 100 g.

This term is used to grade different food stuffs or fuels. Greater the calorific value higher the quality of the food stuff or fuel.

Different fuels as well as food stuffs are graded on the basis of their calorific values.

3.1.1 Energy Units

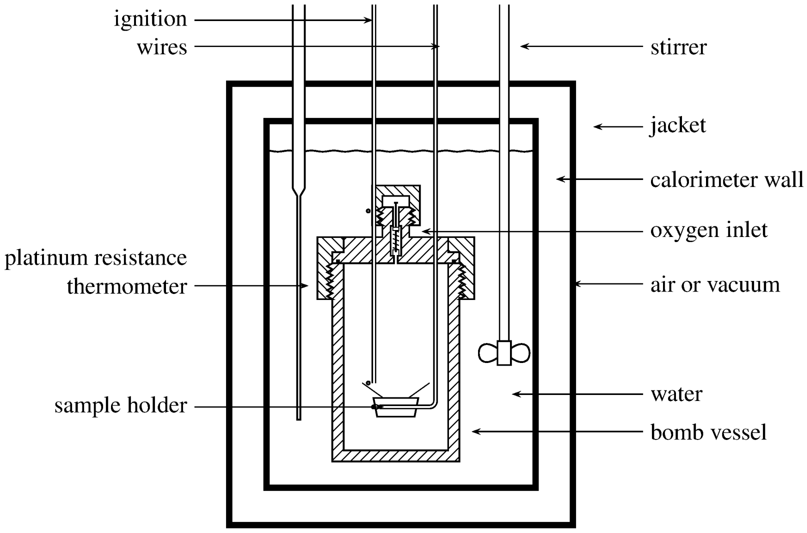
The energy value of foods can be expressed in terms of kilo calories (KCal) or megajoules (MJ). The International Union of Nutritional Sciences had suggested the use of Mega Joule(MJ) as the energy unit in place of KCal.

Kilo Calorie: One kilo calorie is the quantity of heat required to to raise the temperature of 1 kg of water through 1^0C. It is one thousand times the small calorie used in physics measurements.

Mega Joule : One kilo calorie equals 4.186 kilo joules. Hence thousand kilo calorie equals 4.186 $\times 10^3$ kilo joules or 4.186 mega joules.

3.1.2 Determination of Energy Value of Foods

The energy value of foods is usually determined using the instrument called bomb calorimeter. It consists of a heavy steel bomb, with a cover held tightly.



A weighed amount of food sample is placed inside the calorimeter, in a crucible. It is filled with oxygen under pressure. The calorimeter is immersed in a known quantity of water. The sample is ignited by means of electric fuse and heat liberated is measured by the rise in temperature.

For example, consider the evaluation of calorific value of 2 g of wheat measured with with a calorimeter containing 3 kilograms of water.

$$
\begin{array}{lcl}
Weight\ of\ wheat\ taken & = & 2\ g \\
Weight\ of\ water\ in\ the\ outside\ vessel & = & 3000\ g \\
Water\ equivalent\ of\ calorimeter & = & 500\ g \\
Initial\ temperature\ of\ water & = & 24^0C \\
Final\ temperature\ of\ water & = & 26^0C \\
Rise\ in\ temperature & = & 2^0C \\
Heat\ gained\ by\ water\ and\ calorimeter & = & 3500 \times 2\ =\ 7000\ calories
\end{array}
$$

2 g of wheat produces 7 kilo calories

1 g wheat produces 3.5 KCal

Calorific value of 100 g of wheat = 350 KCal.

Gross Energy Value of Foods

The average gross energy value of pure carbohydrates, fats, and proteins determined with the bomb calorimeter are given below.

1 g	Carbohydrate yields	4.1 KCal
1 g	Fat ,,	9.45 ,,
1 g	Protein ,,	6.65 ,,

Physiological Energy Value of Foods

In the utilization of carbohydrates, fats and proteins in the body, a certain percentage of the above nutrients is lost in digestion and the nitrogen of protein is excreted in urine as urea which still contains some energy value. The average losses in digestion in human subjects have been estimated to be 2.0 percent for carbohydrates, 5.0 percent for fats and 8.0 percent for proteins. The loss of energy in urea has been estimated to be 1.2 KCal per gram of protein oxidised. The physiological energy value of foods calculated from the gross energy values after allowing for the above losses in digestion and metabolism are as follows: carbohydrates 4.0; fats, 9.0 and proteins 4.0.

