Lecture 3: Energy and Nutritional Value of Foods
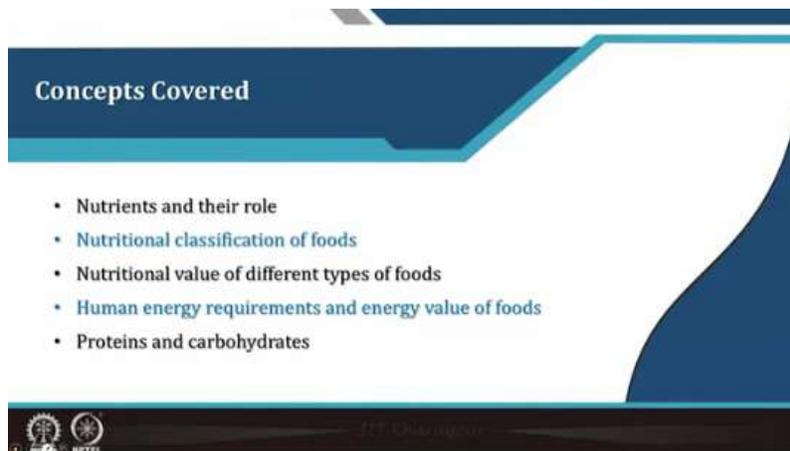
Hello everyone, Namaste.

In this third lecture today, we will talk about the energy and nutritional value of foods.

The concepts that we will discuss today include nutrients and their role, and the classification of food based on their nutrients. Then we will also discuss some important foods and their nutritional value, human energy requirements, and the energy value of major foods and towards the end, we will also devote some time to discussing carbohydrates and proteins, important aspects particularly from the nutrition and energy point of view.

So, as you know, in the earlier classes, we also discussed that food is very important for our healthy living. It is a material that provides nourishment to our body. Anything eaten or drunk that can be absorbed by the body to be used as an energy source as body-building material or for the regulation of body processes is food. Food is made up of a number of chemical components which are popularly called nutrients. These nutrients are required by the body in adequate amounts in order to grow, reproduce, and lead a normal, healthy life. So, when we actually take food, basically we take these nutrients in the form of foods which are present in the food in various chemical forms and there are over 40 essential nutrients which we consume or which we take by food, and these essential nutrients which are taken from food in the body, they are used by the body to generate literally thousands of compounds needed for a healthy life. So, the major nutrients in food include water, fat, carbohydrates, proteins, minerals, and vitamins.

It is a known fact now that we will discuss briefly what is the nutrition and health interplay, the interplay between food, nutrition, and health we are discussing in this module. So, the role of nutrition in maintaining our health is very important. Nutrition good nutrition is

essential for growth and development during fetal life and during childhood. It is necessary for the maintenance of optimum health and efficiency during adult life. Even pregnant and lactating mothers require more protein and nutrients for healthy babies. So, these nutrients are essential for the proper growth and development of the body. Good nutrition enhances healing and improves resistance towards infection. If we are not taking the required nutrients in the proper amount, it may lead to specific deficiency diseases and this deficiency leads to nutritional deficiency diseases like malnutrition and blindness. Incidence of prematurity, stillbirth, and so many other issues, which we will also discuss later. Then, even malnutrition and overnutrition cause critical diseases. They cause major issues, many issues like malnutrition or deficiency diseases that increase the rate of mortality. So, there are certain nutrients, etcetera, which are taken in excess or which are taken in less than the requirement, which may ultimately lead to morbidity or even mortality of the persons.
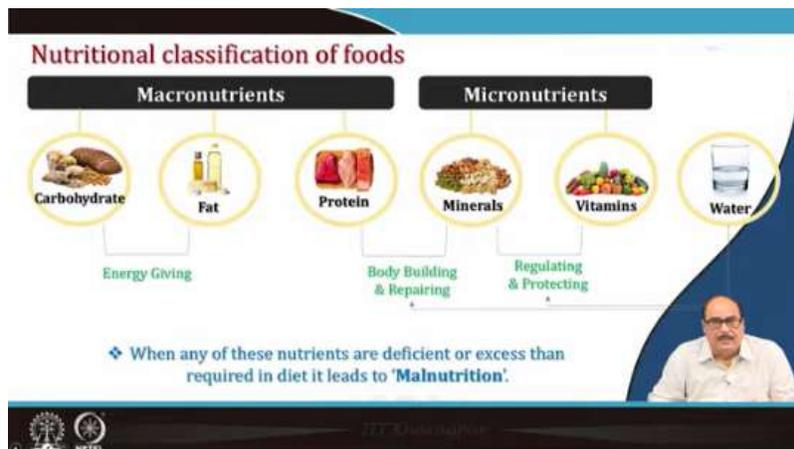
Then, let us talk about or classify the food based on its nutrient content or nutritional value. So, accordingly, these nutrients, which I told you earlier, that is water, protein, fat, carbohydrates, vitamins, minerals, etc. They are classified into two groups depending on the amount present in the food. So, they are macronutrients and micronutrients. So, carbohydrates, fats, and proteins are categorized as macronutrients, whereas minerals and vitamins, although they are present in smaller amounts, are very important from a health point of view. So, they are called micronutrients. Water is another important nutrient which again varies depending upon the food. So, these two nutrients, carbohydrates and fats, are mainly responsible for supplying energy to the body. Proteins and minerals are for bodybuilding and repairing, that is, nutrients that are. They build body cells, repair the worn or torn-out cells, etc., and these vitamins and minerals regulate the body processes and protect us from diseases, etc. Then, this water has a role in protecting and regulating

the body processes as well as in building and repairing the body cells. So, when any of these nutrients, as I told you earlier, are deficient or in excess, then the required amount in the diet leads to malnutrition.

