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GLOBAL PROTEIN NUTRITION: ESSENTIAL AMINO ACIDS AVAILABILITY

**A thesis presented in partial fulfillment of the requirements of
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Abstract

Information on protein production and consumption by country and by food type is well known and accepted, and is available on the internet from FAOSTAT. However, this database contains no information about the nutritional value of those proteins and is not corrected for digestibility, so is not possible to identify where there may be insufficiencies of protein nutrition or of particular essential amino acids. In this work, the data from FAOSTAT is corrected for true protein digestibility values and amino acid composition of the main food protein types, to develop a model of protein nutrition that identifies current patterns of essential amino acid (EAA) availability in different countries.

It was found that a population lacking in total protein supply could still get all the required EAA in the required amounts if the consumed food pattern is designed properly. Forty countries were identified as having a lower protein supply than 56 g. per day per capita, but only 13 countries were estimated to receive an inadequate supply of essential amino acids. Lysine deficiency was most common in these 13 countries due to consumption of a high proportion of protein from cereals, which are a poor source of lysine, because of both composition and poor digestibility. Thus a greater quantity of low quality protein such as cereal protein is needed to meet the recommended requirement of all the essential amino acids, particularly lysine.

The impact of income and specifically rapid *per capita* income growth on diet over time and by different socioeconomic classes is studied for India. This study found that food distribution and ability to purchase nutritionally adequate foods was dependent on income of an individual person. Cereals continued to constitute the main category of food consumed in both rural and urban India. There were large rural-urban and inter-state differences in the monthly consumption of even the basic food items. Rural Gujarat was the only region in this study where inadequate supply of lysine was observed for the population in the all-Gujarat average figure, at 95.9%.

The nutritional requirement of elderly population, mainly increased RDA of protein intake and role of essential amino acids were studied, considering that

the proportion of population aged 60 or over will be 22% in 2050 compared to 11% in 2009. Different protein sources have been shown in the literature to stimulate muscle protein synthesis in varying degrees in elderly population. The most important factor was the amount of essential amino acids in the protein, in particular, leucine. Differences in digestibility and bioavailability of certain protein-rich foods may also influence muscle protein synthesis.

During the World Summit on Food Security in 2009, it was recognized that by 2050 there will a requirement to supply 70% additional food to the global population. One of the options to increase food supply and to decrease the environmental pressure of current food production system is to minimise the waste. It is also important to plan an integrated approach about agricultural innovation and population health which will help us to prepare a matrix to supply the nutritional quality of food to the future world. It was also concluded that cereals were the major source of protein and calories for nearly half of the world's population including China, India and sub-Saharan African countries. The improvement in the cereals would be helpful to close the inadequacy gaps in protein and essential amino acids in many countries by increasing the essential amino acids in plant crops with emphasis on lysine and leucine, e.g. by genetically modified food crops specific requirements to meet future demand for protein and EAA are described.

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1.0 Introduction

1.1 World hunger scenario

1.1.1 Hunger and the need for food

Every day, millions of people around the globe do not get enough food to eat and remain hungry. Hunger has been described to as “*the uneasy or painful sensation caused by a lack of food*” and “*the recurrent and involuntary lack of access to food*”(Anderson, 1990). There is no assurance that these hungry people will get the minimum required quantity of food on a daily basis. This unpredictability about where the next meal will come from is called ‘food insecurity’. The ‘Food and Agriculture Organization’ (FAO) of the United Nations defines food insecurity as:

“A situation that exists when people lack secure access to sufficient amounts of safe and nutritious food for normal growth and development and an active and healthy life” (FAO, 2000).

Following this definition, people are hungry if they do not get enough energy supply from food (fewer than about 1,800 kilocalories a day) or if the food is not of sufficiently high quality (containing essential nutrients). Hunger is usually referred to the discomfort associated with lack of food (IFPRI, 2010).

1.1.2 Hunger targets

Two main hunger targets are currently monitored by FAO. They are the World Food Summit target and Goal 1 of the Millennium Development Goals.

- During the World Food Summit in Rome (1996), the world leaders made the commitment to decrease the number of undernourished people to around 425 million by 2015 (considering 850 million undernourished people as the baseline during the period 1990-1992) (FAO, 2011).
- At the 2000 Millennium Summit in New York, this objective was reiterated when the eight “*Millennium Development Goals*” (MDG) were introduced. The first goal pertains directly to hunger, which is the fundamental global

issue of concern for FAO. It aims to reduce the number of people suffering from hunger between 1990 and 2015.

“Goal 1 of the Millennium Development Goals (MDG) calls for a reduction by half of the proportion of people suffering from hunger between 1990 and 2015. Rather than setting a definite number to be reached, this hunger objective therefore depends on the size of the future world population” (FAO, 2011, United Nations, 2010).

1.1.3 World hunger and under-nutrition status

According to the most recent FAO report, the total number of undernourished people in the world was estimated to be 1023 million in 2009, and it was projected to decrease by 9.6% to 925 million in 2010. The largest number of undernourished people live in the developing countries, mainly in the seven countries, Bangladesh, China, the Democratic Republic of the Congo, Ethiopia, India, Indonesia and Pakistan, and over 40 percent live in China and India alone (FAO, 2010a). The territory with highest number of undernourished people (578 million) continues to be ‘Asia and the Pacific’ (figure 1.1).

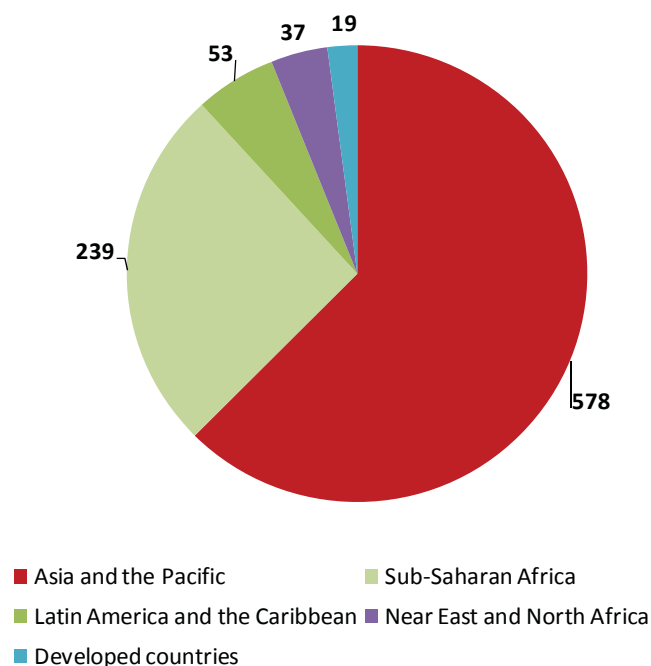


Figure 1.1 Undernourishment in 2010, by region (FAO, 2010)

1.1.4 Global Hunger index (GHI)

The International Food Policy Research Institute (IFPRI) has introduced the “Global Hunger Index” (GHI) tool to measure and track global hunger. Appendix 1.1 has the details of GHI calculation method and GHI scale details.