These values are known as Atwater-Bryant values.

Nutrient (Type)	Gross Energy Value	Loss of Food Energy in Digestion	Energy Available after Digestion	Loss of Food Energy in Metabolism	Physiological Energy Value of Foods
Carbohydrates	4.1KCal/g	2	4.0 KCal/g	0	4.0 KCal/g
Fats	9.45 KCal/g	5	9.0 KCal/g	0	9.0 KCal/g
Proteins	5.65 KCal/g	8	5.2KCal/g	1.2 KCal/g	4.0 KCal/g

On the basis of the above table we can calculate the energy values of foods from their contents of carbohydrates, fats and proteins using the physiological energy values of 4.0 KCal per gram of carbohydrate or protein and 9.0 KCal per gram of fat.

Relation Between Oxygen Consumption and Energy Value

The results of studies in animals and man have shown that 1 litre of oxygen used in the oxidation of fats yield 4.7 KCal/g carbohydrates, 5.0 KCal/g and proteins 4.8 KCal/g . When all the three nutrients are oxidised as per example during the post absorptive state, the energy value of 1 litre of oxygen consumed has been found to be 4.8 KCal. The above value is used in the calculation of energy output from the quantity of oxygen consumed by human subjects

3.2 Basal Metabolism

Definition

The energy metabolism of a subject at complete physical and mental rest and having normal body temperature and in the post absorptive state(i.e. 12 hours after the intake of the last meal)is known as Basal Metabolism.

3.2.1 Determination of Basal Metabolism

Basal metabolism is usually determined using the apparatus of Benedict and Roth. The apparatus is closed circuit system in which the subject breathes in oxygen from a metal cylinder of about 6 litre capacity and CO_2 produced is absorbed by soda lime present in the tower. The oxygen cylinder floats on water present in an outer tank. The subject wears a nose clip and breathes the oxygen present in the cylinder through a mouthpiece for a period of 6 minutes. The volume of O_2 used is recorded on a graph paper attached to a revolving drum by a pen attached to it. Since the subject is in the post absorptive state, R.Q. is assumed to be 0.82 and the calorific value of one litre of O_2 consumed is taken as 4.8 KCal.

Example: Subject: adult male, 50 kg body weight.

$$\begin{aligned} Oxygen\ consumed\ in\ 6\ minutes &= 1.1\ litres \\ Heat\ produced\ in\ 6\ minutes &= 4.8 \times 1.1 \\ &= 5.28\ KCal \\ Heat\ produced\ in\ 24\ Hours &= 5.2 \times 60 \times 24 \\ &= 1267\ KCal \end{aligned}$$

The basal metabolism of the individual for 24 hours = 1267 KCal

3.2.2 Standards for Basal Metabolism

Studies carried out by various workers have shown that basal metabolism is most closely related to the body surface area and less directly related either to the weight or height of the individual. The body surface area can be calculated according to the formula Du Bois and Du Bois given below:

$$A = W^{0.425} \times H^{0.725} + 71.84$$

Where, A is the body surface area in square centimetres , H is Height in centimetres and W is the weight in Kilograms.
The logarithmic form is given by:

$$\log A = 0.425 \times \log W + 0.725 \times \log H + 1.8564$$

3.2.3 Factors Affecting Basal Metabolic Rate(B.M.R.)

There are many factors that affect the BMR. These include body temperature, age, sex, race, emotional state, climate and circulating levels of hormones like catecholamines (epinephrine and nor epinephrine) and those secreted by the thyroid gland. The factors affecting BMR is briefly discussed below:

1. Genetics (Race) :- Some people are born with faster metabolism and some with slower metabolism. Indians and Chinese seem to have a lower BMR than the Europeans. This may as well be due to dietary differences between these races. Higher BMR exists in individuals living in tropical climates. Ex. Singapore.