The nutritional classification of the food is based on their role. That is, the role of these nutrients is chemical in our healthy daily life. That is, these nutrients you can see here in this table. They have, that is, water, protein, fat, all these nutrients. They have the energy-giving role, body-building and repairing role, and regulating and protecting role. So, the water, as I showed you in the earlier slide, also has a main function. M stands for main function, main role, and A is the additional role. So, the main role of water is in bodybuilding, repairing, regulating, and protecting the body's processes. Whereas protein's main role is body building and repairing, its additional role is energy giving as well as regulating and protecting the body processes. Fat's main role is energy giving, but it also plays some role; its additional role is bodybuilding and repairing; similarly, carbohydrates also have a main role in energy giving and an additional role in bodybuilding and repairing. The minerals' main role is body building and repairing as well as regulating and protecting. Meanwhile, vitamins' main role is to regulate and protect the body processes and protect it from health issues, but they play an additional role in bodybuilding and repair. So, accordingly, that is obviously the foods which are rich in water. Protein and minerals like meat, milk, eggs, fish, pulses, etc. They are categorized as body-building foods. So, if you are interested in building up your body, building up your muscles, etc., you must take the foods which are rich in these nutrients. Food's rich in carbohydrates and fats like cereal, sugar, fats, oils, oilseeds, butter, ghee—all these things are categorized as energy-yielding foods. Protective foods are foods that are rich in water, minerals, and vitamins, and they mostly include fruits and vegetables. So, you know that energy—it is very simple—you must have learned in your earlier classes in school or in college that it is the capacity to

work, and this energy is measured in kilocalories or kilojoules or calories, whatever you say. So, when we are taking any food, we will discuss later also that these foods are actually utilized in the body, metabolized, and broken down into smaller components, particularly carbohydrates, lipids, fats, or proteins. They are broken into smaller components and these are absorbed by the body and taken into different processes. Wherever it is required, they are converted into ATP or energy. So, accordingly, 1 gram of carbohydrate, if you take 1 gram of carbohydrate, particularly glucose because most of these carbohydrates are made up of glucose. So, finally, glucose is oxidized. Upon complete oxidation, 1 gram of glucose gives around 4 kilocalories of energy. 1 gram of protein, 4 kilocalories. And 1 gram of fat gives 9 kilocalories. So, you see, fat almost gives more than twice, two times the energy than that given by carbohydrates or proteins. The main reason for this is that these fats are stored in the body in adipose tissues in a more concentrated and anhydrous form. So, they contain more energy.

So, accordingly, we already discussed that energy-yielding foods are given here, like sugar, butter, rice, oil, potato, bread, etc. So, as I told you earlier, the digestive system when you consume foods, breaks down the nutrients, carbohydrates, proteins, and fats into their simpler forms like glucose, amino acids, or fatty acids respectively, and these are absorbed into the bloodstream and from where they go into the different processes like glycolysis and the TCA cycle and such other HMPs. And all those metabolic pathways, and the glucose and fatty acids are finally converted into ATP. That is called the energy molecule adenosine triphosphate, and these are converted into a form in the cell during the TCA cycle. So, ATP is the energy currency of the cell, you can say, and it is used for all bodily functions. Excess energy is stored in the body as fat or glycogen, meaning that if you are taking more amounts of carbohydrates and fats, and if you are not doing proper physical work, all this energy is consumed if it is not utilized in the body, then it is stored. That is,

the carbohydrates are stored in the form of glycogen, as well as these fats, which are stored in the adipose tissues, etc. And this is stored in the liver as well as in the muscles. So, energy-yielding foods are mostly rich in carbohydrates and fatty foods, and in the daily diet, about 60 percent of the energy comes from carbohydrates, and 30 percent normally from protein-based foods because these protein-based foods also contain that is grains, pulses, etcetera, they also contain some amount of lipids as well as carbohydrates, etcetera. So carbohydrate-containing foods mainly include cereals, pulses, roots, tubers, sugarcane, etcetera, whereas fats and oils are obtained from plant and animal sources like oilseeds, tree nuts, dairy cream, fatty fish, and so on.

Body-building foods help to grow and build the muscles, lack of these foods causes protein-energy malnutrition, in fact, PEM. Basically, if you are scarce in the supply of energy, then some of these proteins are utilized for energy purposes by the body, and therefore, it also results in protein. So, basically, jointly, it is called protein-energy malnutrition, and the diseases are kwashiorkor, marasmus, obesity, etcetera. Protein-containing foods include milk, eggs, fish, meat, pulses, oilseeds, and nuts; as was told earlier, 1 gram of protein provides 4 kilocalories of energy upon complete oxidation. Then, protective foods are rich in protein, vitamins, and minerals. They help regulate the body's functions, and protective foods are broadly classified into two groups: foods that are rich in certain vitamins and minerals. For example, green leafy vegetables and fruits and foods which are rich in vitamins, minerals, and proteins of high biological value such as milk, eggs, fish, legumes, and pulses, and fruits and vegetables are storehouses of minerals and vitamins also, they contain water, sometimes ranging from 12 to 15 percent to as high as 95 to 98 percent in the food. So, they are the major source, and it is well said that a banana a day keeps the doctor away, and an apple keeps the hospital away. So, one should take these fruits and vegetables to remain healthy and keep fit. So, earlier, we just discussed the lack of these

nutrients, whether both macronutrients and micronutrients; if you do not consume them in the proper amount, it leads to malnutrition or nutritional deficiency diseases.

Malnutrition

Macronutrients | Micronutrients

Carbohydrate | Fat | Protein | Minerals | Vitamins | Water

Protein-Energy Malnutrition (PEM)
- Marasmus
- Kwashiorkor
- Obesity

Micronutrient Malnutrition (MNM)
- Anemia
- Rickets
- Scurvy, etc.