The 2010 world GHI showed some improvement over the 1990 world GHI, falling from 19.8 to 15.1. The index was reduced by 14 percent in Sub-Saharan Africa, by about 25 percent in South Asia, by 33 percent in the Near East and North Africa, by 40 percent in Southeast Asia and by 43 percent in Latin America and the Caribbean compared with the 1990 score (IFPRI, 2010) (figure 1.2).

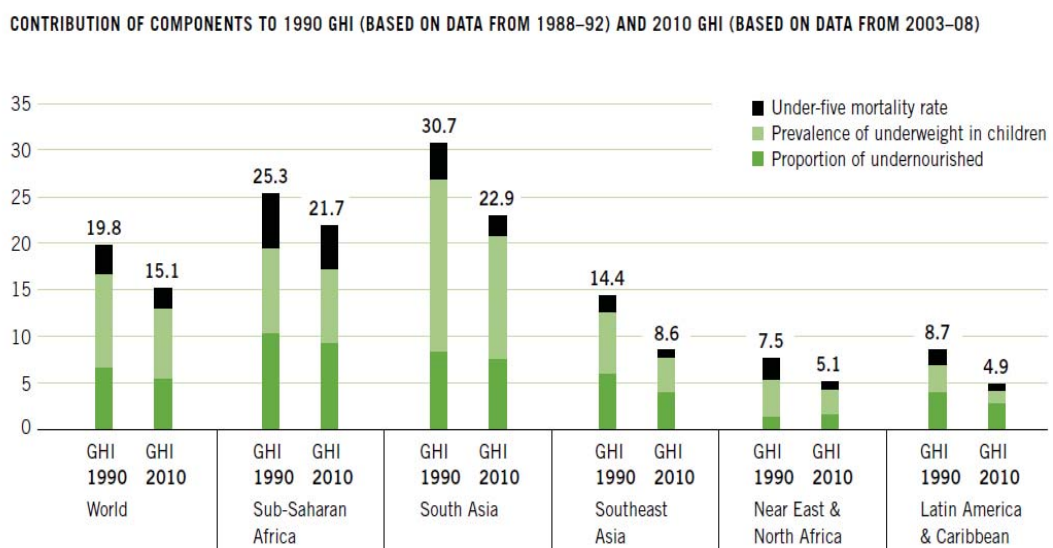


Figure 1.2 Global and regional trends of GHI (IFPRI, 2010)

1.2 World protein supply

1.2.1 Protein composition and bioavailability

An adequate dietary intake of protein is necessary to maintain normal body composition, growth and development. WHO defines the dietary requirement of protein as:

“Dietary requirement is the amount of protein or its constituent amino acids, or both, that must be supplied in the diet in order to satisfy the metabolic demand and achieve nitrogen equilibrium” (WHO, 2007).

Proteins are made up from 20 amino acids, and some amino acids are “essential” in that the human body is unable to make them. Lack of a full complement of essential amino acids will result in stunted growth and poor health. Animal proteins are generally much better nutritionally balanced than plant proteins. Some crop proteins are better than others, and in particular many cereals have serious deficiencies in their nutritional value (for example poor in lysine), while legumes are better. The digestibility of proteins is one of the significant factors to define dietary protein adequacy, with protein sources in typical Western diets having a digestibility of approximately 95%, while proteins from a typical Indian rice-based diet have a digestibility of only 77% (WHO, 2007).

1.2.2 World protein supply status

The global supply of total protein has increased in recent decades. Before 1981 protein supply in Africa was higher than Asia, but since that time in Asia protein supply has increased by 28.67 % and in 2007 it was 72.33 g/capita/day. In Africa the progress has been relatively slow, with an increase in protein supply of only 11.34% between 1981 and 2007. Of the global regions, ‘Australia+ New Zealand’ has had the highest supply of protein to its population for the last 47 years (except in 2001 and 2004) with a decreasing trend (figure 1.3). In the developed countries the major sources of proteins are meat and cereals, while in the developing countries, cereals are the only major source. Cassava (a starchy root, containing 1.6 g protein per 100 g cassava) is also a major source of protein in African countries.

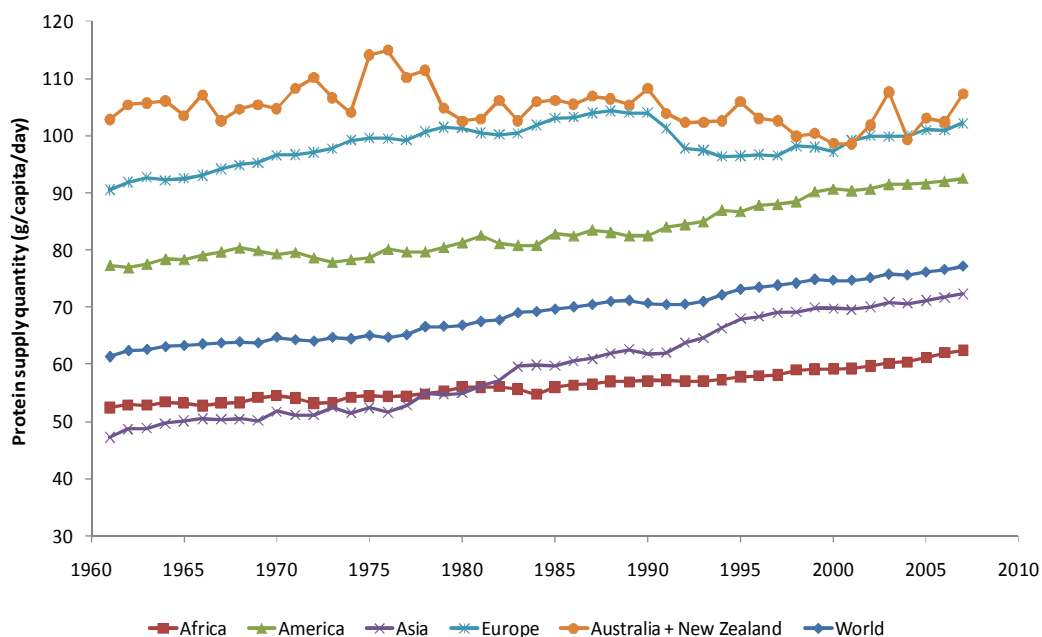


Figure 1.3 Global and regional protein supply trends (FAOSTAT, 2007)