2. Gender :- Men have a greater muscle mass and a lower body fat percentage. Thus men have a higher basal metabolic rate than women. The BMR of females declines more rapidly between the ages of 5 and 17 than that of males.

3. Age :- BMR reduces with age i.e. it is inversely proportional to age. Children have higher BMR than adults. After 20 years, it drops about 2 per cent, per decade.

4. Weight :- The heavier the weight, the higher the BMR, ex. the metabolic rate of obese women is 25 percent higher than that of thin women.

5. Body surface area : 1 This is a reflection of the height and weight. The greater the body surface area factor, the higher the BMR. Tall, thin people have higher BMRs. When a tall person is compared with a short person of equal weight, then if they both follow a diet calorie-controlled to maintain the weight of the taller person, the shorter person may gain up to 15 pounds in a year.

6. Body fat percentage :- The lower the body fat percentage, the higher the BMR. The lower body fat percentage in the male body is one reason why men generally have a 10 - 15% higher BMR than women.

7. Diet :- Starvation or serious abrupt calorie-reduction can dramatically reduce BMR by up to 30%. Restrictive low-calorie weight loss diets may cause BMR to drop as much as 20%. BMR of strict vegetarians is 11% lower than that of meat eaters.

8. S.D.A. of food :- Food has a stimulating effect on BMR. If a person in a post absorptive state is given food, the BMR has been found to increase by about 8%. This is known as Specific Dynamic Action of food.

9. Body temperature/health :- For every increase of 0.5^0C in internal temperature of the body, the BMR increases by about 7 percent. The chemical reactions in the body actually occur more quickly at higher temperatures. So a patient with a fever of 42^0 C (about 4^0 C above normal) would have an increase of about 50 percent in BMR. An increase in body temperature as a result of fever increases the BMR by 14 - 15% per degree centigrade which evidently, is due to the increased rate of metabolic reactions of the body.

10. External temperature :- Temperature outside the body also affects basal metabolic rate. Exposure to cold temperature causes an increase in the BMR, so as to create the extra heat needed to maintain the body's internal temperature. A short exposure to hot temperature has little effect on the body's metabolism as it is compensated mainly by increased heat loss. But prolonged exposure to heat can raise BMR.

11. Glands :- Thyroxine is a key BMR-regulator which speeds up the metabolic activity of the body. The more thyroxine produced, the higher the BMR. If too much thyroxine is produced (thyrotoxicosis) BMR can actually double. If too little thyroxine is produced (myxoedema)

BMR may shrink to 30-40 percent of normal rate. Like thyroxine, adrenaline also increases the BMR but to a lesser extent. Anxiety and tension may not show on the face but they do produce an increased tensing of the muscles and release of nor epinephrine even though the subject is seemingly quiet. Both these factors tend to increase the metabolic rate.The anterior pituitary influences BMR through its thyrotropic hormone, the BMR being low in hypo-activity. and high in hyper-activity of the glands.

12. Exercise :- Physical exercise not only influences body weight by burning calories, it also helps raise the BMR by building extra lean tissue. (Lean tissue is more metabolically demanding than fat tissue.) So more calories are burnt even when sleeping.

13. Pregnancy :- The BMR is not changed during pregnancy. The higher value of BMR in late pregnancy is due to the BMR of the foetus.

14. Sleep :- The BMR in sleep is 5 % less than in the normal Basal Metabolic State.

15. Nervous tension :- Nervous tension during the test increase the BMR.

Significance of BMR

1. The determination of BMR is the principal guide for diagnosis and treatment of thyroid disorders.

2. If BMR is less than 10% of the normal, it indicates moderate hypothyroidism. In severe hypothyroidism, the BMR may be decreased to 40 to 50 percent below normal.

3. BMR aids to know the total amount of food or calories required to maintain body weight.

4. The BMR is low in starvation, under nutrition, hypothalamic disorders, Addison's disease and lipid nephrosis.

5. The BMR is above normal in fever, diabetes insipidus, leukemia and polycythemia.

3.2.4 Determination of Energy Metabolism During Work

The energy metabolism is profoundly influenced by physical work. The energy metabolism during work can be determined by using Max-Plank Respirometer.