So, basically, protein, fat, and carbohydrate deficiencies result in protein-energy malnutrition or sometimes called protein-calorie malnutrition, and the diseases are marasmus, kwashiorkor, and obesity. Whereas, micronutrient malnutrition, which is also known as hidden hunger, this is mainly because of the deficiency, less supply, or even sometimes oversupply of vitamins and minerals, and this causes anemia, rickets, scurvy, and many other diseases that are mainly because of the lack or less intake of the essential vitamins and minerals like vitamin A, vitamin D, mineral iron, zinc, and so on.

Proximate composition of major legumes

Legumes	Moisture (gm)	Protein (gm)	Fat (gm)	Minerals (gm)	Crude fibre (gm)	Carbohy drates (gm)	Energy Kcal	Calcium (mg)	Phosphorus (mg)	Iron (mg)
Black Gram, Dhal (Urd)	10.9	24.0	1.4	3.2	0.9	59.6	347	154	385	3.8
Bengal Gram, Whole (Chana)	9.8	17.1	5.3	3.0	3.9	60.9	360	202	312	4.6
Bengal Gram, Dhal	9.9	20.8	5.6	2.7	1.2	59.8	372	56	331	5.3
Bengal Gram, Roasted	10.7	22.5	5.2	2.5	1.0	58.1	369	58	340	9.5
Field Bean, Dry (Sem)	9.6	24.9	0.8	3.2	1.4	60.1	347	60	433	2.7
Cowpea (Lobia)	13.4	24.1	1.0	3.2	3.8	54.5	323	77	414	8.6
Horse Gram, Whole (Kulthi)	11.8	22.0	0.5	3.2	5.3	57.2	321	287	311	6.77
Green Gram, Whole (Mung)	10.4	24.0	1.3	3.5	4.1	56.7	334	124	326	4.4
Green Gram, Dhal	10.1	24.5	1.2	3.5	0.8	59.9	348	75	405	3.9
Khesari, Dhal	10.0	28.2	0.6	2.3	2.3	56.6	345	90	317	6.30
Moth Beans	10.8	23.6	1.1	3.5	4.5	56.5	330	202	230	9.5
Lentil (Masoor)	12.4	25.1	0.7	2.1	0.7	59.0	343	69	293	7.58
Rajmah	12.0	22.9	1.3	3.2	4.8	60.6	346	260	410	5.1
Peas, Green (Matar)	72.9	7.2	0.1	0.8	4.0	15.9	93	20	139	1.5
Peas, Dry	16.0	19.7	1.1	2.2	4.5	56.5	315	75	298	7.05
Peas, Roasted	10.1	22.9	1.4	2.4	4.4	58.8	340	81	345	6.4
Soybean	8.1	43.2	19.5	19.5	3.7	20.9	432	240	690	10.4
Redgram, Dhal (Arhar)	13.4	22.3	1.7	3.5	1.5	57.6	335	73	304	2.7
Redgram, Tender	65.1	9.8	1.0	1.0	6.2	16.9	116	57	164	1.1

(Gopalan, et al., 1989)

National Institute of Nutrition

☐ Nutritional value of cereals, legumes & millets

So, let us give some time to discuss the nutritional value of certain major foods. So, first, we will take up the nutritional value of cereals, legumes, and millet. So, in this table, I have provided for your ready reference the major legumes, which we consume in our diet, like black gram, Bengal gram, Bengal gram dal, whole, roasted, etc., even green gram, cowpea, and all these things I am not going to read, and this is taken from the references also

provided. So, all the major nutrients present in these, like protein, fat, minerals, crude fibres, carbohydrates, and their energy value in kilocalories and micronutrients like calcium, phosphorus, and iron, are given. So, as you can see, in general, these legumes contain moisture content. From around 8 per cent to as high as about 12 to 13 per cent in dry legumes and pulses, but tender or green pulses, like tender red gram, may contain around 65 per cent moisture content, whereas green pea, popularly known as matar, contains moisture as high as 73 per cent or so. Similarly, protein, if you can see, all these legumes may contain protein; like in red gram, there is around 9.8%, in green pea, around 7.2%, but in all other dry legumes, the protein varies from around an average of 20 per cent or sometimes. In some cases, as high as 28 percent or 29 percent. Even soybean contains around 43 percent protein. Similarly, fats also you can see. It may vary; soybean contains protein as high as 19 percent and fat 19.5 percent. Similarly, total minerals in the gram, crude fibers are given, and energy value that you can see. nThey also have energy values varying from 116 to as high as 370 or 380 kilocalories per mole.

Proximate composition of major cereals

Cereals	Protein (%)	Fat (%)	Crude fiber (%)	Ash (%)	Starch (%)	Total dietary fiber (%)	Total phenol (mg/100 g)
Wheat	14.4	2.3	2.9	1.9	64.0	12.1	20.5
Rice	7.5	2.4	10.2	4.7	77.2	3.7	2.51
Maize	12.1	4.6	2.3	1.8	62.3	12.8	2.91
Sorghum	11	3.2	2.7	1.8	73.8	11.8	43.1
Barley	11.5	2.2	5.6	2.9	58.5	15.4	16.4
Oats	17.1	6.4	11.3	3.2	52.8	12.5	12
Rye	13.4	1.8	2.1	2.0	68.3	16.1	13.2
Finger millet	7.3	1.3	3.6	3.0	59.0	19.1	102
Pearl millet	14.5	5.1	2.0	2.0	60.5	7.0	51.4
Proso millet	11	3.5	9.0	3.6	56.1	8.5	-
Foxtail millet	11.7	3.9	7.0	3.0	59.1	19.11	106
Kodo millet	8.3	1.4	9.0	3.6	72.0	37.8	368