1.2.3 Growing animal protein demand and environmental stress

In developing countries a major shift in the food intake pattern is occurring (Drewnowski and Popkin, 1997). It is estimated that the consumption of protein from animal sources will increase continuously in the world (Alexandratos, 2006, Kearney, 2010, Speedy, 2004). Figure 1.4 shows the trend of animal protein supply to the world and also describes the increased supply of animal protein mainly in the Asian continent. Considering the increase in global population and the projected increase in animal protein consumption there is a requirement to produce more animal protein to feed the world. But producing the required additional protein will put pressure on limited resources such as land, energy and water, as well as having an environmental cost (Kawashima et al., 1997, Pimentel and Pimentel, 2003). White (2000) reported that a vegetable-based diet causes less environmental pressure than an animal based diet (White, 2000).

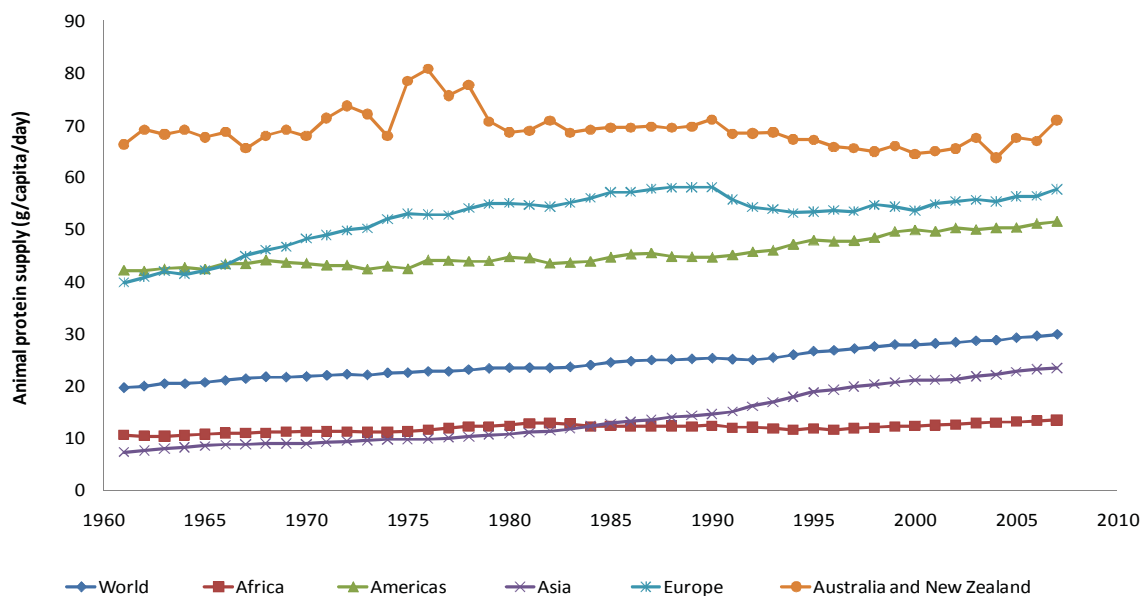


Figure 1.4 Global and regional animal protein supply trends (FAOSTAT, 2007)

For example to produce 1 kg boneless beef approximately 6.5 kg of grains (wheat, oats, barley, corn, dry peas, soybean meal and other small grains), 36 kg of roughages, and 155 liters of water (only for drinking and servicing) is required, for 1 kg boneless chicken meat it is 2 kg of grains (mainly soybean meal, wheat, corn, canola meal and mill screen) and 20 liters of drinking and servicing water. On the other hand each kg of wheat or barley production only needs 1300 liters of water (University of Twente, 2011). It is reported in studies that 6 kg of plant protein is required to yield 1 kg of meat protein on average (Gilland, 2002, Pimentel and Pimentel, 2003) or in terms of energy it is concluded that 25 kcal fossil energy is required per 1 kcal of meat protein production which is approximately 11 times greater than that for grain protein production, which is 2.2 kcal of fossil energy input per 1 kcal of plant protein produced (Pimentel and Pimentel, 2003).

1.3 Objective of the thesis and research questions

It is important to understand the existing and projected demand for protein in order first to understand where deficiencies in protein nutrition are occurring today, and how they might best be met, and second to develop appropriate

planning for production in the future to ensure adequate supply of all essential amino acids to all people. As a part of this broad objective, the aim of the study is to estimate the essential amino acid availability based on food and protein supply data together with known amino acid compositions and bioavailability of food proteins, and to look at the feeding needs of the growing ageing population. The following research questions address the objective of this project.

- Is the available supply of protein enough to meet all the requirements for essential amino acids in all countries?
- What is the role of income in access to food, and can increased income confirm the supply of quality protein?
- What is the need of a growing aged population in order to be healthy?

1.4 The FAO statistical database (FAOSTAT): food and protein supply

The Food and Agriculture Organization of the United Nations (FAO) compiles information on various aspects of food from all its member countries and these are available in www.faostat.fao.org website.

The FAOSTAT website provides data related to food and agriculture for the last 47 years, starting from 1961, for some 200 countries. The FAOSTAT website comprises 9 domains. The food balance sheet (FBS) domain covers national data on food availability for almost all commodities and for nearly all countries. Food balance sheets give a complete picture of food availability (including production, imports, stock changes and exports) and utilization (including export, losses during storage and transportation, animal feed and seed use, waste and food supplies available for human consumption) by commodity of a country on yearly basis. The per capita supply of each food item available for human consumption is then calculated by dividing the respective quantity by the population of the country. The per capita food supply data can also be retrieved from the FAOSTAT website in terms of dietary energy value, protein and fat content.