Max Plank Respirometer

The instrument is portable and can measure directly the volume of expired air and pass on simultaneously a small quantity into a rubber bladder attached to it. The general principle of the method is as follows:

a. Measuring the volume of expired air during work for fixed periods of 5 to 10 minutes.

b. Collection of a sample of expired air for the analysis of O_2 and CO_2 contents.

c. Calculation of O_2 consumption and CO_2 output; and

d. Calculation of the energy output from the O_2 consumption using the factor 4.85 KCal per litre of O_2 consumed.

3.3 Energy Needs of Body

The energy requirements for adult men for various types of physical activity determined by Max Plank Respirometer are given the following table.

Grade of work	Mean of Calorie requirements	Range (KCal/hr)
Sleep	60	–
Basal Metabolism	65	–
Sitting at rest	75	–
Standing	85	–
Very light work	120	100 - 140
Light work	225	150 - 290
Moderate work	375	300 - 440
Heavy work	525	450 - 590
Very heavy work	675	600 - 750

3.3.1 Specific Dynamic Action of Food

Rubner observed that carbohydrates, fats, and proteins fed to a fasting dog, stimulated the energy metabolism over the basal level to varying extents. For example, he found that in a fasting dog requiring 400 KCal, feeding of 100 g carbohydrates produces 425 KCal of heat. The extra heat produced is obtained by the oxidation of the tissue constituents and the animal will be in negative energy balance. This stimulating effect of carbohydrates, fats, and proteins on energy metabolism is called Specific Dynamic Action(SDA). The SDA of proteins is the highest (about 30%) while that of carbohydrates and fats is only 6% and 4% respectively. The SDA of a mixed diet containing 80 g carbohydrates, 10 g fat, and 10 g proteins is about 8%.

3.3.2 Energy Requirements During Work

The energy requirements during work can be can be calculated by adding together the energy required for

1. Basal Metabolism
2. Additional energy required for work.
3. Specific dynamic action of food.

The requirements are influenced by

i. Age.

ii. Body size and weight.

iii. Type of physical activity.

iv. Climate.

v. Physiological state(pregnancy or lactation)

The recommended energy allowances of Nutrition Expert Group of ICMR is given in the following table.

	Particulars	Type	Kcal
Man (55kg)		Sedentary work	2,400
		Moderate work	2,800
		Heavy work	3,900
Woman(45kg)		Sedentary work	1,900
		Moderate work	2,200
		Heavy work	3,000
		Latter half of pregnancy	+300
		Lactation	
Infants:Under 1 year	0 - 6 months		120/kg
	7 - 12 months		100/kg
Children	1 - 3 years		1,200
	4 - 6 years		1,500
	7 - 9 years		1,800
	10 - 12 years		2,100
	13 - 15 years(Boys)		2,500
	13 - 15 years(Girls)		2,300
	16 - 19 years (Boys)		3,000
	16 - 19 years (Girls)		2,200

3.4 Energy Balance of Body

3.4.1 Meaning of the Term

"Energy balance" is the relationship between "energy in" (food calories taken into the body through food and drink) and energy out (calories being used in the body for our daily energy requirements). This relationship, which is defined by the laws of thermodynamics, dictates whether weight is lost, gained, or remains the same. According to these laws, energy is never really created and its never really destroyed. Rather, energy is transferred between entities. We convert potential energy that's stored within our food (measured in calories or KCals) into three major destination; work, heat and storage.

When it comes to "energy out," the body's energy needs include the amount of energy required for maintenance at rest, physical activity and movement, and for food digestion, absorption, and transport. We can estimate our energy needs by measuring the amount of oxygen we consume. We eat, we digest, we absorb, we circulate, we store, we transfer energy, we burn the energy, and then we repeat.

Why Energy Balance is Important

There's a lot more to energy balance than a change in body weight. Energy balance also has to do with what's going on in your cells. When you're in a positive energy balance (more in than out) and when you're in a negative energy balance (more out than in), everything from your metabolism, to your hormonal balance, to your mood is impacted.