Similarly, you can see on this side the nutritional value or composition of major cereals. They again may vary; their protein content in cereals varies from about 7.3 percent in millets, About 7-7.5 percent in rice and then as high as about 17 percent in oats. About 12 to 14 percent in wheat, 12 percent in maize, and so on. Even you can see that millet, like pearl millet, has about 14.5 percent, Foxtail millet 11.7 percent, etcetera; they have a good amount of protein. Similarly, fat also they have about 2 per cent to as high as 6 per cent or 7 per cent protein varies in them. Then, according to that, they also have a good source of crude fibers. In all these cereals, the crude fibre content in pearl millet is around 2%, whereas, in proso millet, it is 9%. In Kodo millet, again, 9 percent. So, they contain oats, which have 11.3 percent. Similarly, ash content and starch. So, total dietary fibres contain a significant amount, ranging from about 3.7 per cent in rice to about 19 or 20 per cent in

foxtail millet. In Kodo millet, dietary fibre is 37.8 per cent. So, they have a very good amount, and these dietary fibres are also very important to keep us healthy because they aid in the excretion process in the body and in digestion. They help improve the digestion of various components inside the body. Also, you can say bioactive total phenol content, again here, pearl millet has a very high amount, that is 51.4 milligrams per 100 grams of total phenols. Even foxtail millet has 106, and Kodo millet has 368. Even wheat also has 20.5 milligrams per 100 grams of phenols. So, you see that these millets, etc., particularly, that is why they are called Sri Yana, and more and more emphasis is now being given to them as healthy foods. So, they contain amounts of these phenols, etc. They are bioactive components, and many of them have antioxidant and other properties.

You can say the approximate composition of the nutritional value of meat and its related products and then different types of meat sources like chicken breast, raw chicken breast, skinless chicken breast or beef, pork, turkey, etc. All these things have energy value as well as protein, and even vitamin B_{12}. One important thing is that in all these foods of animal origin, vitamin B_{12} is found, which is very, very important as an essential micronutrient for our body, particularly for the formation of red blood cells. So, vitamin B_{12} deficiency, if present, will lead to less absorption of iron in the body and less formation of blood cells, etcetera. So, it results in pernicious anaemia. So, that is one important aspect, which is that most animal products, meat, etc., carry a good amount of vitamin B12 along with other micronutrients like sodium, potassium, iron, zinc, and so on. They also contain saturated fats, and mostly the fats are saturated in there. The protein and energy values are given here; they have a good amount of protein and energy value.

Proximate composition of fish

❑ Nutritional value of fish

Fish species	Moisture	Protein	Lipid	Ash	Carbohydrate
Puntius sophore	70.65±0.33[a]	14.44±0.29[cd]	6.19±0.12[k]	4.29±0.11[c]	4.44±0.64[bc]
Chanda nama	74.19±0.27[e]	13.23±0.23[a]	2.87±0.09[g]	2.58±0.01[b]	7.13±0.40[d]
Parambassis ranga	76.95±0.21[e]	14.24±0.20[cd]	5.06±0.36[f]	3.08±0.09[c]	0.68±0.20[y]
Amblypharyngodon mola	74.68±0.09[cd]	16.75±0.12[e]	1.84±0.03[a]	1.93±0.09[a]	4.79±0.17[c]
Colisa fasciata	73.18±0.17[b]	13.86±0.09[bx]	4.79±0.18[f]	3.14±0.04[c]	5.03±0.41[c]
Botia dario	72.92±0.71[b]	14.59±0.26[d]	6.15±0.17[a]	3.13±0.03[c]	3.21±0.80[b]
Mystus vittatus	74.26±0.29[c]	13.33±0.29[ab]	3.84±0.29[c]	4.11±0.15[a]	4.46±0.39[bc]
Esomus danricus	75.58±0.19[d]	12.89±0.14[a]	3.83±0.19[c]	2.43±0.10[b]	5.28±0.11[c]
Lepidocephalichthys guntea	72.80±0.27[b]	14.10±0.14[cd]	5.81±0.10[a]	3.29±0.18[cd]	3.99±0.26[bc]
Magrognathus pancalus	75.12±0.40[cd]	16.53±0.06[e]	3.02±0.13[b]	3.58±0.05[d]	1.75±0.33[a]

If we look at the nutritional value of fish, again, different types of fish species are given. They contain, on average, around 70 to 75 per cent or 76 per cent of moisture content in different varieties of fish. The protein content varies, on average, from around 12 per cent to as high as 16 or 18 per cent in certain fishes. Similarly, lipids also vary from 2 to 8 or 10 percent. They contain a significant amount of yeast and also some amount of carbohydrates, etc. in some of them.

Nutritional value of egg

❑ Nutritional value of egg

Nutrient (unit)	Whole Egg
Weight	60g
Water (percentage)	65-68.5
Calories (kcal)	70
Protein (g)	6.3
Carbohydrate (g)	0.36
Total fat (g)	4.8
Polyunsaturated fat (g)	1
Monounsaturated fat (g)	1.8
Saturated fat (g)	1.6
Cholesterol (mg)	185
Choline (mg)	126
Vitamin A (IU)	270
Vitamin D (IU)	41
Vitamin E (mg)	0.5

This table gives you the nutritional value of an egg, that is, an egg weighing 60 grams. It contains around 65 to 68.5 per cent water, provides around 70 calories of energy, and protein may be around 6 to 7 per cent, carbohydrates may be less, around 0.5 per cent or so, and fat content may be from 4 to 5 per cent depending upon the type of egg or eggs from different species. Polyunsaturated fat is 1%, monounsaturated fat is around 1.8%, and saturated fat is 1.6% or so. They also contain choline, vitamin A, vitamin D, vitamin E, and so on.

So now let us talk about human energy requirements. After knowing the nutritional value of food, let us discuss human energy requirements obviously, the science of nutrition is founded on the study of energy metabolism. The largest contribution to energy expenditure is the basal metabolic rate, which is popularly known as BMR. So BMR may be defined as the sum total of the minimum activity of all tissue cells of the body under steady-state conditions. It is also referred to as the minimal rate of energy expenditure compatible with life. There are direct and indirect methods for the measurement of BMR. Both direct calorimetry and indirect calorimetry methods can be used.