Although FAOSTAT is the most reputable resource for food supply in countries, a number of limitations may affect the usefulness of the data.

- As reported by WHO, FAOSTAT, being based on national data, does not provide information on the distribution of food within countries, or within communities and households (WHO, 2003a).
- To describe consumption of foods per capita of the population for a country, Food Balance Sheets do not represent the amount of food actually consumed and will result in an overestimation in food consumption compared with dietary surveys at the individual level. Individual dietary intake data in different countries are collected using diverse study designs, sampling frames, method of data collection. These factors can influence the actual food consumption data (Serra-Majem et al., 2003, Hawkesworth et al., 2010).
- Food Balance Sheets do not give any suggestion of the differences that may be present in the diet consumed by different population groups, e.g. different socio-economic groups and geographical areas within a country, nor do they provide information on seasonal variations in the total food supply (Kearney, 2010).
- When countries undertake national nutrition household surveys a number of factors can influence the data like cultural / festival seasons.
- In a few occasions semi-official or estimated data of food commodities are used to prepare the food balance sheets due to lack of actual information.

However, only the Food Balance Sheets data can show long-term trends in food availability for a large number of countries as they are available for every country in the world, for every food item (Kearney, 2010).

1.5 Quality of protein: based on essential amino acid composition and digestibility

Proteins are very complex nitrogenous organic compounds made up of amino acids joined by peptide bonds. Protein is required by the body for the growth, maintenance and repair of all cells. Protein is a major component of all muscles,

tissues and organs and is vital for practically every process that occurs within the body such as metabolism, digestion and the transportation of nutrients and oxygen in the blood. It is also necessary for the production of antibodies and enzymes (which are themselves proteins). Each protein is composed of 20 amino acids in many different combinations and sequences. These amino acids are α -amino acids. They have a carboxyl group and an amino group bonded to the same carbon atom. They differ from each other in their side chains. Most proteins are large molecules that may contain several hundred amino acids arranged in branches and chains (Nelson and Cox, 2005, Gutbrie et al., 1995, Hoffman and Falvo, 2004).

Amino acids may be classified in a variety of ways, including by structure, net charge, polarity and essentiality. However in a nutritional context essentiality is the most important basis for amino acid classification. Essential amino acids (EAA) cannot be synthesized by the body in quantities sufficient to meet the requirements for growth and maintenance, which means these amino acids must be provided in the daily diet. The essential amino acids are listed in table 1.1. Nonessential amino acids can be synthesized in the body if sufficient nitrogen is available in the daily diet. The term nonessential does not mean that the body does not need these amino acids but these amino acids are not essential components of the diet (Sareen S. Gropper, 2009, Gutbrie et al., 1995). Non essential amino acids are listed in table 1.1.

Originally, only 8 amino acids were recognized as essential, namely isoleucine, leucine, valine, lysine, methionine, phenylalanine, threonine and tryptophan (Rose, 1957). Subsequently histidine was recognized as an EAA (Gutbrie et al., 1995, WHO, 2007).

Table 1.1 List of essential and non essential amino acids (Sareen S. Gropper, 2009).

Essential amino acids	Non essential amino acids
Isoleucine	Alanine
Leucine	Glycine
Valine	Serine
Lysine	Cysteine
Methionine	Tyrosine
Phenylalanine	Aspartic acid
Threonine	Glutamic acid
Tryptophan	Arginine
Histidine	Asparagine
	Glutamine
	Proline

The dietary supply of nitrogen-containing compounds to the human body is predominantly protein, but not all protein consumed is available to maintain body composition and function. Bioavailability of consumed protein depends on digestibility, a measure of the dietary intake which is made available to the organism after digestion and absorption (Moughan, 2005). In chapter 2 “True protein digestibility” values of different protein sources are used to correct the FAOSTAT protein intake quantity information. The amino acid profile of different food items (vegetable as well as animal source) is used in this work to estimate the availability of essential amino acids to population.

1.6 Effect of income disparity on supply of food

Economic growth is normally accompanied by improvements in a country’s food supply and the gradual elimination of dietary deficiencies, thus improving the overall nutritional status of the country’s population (WHO, 2003a, Marmot, 2001). It is also recognized that income plays a vital role in determining the quantity and quality of the food intake of individuals and households (Chatterjee et al., 2010, Du et al., 2004).

In chapter 3 the influence of income on the household food supply pattern of India is studied. The availability of protein to the population in terms of essential amino acids (EAA) is estimated. India is a large developing country, with a relatively large number of poor people; its economy has been developing rapidly in recent years, and is already the fourth largest economy in the world. All these factors make India a useful candidate for this case study.

1.7 Population trends and nutritional requirements of the elderly

Recommended intakes of protein and requirements of essential amino acids for children and adults are well established (WHO, 2007). Recent studies have shown that elderly people need an additional supply of protein and certain essential amino acids compared with the adult daily requirement, to be healthy. Population projections indicate an increasing graying of the world's population, with the proportion of persons aged more than 60 years and above predicted to increase from 11% in 2009 to 22% in 2050 (UN, 2010). In chapter 4 the nutritional needs of this group are reviewed.

1.8 Thesis organization

The thesis is organized into seven sections, these being:

Chapter 1: Introduction

Chapter 2: Estimation of essential amino acid availability to the world population

Chapter 3: Impact of economic disparity on food consumption and nutrition in India: estimation of the availability of essential amino acids at different levels of total household expenditure

Chapter 4: Healthy aging and need of quality protein and essential amino acids

Chapter 5: Conclusions

References

Appendices

2.0 Estimation of essential amino acid (EAA) availability to the world population

2.1 Introduction

In this chapter we estimate the availability of EAA to the population of various countries. A number of countries with low per capita protein intake are studied to estimate the availability of EAA to their populations. FAOSTAT (www.faostat.fao.org) food balance sheet data is used as the key source of information for protein and food supply. This website has the data for most countries of the world for the past 47 years starting from 1961. In this chapter we have used information from 2007, as it is the latest complete data set available. The estimated EAA per day per capita data of countries are then compared against the recommended EAA values of adults as per the latest WHO/FAO/UNU report, published in 2007. Further correction for bioavailability of available protein sources is done using the “True protein digestibility” values in this chapter. In this chapter we have used the information of food and protein supply in various countries from food supply domain of FAOSTAT website and food supply domain is developed only from this food balance sheet domain.