Our energy balance is regulated and monitored by a rich network of systems. There's a complex interplay between the hypothalamus, neural connections in the body and hormone receptors. Information is received about energy repletion/depletion, the diurnal clock, physical activity level, reproductive cycle, developmental state, and acute and chronic stressors. Moreover, information about the acquisition, storage, and retrieval of sensory and internal food experiences are relayed. These signals can impact energy balance. Even the best spreadsheet skills will have trouble tracking that.

3.4.2 Negative Energy Balance

A severe negative energy balance can lead to a decline in metabolism, decreases in bone mass, reductions in thyroid hormones, reductions in testosterone levels, an inability to concentrate, and a reduction in physical performance. Yet a negative energy balance does lead to weight loss. The body detects an energy "deficit" and fat reserves are called upon to make up the difference. The body doesn't know the difference between a strict diet and simply running out of food. The body just knows it isn't getting enough energy, so it will begin to slow down (or shut down) all "non-survival" functions.

3.4.3 Positive Energy Balance

Overfeeding (and/or under exercising) has its own ramifications not only in terms of weight gain but in terms of health and cellular fitness. With too much overfeeding, plaques can build up in arteries, the blood pressure and cholesterol in our body can increase, we can become insulin resistant and suffer from diabetes, we can increase our risk for certain cancers, and so on. The relationship between the amount of calories we eat in the diet and the amount of energy we use in the body determines our body weight and overall health. The body is highly adaptable to a variety of energy intakes/outputs. It must be adaptable in order to survive. Therefore, mechanisms are in place to ensure stable energy transfer regardless of whether energy imbalances exist.

Factors That Affect Energy In

1. Calorie intake.
2. Energy digested and absorbed (90-99%).

Factors That Affect Energy Out

1. Work : Physical work (exercise and activity).
2. Heat :
   (a) Heat produced with physical work.
   (b) Heat produced via the thermic effect of food (TEF).
   (c) Heat produced by resting metabolism.
   (d) Heat produced: adipose creation.
   (e) Heat produced: adipose thermoregulation.
3. Storage :
   (a) Efficiency of work.
   (b) Efficiency of food metabolism.
   (c) Energy stored in adipose tissue.

3.4.4 How To Be Positive or Negative?

While necessary for fat loss, a negative energy balance can be uncomfortable. Being in a negative energy state can result in hunger, agitation, and even slight sleep problems. On the flip side, while necessary for muscle gain, a positive energy balance can be uncomfortable as well. Both extremes cause the body to get out of, well, balance. Accomplishing a negative energy balance can be done in different ways. Increasing the amount of weekly physical activity you participate in is one of the best options.

Creating a Negative Energy Balance

1. Build muscle with weight training (about 5 hours of total exercise each week) and proper nutrition.
2. Create muscle damage with intense weight training.
3. Maximize post workout energy expenditure by using high intensity exercise.

4. Regular program change to force new stimuli and adaptations.
5. Boost non-exercise physical activity.
6. Increase thermic effect of feeding by increasing unprocessed food intake.
7. Eat at regular intervals throughout the day.
8. Eat lean protein at regular intervals throughout the day.
9. Eat vegetables and/or fruit at regular intervals.
10. Incorporate omega - 3 fats.
11. Incorporate multiple exercise modes.
12. Stay involved with "life" outside of exercise and nutrition.
13. Sleep 7 - 9 hours each night.
14. Don't engage in extreme diets for risk of long-term overcompensation.
15. Stay consistent with habits.
16. Ignore food advertising.

Creating a Positive Energy Balance

1. Build muscle with weight training (at least 4 hours of intense exercise per week) and proper nutrition.
2. Create muscle damage with intense weight training.
3. Minimize other forms of exercise (other than high intensity and resistance training).
4. Limit excessive non-exercise physical activity.
5. Try consuming more shakes and liquids with calories.
6. Build in energy dense foods that don't cause rapid satiety (nut butters, nuts, trail mix, oils, etc.).
7. Eat at regular intervals throughout the day.
8. Incorporate additional omega - 3 fats.
9. Take advantage of peri-workout nutrition, with plenty of nutrients consumed before, during, and after exercise.
10. Sleep 7 - 9 hours per night.
11. Stay consistent with habits.

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