In the indirect calorimetry method, it is the most common method to measure BMR. It usually refers to the calculation of heat production using the measurement of gaseous exchange, notably oxygen consumed and carbon dioxide released. You can find out that the moles of CO_2 released per moles of oxygen consumed is known as the RQ.

$$RQ = \frac{moles\ of\ CO_2}{moles\ of\ O_2}.$$

So, the RQ value varies when carbohydrates, fats, and proteins are oxidized. Differences in their composition, that is the composition of these components, nutrients, determine the amount of oxygen required for complete oxidation. The RQ for carbohydrates is 1, which is the oxidation of glucose. It may be like glucose plus 6 oxygen molecules, one molecule of glucose is there, 6 molecules of oxygen are there, and upon complete oxidation, it gives 6 molecules of carbon dioxide and 6 molecules of water, and also ATP.

Fats require more oxygen than carbohydrates for combustion as the fat molecules contain a lower ratio of oxygen to carbon and hydrogen. So, two molecules of, if you say here, a fat $C_{57}H_{100}O_6$, it takes 163 molecules of oxygen and finally gives 114 molecules of CO_2 and 110 H_2O and here, if you divide that, then

$$RQ = \frac{114}{163} = 0.70.$$

So, the RQ for fats is less than that of carbohydrates. The respiratory coefficient is 0.7. Similarly, you can find out for the protein also; its respiratory quotient (RQ) is 0.80. So, this table here, that is, it gives energy release from the starch, fat, and protein like that is the oxygen consumed per gram, that litre per gram, carbon dioxide produced litre per gram, respiratory quotient, energy release, and then kilojoule per gram of food as well as energy released kilojoule per gram per mole of oxygen consumed, and these values are provided here. So, this gives you quite a good idea about how much energy is released and what is the oxygen required to burn these carbohydrates and fats, etcetera, and accordingly, what is their RQ value.

Estimation of energy requirement

- One practical use of BMR is in the estimation of energy requirement for population groups and subsequently their food needs.
- FAO/WHO/United Nations University reported two main purposes of determining energy requirements
  - ✓ Prescriptive purpose i.e. for making recommendations
  - ✓ Diagnostic purpose i.e. assessment of adequacy or inadequacy of the food
- Harris and Benedict (1919) predicted BMR using the following equations.

  Male : h = 66.4730 + 13.7516 W – 5.0033 S – 6.7750 A

  Females h = 665.0955 + 9.5634 W + 1.8496 S – 4.6756 A

  Where, h = kcal/h
  W = Weight in kg   Kleiber–Brody equation
  S = Stature in cm
  A = Age in years   BMR (kcal/day) = 70 W 0.75

So, in the estimation of energy requirement in the body: One practical use of BMR is in the estimation of energy requirement for population growth and, subsequently, their role or their food needs. Even FAO, WHO, and the United Nations University reported two main purposes for determining energy requirements. One is the perspective purpose, that is, for making recommendations and then for diagnostic purposes, that is, for the assessment of adequacy or inadequacy of the foods. So, even Harris and Benedict predicted BMR using the equation for males $h = 66.4730 + 13.7516\,W - 5.0033\,S - 6.7750\,A$, whereas the same equation for females becomes $h = 665.0955 + 9.5634\,W + 1.8496\,S - 4.6756\,A$, where h is the kilocalorie per hour, W is the weight in kilograms, S is the stature in centimeters, and A is the age in years. Also, the BMR, that is, the Kleiber-Brody equation for

$BMR\left(\frac{kilocalories}{day}\right) = 70W^{0.75}$, where W is the weight of the body.

Total energy expenditure (TEE)

- BMR represents approximately 50–75% of TEE in adults, and is influenced by gender, body size, body composition and age.

  TEE = BMR + TEF + PA

- The percentage increase in energy expenditure over BMR due to TEF (thermic effect of food) which ranges from 8% to 15% depending on the composition of the food consumed.
- The most commonly used value for TEF is 10% of the caloric value of mixed meals consumed over a 24-h period.
- For proteins, DIT (dietary-induced thermogenesis) or TEF is 15 % which is maximum.
- Physical activity or exercise (PA) is the most variable of the components; it is also the only component that can be easily altered.
  - ❖ For pregnant women, additional energy requirement is approximately 77000 kcal.
  - ❖ During lactation, an additional energy of 675 kcal/day is required.

Total energy expenditure—let us talk about that. BMR represents approximately 50 to 75% of total energy expenditure in adults and is influenced by gender, body size, body

composition, and age. So, total energy expenditure (TEE)=BMR + TEF+ PA, where TEF is the thermic effect of food. That is the percentage increase in energy expenditure over BMR. It ranges from 8 percent to 15 percent depending upon the composition of the food consumed. The most commonly used value of TEF is 10% of the calorie value of mixed meals consumed over a 24-hour period. For protein, it is DIT, that is dietary-induced thermogenesis or TEF, which is 15%, the maximum. And PA represents physical activity or exercise. It is the most variable component, and it is also the only component that can be easily altered. So, for a pregnant woman, overall, about 77,000 or 280,000 kilocalories of energy is required during the entire period, during lactation, and additional energy of 675 kilocalories per day or so is required.

❑ Energy value – unit conversions

- Energy may be measured in many different ways (calories, ergs, joules, watts).