Based on the information of FAOSTAT about food balance sheets, the FAOSTAT data can be considered as the most consistent information on this subject in most of the countries.

2.2 Methodology

2.2.1 Protein availability data

The apparent protein supply data needed in this work has been obtained from the FAOSTAT website. The original statistical data is supplied by each country or governmental organisation to FAO.

Food supply domain information is used here. This domain has two parts:

- Crops Primary Equivalent - 71 different vegetable food items are registered in this group. Every food item has a unique FAO code and

default composition pattern, termed as definition. For example, millet is one of the food items of this group. The item code of millet is 2517. The definition of default composition of millet is “79 Millet, 80 Flour of Millet; nutrient data only: 81 Bran of Millet” (FAOSTAT, 2007).

- Livestock and Fish Primary Equivalent - This group has 28 food items. Each food item also has a unique FAO code and definition of default composition. For example FAO code of egg is 2744 and the definition of default composition is “1062 Hen eggs, in shell, 1063 Eggs Liquid, 1064 Eggs Dried, 1091 Other bird eggs, in shell; nutrient data only: 916 Egg Albumine” (FAOSTAT, 2007).

Both modules of the food supply domain contain information of food, protein and fat supply quantity from each food item for 184 countries. From this section of the FAOSTAT database ‘per day per capita food and protein supply’ 2007 information for each food item was retrieved in terms of ‘g/capita/day’ for every country listed in this website (FAOSTAT, 2007).

Some food items among the 99 items which are listed in the food supply domain of FAOSTAT website are not a good source of protein due to very low content of protein. Based on protein content food items were classified into two groups. The groups are designated major protein source and minor protein source (table 2.1). In this chapter only major protein sources are considered. The percentage of protein in the major protein sources can also be found in table 2.1 (Souci et al., 2000).

2.2.2 Correction for protein bioavailability

The protein supply data of each food item for each country is further corrected for the bioavailability, as some quantity of consumed protein is not available for use in human body due to losses. The nutritional benefits of protein mainly depend on the quality of a protein. The quality of a protein is determined by assessing its essential amino acid composition, digestibility and bioavailability of amino acids (WHO/FAO, 1991, Schaafsma, 2000). A number of different measurement scales and techniques / methods have been used to assess the nutritional quality of proteins, like protein efficiency ratio (PER), protein

digestibility-corrected amino acid score (PDCAAS), indicator amino acid oxidation (IAOO) utilizing stable amino acid isotopes, biological value, true ileal amino acid digestibility, and true protein digestibility (Hoffman and Falvo, 2004, Elango et al., 2009, Rutherford et al., 2006, Pencharz and Ball, 2003, WHO, 2007, Schaafsma, 2000). This correction of protein aims to determine the capacity of food protein sources to satisfy the demand of amino acids.

In this study the 'True Protein Digestibility' (TPD)^{1,2} method has been applied to correct the bioavailability of protein because of the availability of information on a wide variety of food proteins (WHO, 2007). Values of TPD of major protein sources (in humans) can be found in table 2.1 (FAO, 1970, WHO/FAO, 1991).

"Vegetable others" and "pulses others" food items are classified as major protein sources (Table 2.1). Due to lack of specific amino acid profiles and true protein digestibility values of these items "vegetable others" and "pulses others" have been substituted with values for tomato and beans respectively as a surrogate estimate of EAA bioavailability. This is one of the assumptions in this chapter.

¹ Definition of 'True Protein Digestibility' (TPD) can be found in appendix 2.1

² True ileal amino acid digestibility values of some Indian raw food ingredients is tabulated in appendix 2.2, it is well recognized now that 'true ileal amino acid digestibility' is more accurate value than 'true protein digestibility' value (Rutherford et al., 2012). In this chapter Protein supply data is not corrected by this method due to lack of information about 'true ileal amino acid digestibility' values of major protein sources.

Table 2.1 Major protein sources and respective 'True Protein Digestibility' values (FAO, 1970, FAOSTAT, 2007, Souci et al., 2000, WHO/FAO, 1991)

Major protein sources			Minor protein sources
Food item	Protein content per 100 gram food (gram)	True Protein Digestibility value	Food item
Soyabeans	37.6	0.905	Beer
Groundnuts (Shelled Eq)	29.8	Not available	Beverages, Alcoholic
Sunflowerseed	26.5	0.819	Beverages, Fermented
Cheese	24.9	0.988	Cereals, Other
Bovine Meat	22	0.94	Citrus, Other
Pigmeat	22	0.94	Cloves
Pelagic Fish	21.5	0.94	Cocoa Beans
Beans	21.1	0.728	Coconut Oil
Nuts	20.6	0.848	Coffee
Mutton & Goat Meat	20.4	0.94	Cottonseed Oil
Poultry Meat	19.9	0.94	Fruits, Other
Freshwater Fish	19.9	0.94	Groundnut Oil
Offals, Edible	19.5	0.94	Maize Germ Oil
Marine Fish, Other	17.7	0.94	Molasses
Demersal Fish	16.5	0.94	Oilcrops Oil, Other
Crustaceans	15.9	Not available	Oilcrops, Other
Cephalopods	15.3	Not available	Olive Oil
Eggs	12.8	0.97	Olives
Oats	12.6	0.657	Palm kernel Oil
Wheat	11.7	0.909	Palm Oil
Sorghum	11.1	0.763	Pepper
Barley	10.6	Not available	Pimento
Millet	10.6	0.79	Pineapples
Molluscs, Other	10	Not available	Rape and Mustard Oil
Rye	9.51	Not available	Rice bran Oil
Maize	9.2	0.85	Roots & Tuber Dry Equiv
Rice (Milled Equivalent)	7.78	0.88	Roots, Other
Peas	6.55	0.876	Sesame seed
Coconuts - Incl Copra	4.63	Not available	Sesame seed Oil
Milk - Excluding Butter	3.43	0.969	Soya bean Oil
Milk, Whole	3.28	0.969	Spices, Other
Cream	2.31	Not available	Sugar Beet
Potatoes	2.04	0.89	Sugar Cane
Yams	2	Not available	Sugar, Non-Centrifugal
Dates	1.85	Not available	Sugar, Raw Equivalent
Sweet Potatoes	1.63	Not available	Sugar, Refined Equiv
Cassava	1.6	Not available	Sunflower seed Oil
Onions	1.18	0.965	Sweeteners, Other
Bananas	1.15	Not available	Tea
Plantains	1.15	Not available	Wine
Oranges, Mandarines	1	Not available	Aquatic Plants
Tomatoes	0.95	Not available	Fats, Animals, Raw
Whey	0.81	Not available	Fish, Body Oil
Lemons, Limes	0.7	Not available	Fish, Liver Oil
Grapes	0.68	Not available	Honey
Butter, Ghee	0.67	Not available	Meat, Aquatic Mammals
Grapefruit	0.6	Not available	Aquatic Animals, Others
Apples	0.34	Not available	Meat Meal
Vegetable others	Same as Tomato	Same as Tomato	Meat, Other
Pulses other	Same as Beans	Same as Beans	