Unit	Joule	Calorie	kW-h	BTU
Joule	1	0.239	$2.78 * 10^{-7}$	0.000948
Calorie	4.18	1	$1.16 * 10^{-6}$	0.00397
kW-h	$3.6 * 10^{6}$	$8.6 * 10^{5}$	1	3412
BTU	1055	352	0.000293	1

Here, in this table, I have given you just energy unit conversions, like energy value can be measured in different units like calories or joules, etc. For example, you can see that 1 joule is around 0.239 calories; it may be about 2.78 into 10 to the power of minus 7 kilowatt-hours or 0.0000948 BTU. Or 1 calorie will become 4.18 joules, 1.16 multiplied by 10 to the power of minus 6 kilowatt-hour or 0.00397 BTU. Similarly, you can find out how much 1 kilowatt-hour will be in joules, calories, BTU, etc., or how much 1 BTU in terms of joules, calories, and kilowatt-hour can be calculated from this table.

So, the energy value of food, Especially the gross energy value as we discussed earlier also is when the food is consumed, it takes around and gives if the food is combusted in the calorimeter, etcetera when we want to determine the energy value of food. So, if you determine by burning the food in the calorimeter the energy generated is defined as the gross energy value. So, if the gross energy value of carbohydrates is 4.15, fat 9.4, and protein, it is 5.65 kilocalories per gram. Then, in our food, during the digestion process, some energy is lost So, digestible energy is basically 4 kilocalories per gram from the carbohydrate, 9 kilocalories from the fat and about 5.2 kilocalories per gram from the proteins. Then again when it is metabolized after digestion, these nutrients go into the bloodstream and their metabolic process, then there is certain energy lost in the urine and finally for the body, you get that metabolized energy about 4 kilocalories per gram, 9 kilocalories per gram from fat and 4 kilocalories per gram from both protein and carbohydrate. So, you can say that the digestibility of most foods is high. On average, 97 percent of the ingested carbohydrates, 95 percent of ingested fats, and 92 percent of the ingested proteins are absorbed by the human gut. So, metabolizable energy represents the potential energy available to the human body when foods are ingested. So, accordingly, when you are calculating, when you are formulating any food on the basis of their energy requirements, etcetera, these parameters must be taken into consideration.
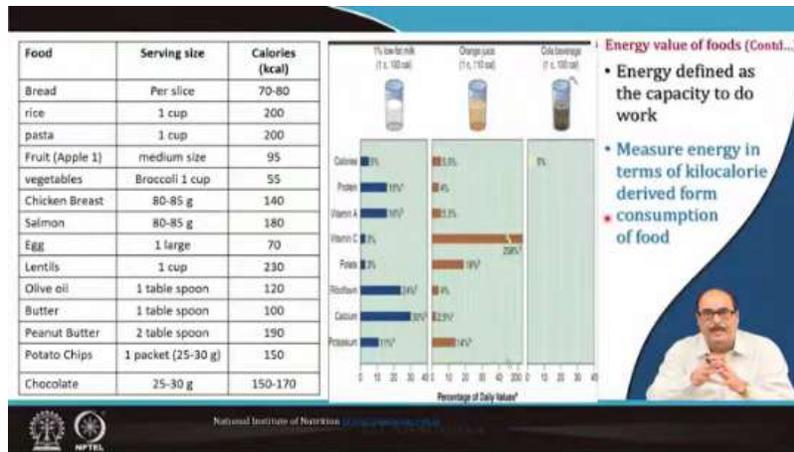
Here in this slide, again given the energy value of certain foods on the basis of their calorie content like 1 percent low-fat milk, how many calories it will give, it will give around 5 percent calories, 16 percent protein, or orange juice, how much percentage of calories it provides, similarly cola beverages, etc. In cola beverages, since the sugar is used in their formulation to make it sweet, provides some energy; otherwise, it does not contain any. So, here a comparison is made like a bread per slice around 70 to 80 kilocalories of heat energy you can get from fruit, 1 apple you can get around 95 kilocalories from a medium-sized apple, olive oil, 1 tablespoon gives 120 kilocalories of heat energy, peanut butter may give around 190 kilocalories, potato chips, 150 kilocalories of heat energy, pasta gives 200 kilocalories, and so on. So, this is the energy value, serving size is also given, serving size and then you get the energy value provided by these.

Now, the proteins, you know, proteins are composed of amino acids, both essential and non-essential, and the amino acid composition dictates the biological value of the protein. That is, when we utilize this protein in the body, the biological value means what is the actual amount of the protein that is essential amino acids which are biologically available

for the body. So, proteins are hydrolyzed into amino acids during the digestion process and essential amino acids are those that cannot be synthesized by the body in adequate amounts. So, pure protein contains around 16 percent nitrogen. So, thus one gram of nitrogen corresponds to around 6.25 grams of protein, and that is why, in the calculation of protein, the determination of protein, we determine nitrogen in the Kjeldahl method, etc. and that is multiplied by 6.25. So, the nitrogen value of cereals should be multiplied by 5.7 sometimes, and milk by 6.36 to get the protein content and that exactly depends upon the nature of the essential amino acids present amino acids present in their protein and their total nitrogen content.

❑ **Digestibility of proteins**

- The presence of fiber and polyphenols and the influence of high-temperature processing may affect the digestibility of proteins.
- Digestibility (DC) may be assessed by measuring the difference between intake and fecal losses.

$$\text{Apparent protein digestiblity (\%)} = \frac{I - F}{I} \times 100$$

$$\text{True protein digestiblity (\%)} = \frac{I - (F - Fk)}{I} \times 100$$

Where,
I is nitrogen intake
F is fecal nitrogen output on the test diet
F_k is fecal nitrogen output on a non-protein diet

Protein digestibility is very important, as we have talked about the nutritional value of protein. There are 4-5 parameters: digestibility, coefficient, protein efficiency ratio, net protein utilization, biological value, etc. So, the digestibility of protein, that is, the presence of fibres and polyphenols and the influence of high-temperature processing, may affect the digestibility of the protein. So, actually, the digestibility of a protein is assessed by measuring the differences between intake and fecal loss, that is, how much proportion is actually digested in the body. So, the *apparent protein digestibility*$(\%) = \frac{I-F}{F} \times 100$, and *true protein digestibility*$(\%) = \frac{I-(F-Fk)}{I} \times 100$. So, where I is the protein nitrogen intake, F is the fecal nitrogen output of the tested diet; that is, we take the animals that are given the non-protein diet. There is also some of the Nitrogen that may be synthesized from the body process, so that is subtracted, so that you can get the actual fecal nitrogen output of a protein diet as well as Fk is the fecal nitrogen output of a non-protein diet and these values are that the animals are taken as newborn animals, they are given this protein diet as a controlled non-protein diet and they are fed over a prescribed period of time for the experiment and their different data is taken and these are used to calculate these values. So, digestibility coefficients basically are the total nitrogen consumed minus fecal loss in the

test animal as well as minus fecal nitrogen lost in the control animal. Accordingly, true digestibility or correct protein digestibility is found.

Protein source	True digestibility
Egg	97
Milk, cheese	95
Meat, fish	94
Maize	85
Rice, polished	88
Wheat, whole	86
Oatmeal	86
Peas, mature	88
Soyflour	86
Beans	78
Maize + beans	78
Maize + beans + milk	84
Indian rice diet	77
Chinese mixed diet	96
Filipino mixed diet	88
American mixed diet	96
Indian rice + beans diet	78

Adapted from *Energy Requirements* (FAO/WHO/UNU, 2001).

Digestibility of proteins (Contd...)

- The digestibility of animal proteins is higher than vegetable proteins.

- The digestibility of diets from developing countries (due to the presence of a higher fibre and polyphenols content) is lower than that in western diets.

- The addition of a small amount of animal protein (for example, milk) enhances the digestibility of vegetable protein.

So, the digestibility of animal protein is generally higher than that of vegetable protein. The digestibility of diets from developing countries is lower due to the presence of higher fiber and polyphenol content compared to those in the Western diet. So, the addition of a small amount of animal protein, for example, milk, etcetera, enhances the digestibility of both vegetable proteins, so if the vegetable proteins are taken together with the animal protein, that is why the animal protein is taken, so it increases the digestibility. So here are the different values like egg protein, 97 per cent digestibility, milk cheese, 95 per cent, and even Indian rice, besan diet, bean diet, etcetera, 70. 8 per cent is digestibility, 77 per cent is the Indian rice diet. So, this table provides the digestibility coefficient or digestibility of very different commodities we use.

❑ **Estimation of protein quality**

❖ **Protein efficiency ratio (PER)**

- PER is the gain in body weight per gram of protein consumed.

$$PER = \frac{\text{Gain in body weight}}{\text{Quantity of protein consumed}}$$

❖ **Biological value (BV)**

- BV is a simple measure of nitrogen retained for growth or maintenance divided by nitrogen absorbed.

Where,

$$BV = \frac{I - (F - F_0) - (U - U_0)}{I - (F - F_0)}$$

I is nitrogen intake
F is fecal nitrogen
U is urinary nitrogen
U_0 and F_0 are urinary and fecal nitrogen output on a non-protein diet.

Then, the protein efficiency ratio is determined by the gain in body weight per gram of protein consumed. So, for animals which are taken for the experiment, initially their body

weight and then during the entire experimental period, what is the total amount of protein given to them and what is the body weight? So, from that, the protein efficiency ratio is determined. The biological value (BV) is a simple measure of nitrogen retained for growth or maintenance divided by the nitrogen absorbed, meaning the biological value is what actually happens after the process of DC or after the process of digestion is completed. Then, when metabolism occurs, they are utilized in the body, at least biologically. When it is absorbed, that is, what is the proportion that is actually absorbed into the bloodstream?

$$BV = \frac{I - (F - F_0) - (U - U_0)}{I - (F - F_0)}$$

So, I and F are the same. F_0 is for the control, and then U becomes the urinary nitrogen, that is the after metabolism, etc., which is not utilized by the body, it is excreted through the urine, so that is how much nitrogen is removed through the urine from in the test animal as well as in the experimental animals, that is also taken into consideration here while calculating the biological value.

Then, net protein utilization, another NPU, and NPU combines both BV and DC digestibility. NPU=BV× DC and that gives how much proportion of the protein that you have consumed and what proportion of that has actually been utilized by the body in meeting its requirements of the body, growth and other things. So NPU, you can say nitrogen retained and total nitrogen intake. This is the NPU of various foods like barley, which had 65 maximum net protein. You see milk, cow's milk. It is almost 94 percent, 98 percent for the egg. It is net protein utilization if you take the egg. So almost 98 per cent of this protein is utilized in the body, whereas wheat is only about 40 per cent. It is utilized approximately, maize 50 per cent, and rice, which is net protein utilization, is 62 per cent. So, this NPU data is very important, particularly again when you are calculating a balanced diet, when you are calculating, preparing food, formulating foods, and you want to have

that yes or no, that from 100 grams of that particular food, how much protein should be given, how much protein if you want X amount of protein. So, you say that accordingly, that is taken into consideration, net protein utilization, you decide what should be in the earlier formulation, the total protein content. Then another parameter is the protein digestibility corrected amino acid score. PDCAAS, and while NPU is a full measure for protein quality, its practical application is limited by the need to be conducted on animals. PDCAAS is calculated taking into account the limiting essential amino acid in a particular protein. So, in 1991, they proposed this method, and PDCAAS is equal to the concentration of the most limiting digestibility-corrected amino acid in a test protein divided by the concentration of that amino acid in the 1991 FAO-WHO amino acid scoring reference pattern. So, from that, it gives, actually, it gives the major amount of the essential amino acids.