Not all major protein sources were corrected for true digestibility value in this study due to lack of information. In the 'True Protein Digestibility value' column of table 2.1, the 'not available' term is used to identify these. So it is assumed that these major protein sources are 100% bio-available and the protein supply data for these sources are similar to the FAOSTAT data set. But this assumption is not practically possible. So these protein sources have been corrected by the below mentioned estimated true protein digestibility value to perform a sensitivity test in order to determine the effect of variability of these parameters.³

- TPD of Vegetable protein source: 0.80
- TPD of Animal protein source: 0.90

As a result two sets of estimated EAA data for selected countries are derived and these are available in the result and discussion part of this chapter.

2.2.3 Amino acid profile

The amino acid profiles of the selected major protein sources were obtained from the literature and reputable web sites (Chiou et al., 2000, Souci et al., 2000, FAO, 1970) and tabulated in table 2.2.

2.2.4 Linkage of protein supply data and amino acid data

The following methodology has been applied to estimate the availability of essential amino acids in selected countries.

- The supply of each amino acid for every major food item is calculated by multiplying the respective amino acid amount and food supply data which is downloaded from FAOSTAT website. For example lysine content in banana is 57 mg/100g banana. If banana supply is "X" gm in a country per capita per day then lysine supply from banana is $(57 * X)/100$ mg.

³ To perform sensitivity testing of the estimation of EAA method, these two values are assumed in this chapter to find gaps of the estimation method due to lack of information of 'True Protein Digestibility value' of all major protein sources. These values are assumed based on millet and meat TPD value.

Table 2.2 Amino acid content (mg of amino acid / 100 g food) of major protein sources (Souci et al., 2000).

Name of Food Item	Non Essential Amino Acids										Essential Amino Acids									
	Alanine	Arginine	Aspartic Acid	Glutamic Acid	Glycine	Proline	Serine	Cystine	Histidine	Isoleucine	Leucine	Lysine	Methionine	Phenylalanine	Threonine	Tryptophan	Tyrosine	Valine		
Apples	15	8	101	25	9	10	12	1	6	10	16	15	3	9	8	2	5	12		
Bananas	46	54	115	105	42	40	49	2	77	38	85	57	9	34	38	18	21	57		
Barley	560	560	680	2810	540	1260	540	220	210	460	800	380	180	590	430	150	390	580		
Beans	740	1490	2450	4330	950	980	1380	230	700	1490	2260	1870	260	1400	1150	230	970	1630		
Cassava	61	178	106	262	42	45	53	23	34	46	64	67	22	41	43	19	26	54		
Coconuts - Incl Copra	0	490	0	0	0	0	0	71	71	200	310	150	70	180	130	39	120	220		
Dates	0	40	0	0	0	0	0	0	40	60	62	44	22	51	49	0	0	76		
Grapefruit	20	40	105	42	10	47	26	2	6	10	15	19	3	10	11	4	7	14		
Grapes	30	50	84	150	20	23	32	11	25	5	14	15	23	14	19	4	12	19		
Groundnuts (Shelled Eq)	810	3460	3310	5630	1640	1430	1830	430	710	1230	2030	1100	310	1540	850	320	1190	1450		
Lemons, Limes	41	42	96	80	67	37	19	9	10	19	18	35	10	25	10	4	14	25		
Maize	790	420	620	1780	430	1020	520	140	260	430	1220	290	190	460	390	70	380	510		
Millet	1340	370	640	2240	330	1090	1680	150	190	550	1350	280	250	460	420	180	260	610		
Nuts	0	1980	0	0	0	0	0	500	390	1160	1440	750	330	900	700	450	680	1510		
Oats	720	850	1110	2900	780	870	740	320	270	560	1020	550	230	700	490	190	450	790		
Onions	0	160	0	0	0	0	0	0	13	19	33	57	12	35	20	19	41	28		
Oranges, Mandarines	29	73	122	66	23	189	43	3	12	20	32	39	8	20	20	7	13	33		
Peas	140	1060	550	990	170	140	280	130	220	540	670	610	100	400	450	100	350	520		
Plantains	46	54	115	105	42	40	49	2	77	38	85	57	9	34	38	18	21	57		
Potatoes	110	120	430	460	120	110	100	20	40	100	140	130	30	100	90	30	80	130		
Pulses, Other	740	1490	2450	4330	950	980	1380	230	700	1490	2260	1870	260	1400	1150	230	970	1630		
Rice (Milled Equivalent)	500	570	780	1580	410	420	410	110	170	340	660	290	170	390	280	90	260	490		
Rye	520	490	680	2570	500	1250	450	190	190	390	670	400	140	470	360	110	230	530		
Sorghum	880	380	710	2290	430	1550	420	100	220	580	1360	260	200	440	440	110	250	580		
Soybeans	1530	2360	3990	6490	1420	1820	1690	590	830	1780	2840	1900	580	1970	1490	450	1250	1760		
Sunflowerseed	1290	2200	2380	6400	1630	1070	1170	390	630	1370	1710	890	490	1260	910	310	650	1260		
Sweet Potatoes	0	65	0	0	0	0	0	25	29	68	84	66	28	79	68	28	71	110		
Tomatoes	0	18	121	337	18	16	28	1	13	23	30	29	7	24	23	6	12	23		
Vegetables, Other	110	120	430	460	120	110	100	20	40	100	140	130	30	100	90	30	80	130		
Wheat	510	620	700	4080	720	1560	710	290	280	540	920	380	220	640	430	150	410	620		
Yams	101	181	262	295	84	95	125	27	45	89	154	97	38	114	86	30	76	110		