Here again, this shows how one can calculate the sample of PDCAAS calculation in food, etcetera. Like wheat, you can say it is wheat, chickpea, milk powder, etcetera, three commodities are taken, and in wheat, lysine is the essential amino acid. which is the most limiting essential amino acid and it contains a comparatively small amount of tryptophan and other sulphur-containing amino acids, and that is used. Like you see, protein, what is the protein? $\frac{A \times B}{100} = P$,

the total protein available, and then lysine, which is the limiting amino acid. That is, C is the lysine quantity present in that. Then what is the total protein? $(P \times C)$, and then similarly, total sulphur amino acid, $(P \times D)$, you get sulphur amino acid and threonine except for PEN. So, in this way, you can calculate, and then finally, what is the amino acid reference scoring pattern? amino acid scoring for the mixture divided by amino acid scoring for the mixture is the amino acid gram protein divided by reference pattern. So, in

this way, you can calculate, and finally, that is, there may be a score adjusted for digestibility, may be 0.85 multiplied by 0.86, and it gives around 0.73 or like 73 per cent with lysine limiting. That is why lysine limiting it may be 73 per cent or so in this way. So similarly, this is just to give an indication you can calculate the PDCAAS accordingly. This gives a fairly good idea about the essential amino acid content and how good the nutritional value of the protein is?

Then, similarly, for the carbohydrate, carbohydrates are a major source of energy for most humans around the world. For example, approximately 70% of the global population consumes rice, wheat, and corn. Starch is composed mainly in these carbohydrate-rich foods the starch is there, and there are two forms of starch polysaccharides, which are amylose linear and amylopectin branched; of course, the different detailed chemistry of all this we will discuss later in the coming weeks. But here I will basically discuss food. When we eat this, depending upon how it is utilized in our body, we get a higher glycemic index, that is, or similarly, a glycemic response or a low glycemic response or a high glycemic response, and it gives about the resistance that if you are taking a high GI food, that is the That is when you are consuming these carbohydrates, they are easily digested, and the blood sugar level will increase. So, you have to do active physical work, and if you are not doing that, that sugar may be released, and more blood sugar may result in the diabetic process. So, foods with greater amylose content have been shown to produce a lower glycemic response and have a lower GI. So, the area under the curve, that is AUC, is calculated by multiplying the average blood sugar response by the length of time over which it occurs. So, you can see here that is. So, by this, the AUC number is then compared to that of pure glucose. Similarly, you get the data for pure glucose, and the GI value is assigned based on this composition. The GI is classified as low, less than 55, low or equal
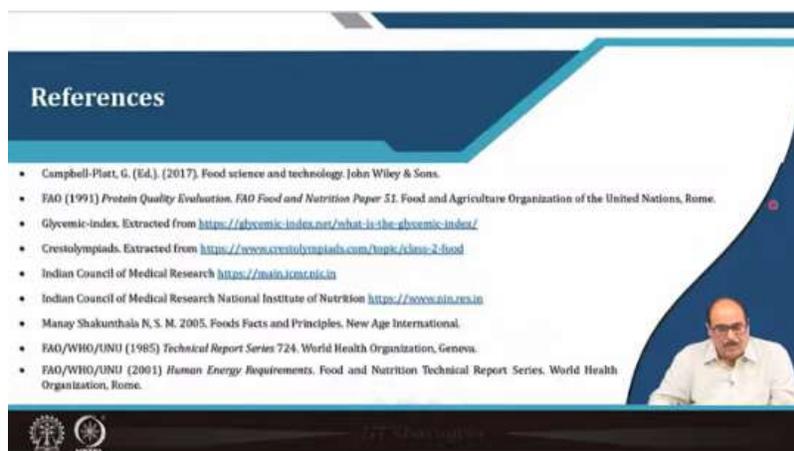
to, 56 to 69 is medium, and high is more than 70. So, for diabetic persons, etc., they should consume low GI food, that is, GI should be less than 55.
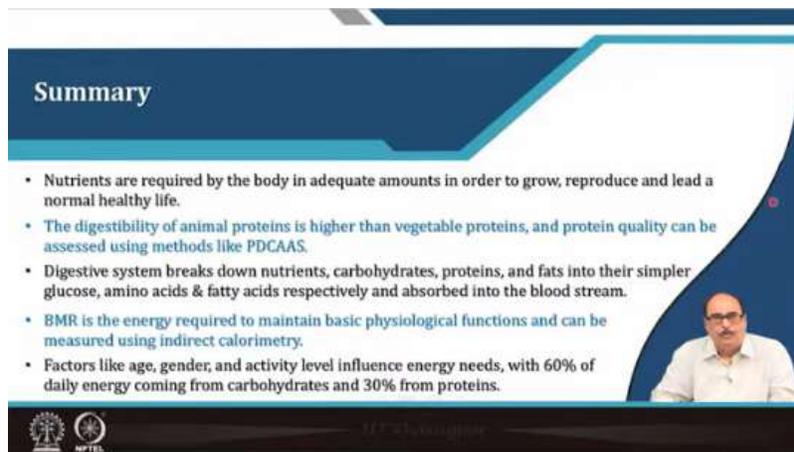
So finally, I will summarize this lecture by saying that nutrients are required by the body in adequate amounts in order to grow, reproduce, and lead a healthy, normal life. The digestibility of animal protein is higher than that of vegetable proteins, and protein quality can be assessed using methods like PDCAAS. The digestive system breaks down nutrients, carbohydrates, proteins, and fats into their simpler forms like glucose, amino acids, and fatty acids, respectively, and they are absorbed into the bloodstream. BMR is the energy required to maintain basic physiological functions and can be measured using direct or indirect calorimetry. Factors like age, gender, and activity level influence energy needs, with 60% of the daily energy coming from carbohydrates and 30% from protein and protein-containing foods.

So, these are the references to this lecture.

Thank you very much for your patience. Thank you