Name of Food Item	Non Essential Amino Acids										Essential Amino Acids									
	Alanine	Arginine	Aspartic Acid	Glutamic Acid	Glycine	Proline	Serine	Cystine	Histidine	Isoleucine	Leucine	Lysine	Methionine	Phenylalanine	Threonine	Tryptophan	Tyrosine	Valine		
Bovine Meat	1690	1540	2340	4130	1560	1280	1140	280	850	1250	1950	2310	650	1060	1150	290	890	1320		
Butter, Ghee	0	0	0	0	17	69	42	0	19	45	74	54	19	36	34	9	36	51		
Cephalopods	441	613	12	179	371	796	24	147	214	20	39	31	47	11	37	0	17	39		
Cheese	760	900	1810	6620	470	3050	1580	210	800	1810	2520	2070	770	1450	980	290	1300	1810		
Cream	86	86	200	510	52	230	130	21	66	140	240	180	62	120	110	33	110	160		
Crustaceans	1120	1320	2000	2730	1120	820	800	220	350	790	1650	1990	550	670	850	120	570	800		
Demersal Fish	1240	1160	2070	3180	930	600	860	150	450	920	1600	1820	580	700	920	210	640	1060		
Eggs	890	890	1460	1810	530	590	1150	310	330	930	1260	890	450	800	710	230	590	1120		
Freshwater Fish	1670	1330	2220	3230	1630	1000	1010	290	660	1160	1770	2020	700	910	1110	260	720	1390		
Marine Fish, Other	1420	1240	2010	3130	940	820	990	250	520	990	1690	2050	600	840	970	240	710	1090		
Milk - Excluding Butter	140	130	290	820	80	380	210	31	92	220	340	270	86	170	160	49	180	240		
Milk, Whole	127	120	280	750	80	354	194	26	89	210	350	260	84	170	150	46	170	230		
Molluscs, Other	565	752	1117	1408	517	414	512	158	238	472	773	797	274	414	469	0	416	626		
Mutton & Goat Meat	1440	1440	2150	4300	1430	1020	1040	290	630	1210	1800	2000	560	920	1090	290	770	1180		
Offals, Edible	1280	1210	1985	2780	1270	1175	1045	295	720	1035	1825	1775	555	1110	965	290	705	1345		
Pelagic Fish	1610	1250	2880	3520	1170	880	1050	290	1090	1210	2170	2210	610	1050	1180	300	970	1420		
Pigmeat	1530	1530	2430	3910	1420	1210	1120	310	990	1270	1920	2200	720	980	1250	310	910	1420		
Poultry Meat	1440	1390	2270	3690	1400	1050	920	300	610	1290	1780	2040	640	910	1010	280	760	1180		
Whey	42	27	100	160	20	39	44	12	20	58	96	79	16	34	70	17	32	62		

Animal Protein Sources

-
- The percentage of each amino acid is then calculated.
 - Protein supply data for each country, from the FAOSTAT website, is corrected by TPD values in table 2.1.
 - Then corrected protein supply data is linked with the calculated percentage of amino acid values. This will generate the estimated bio-available amino acid supply from every major protein source.
 - Then the estimated amino acid content of all major protein sources is summed to get the availability of each amino acid.
 - The estimated essential amino acid values are then compared with recommended daily intake for adults (WHO, 2007), to identify the countries where the population has inadequate average intake.

As an example table 2.3 has the calculation details for Burundi.

The equation which is derived from the methodology is as below; this equation will generate the estimated availability of each amino acid.

$$S_a = \frac{\sum_1^n f_n * G_{n,a} * D_n}{RDI_a * Body\ Wt}$$

Where,

S = bio available supply of each amino acid as percentage of recommended daily intake

a = amino acid

f = food protein (g) supply per capita per day (from FAOSTAT)

G = percentage of each amino acid in each type of protein source

D = true protein digestibility value of protein source

n = number of food items

RDI = recommended daily intake of amino acid

Body weight = 70 kg (as assumed in this chapter)

Sensitivity test:

For all the selected countries a sensitivity test has been performed using the same methodology described here, only one additional step is performed there.

The step is:

Major protein sources, whose TPD values are not available as per table 2.2, are also corrected by the assumed TPD values as described in section 2.2.2 of this chapter.

2.3 Assumptions

A number of simplifying assumptions have been made to estimate the supply of EAA:

- Recommended EAA values for adults (WHO, 2007) are considered as the reference. The adult group has the lowest requirement for all EAA among all the age groups, as shown in table 2.4.
- For adults the recommended dietary allowance (RDA) for protein is 0.8 g protein / kg body weight /day as per the Food and Nutrition Board of the United States National Academy of Science (R. R. Wolfe 2008), again as per the latest 2007 WHO/FAO/UNU report the value is 0.83 g protein / kg body weight /day. And 0.66 g protein / kg body weight /day is considered as the mean requirement of protein for adults to maintain the basic requirements (WHO, 2007).

Here 0.8 g protein / kg body weight /day is assumed as the ideal protein requirement to each person in each country to estimate availability of EAA.⁴

- The average body weight of an adult person is assumed to be 70 kg in each country.
- The FAO statistical database (FAOSTAT), being based on national data, does not provide information on the distribution of food within countries, or within communities and households (WHO and FAO, 2003).

To simplify the estimation method it is assumed that each country has a uniform distribution of food and protein to each person.

This is a patently unrealistic assumption as economic disparities within a country are bound to affect its food consumption patterns. In the next chapter we will address this issue with data from one country.

⁴ In this study everywhere the recommended amount of protein needed to be consumed by an individual adult person (for both genders) is assumed to be 56 g. per day. (Considering the ideal body weight 70 kg and 0.8 g protein / kg body weight /day as the ideal protein requirement to each adult person as assumed in this chapter).

- Population and changing demographic patterns will change the daily requirement of protein and need of EAA (WHO, 2007). Here it is assumed that the whole population of each country comes under the adult group to simplify the estimation of EAA requirements.
- Out of 99 food items, available in FAOSTAT website, only 50 food items are assumed as the major source of protein to humans (Table 2.1), based on percentage of protein in the food items. And only these 50 identified food items are further studied to do the estimation of EAA. The other 49 food items (minor sources of protein) are not included in this study.
- The amino acid profile of 14 food items (assumed as major protein source to humans) is not available in the literature, so the amino acid profile of another food item in the same food group has been used as a surrogate estimate of EAA bioavailability. Appendix 2.3 has the detailed information.

Table 2.4 EAA requirement of children, adolescents, teenager, adults (mg per kg body weight per day) (WHO, 2007)

Essential Amino Acid	Age Years (1-2)	Age Years (3-10)	Age Years (11-14)	Age Years (15-18)	Adults
Histidine	15	12	12	11	10
Isoleucine	27	23	22	21	20
Leucine	54	44	44	42	39
Lysine	45	35	35	33	30
Methionine + Cystine	22	18	17	16	15
Phenylalanine + Tyrosine	40	30	30	28	25
Threonine	23	18	18	17	15
Tryptophan	6.4	4.8	4.8	4.5	4
Valine	36	29	29	28	26

2.4 Results & discussion

In this study from FAOSTAT website 2007 food and protein supply data in different countries is analyzed.

2.4.1 Protein

Total protein supply (including animal and vegetable protein) ranges from 22.05 g. per capita per day in the Democratic Republic of the Congo to 125.66 g. in Iceland per capita per day whereas the world average figure is 74.36 g. per capita per day. Per day per capita availability of vegetable protein ranges from 19.33 g. in Democratic Republic of the Congo to 70.23 g. in Egypt and animal protein availability per day per capita ranges from 2.72 g. in the Democratic Republic of the Congo to 90.66 g. in Iceland. On a global basis vegetable protein provides 60.7% of the world supply of edible protein. The cereal grains, in particular, account for a substantial proportion of the world's protein supply. On the other hand animal products contribute around 39.3% of the per capita availability of total protein (Figure 2.1)

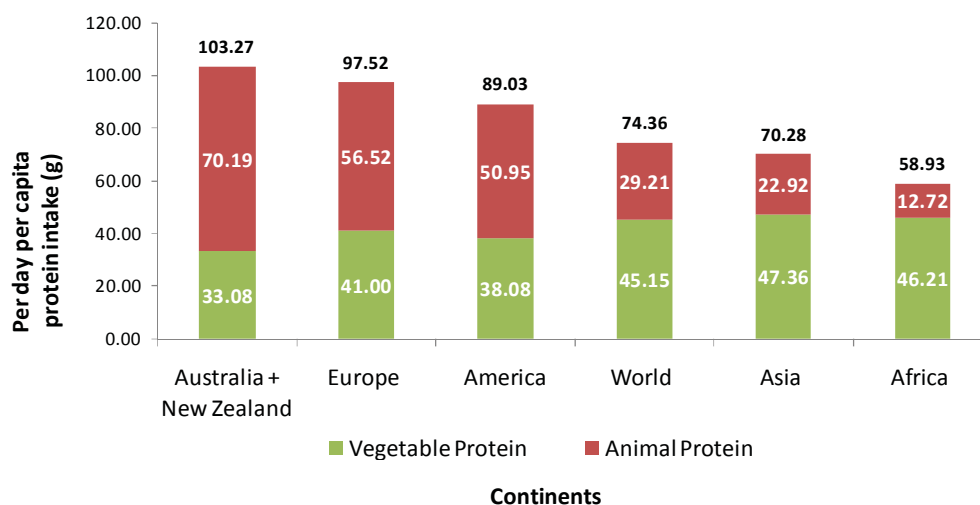


Figure 2.1 Protein supply patterns in world continents (FAOSTAT, 2007)

In Africa, total protein supply per capita per day is the lowest among all the continents (Figure 2.1). Within Africa the highest total protein intake is observed in northern Africa (83.58 g/day/capita) and it is lowest in middle Africa (34.32 g/day/capita). Considering 56 g. protein per day per capita as the recommended amount to be consumed by an adult person, protein deficiency can be considered to exist in the population of middle Africa and eastern Africa (Table 2.5).

People in developing countries have a higher proportion of vegetable protein in their supply (Table 2.5). Vegetable proteins are generally less digestible than animal proteins (Table 2.1), thus people in underdeveloped countries will need more protein to meet the required daily intake.

Forty countries are identified in this study where the protein supply is below the target value of 56 g/capita/day. Table 2.6 has the details of protein supply from major protein sources and availability of EAA in these countries.

Table 2.5 Protein availability in sub continents (FAOSTAT, 2007)

Continent	Per day vegetable Protein Intake (g)	Per day animal protein intake (g)	Per day total protein intake (g)	% of Vegetable Protein	% of Animal Protein
Africa + (Total)	46.21	12.72	58.93	78.42	21.58
Eastern Africa + (Total)	39.42	8.41	47.83	82.42	17.58
Northern Africa + (Total)	61.78	21.80	83.58	73.92	26.08
Southern Africa + (Total)	48.05	28.77	76.82	62.55	37.45
Western Africa + (Total)	49.72	9.80	59.52	83.53	16.47
Middle Africa + (Total)	27.20	7.12	34.32	79.25	20.75
Americas + (Total)	38.08	50.95	89.03	42.77	57.23
Northern America + (Total)	37.55	71.46	109.01	34.45	65.55
Central America + (Total)	45.19	36.93	82.12	55.03	44.97
Caribbean + (Total)	37.42	23.19	60.61	61.74	38.26
South America + (Total)	35.80	40.59	76.39	46.86	53.14
Asia + (Total)	47.36	22.92	70.28	67.39	32.61
Central Asia + (Total)	49.07	31.99	81.06	60.54	39.46
Eastern Asia + (Total)	51.89	34.19	86.08	60.28	39.72
Southern Asia + (Total)	44.69	12.02	56.71	78.80	21.20
South-Eastern Asia + (Total)	39.59	20.68	60.27	65.69	34.31
Western Asia + (Total)	56.79	28.19	84.98	66.83	33.17
Europe + (Total)	41.00	56.52	97.52	42.04	57.96
Northern Europe + (Total)	38.59	61.51	100.10	38.55	61.45
Southern Europe + (Total)	41.90	60.07	101.97	41.09	58.91
Western Europe + (Total)	35.49	63.50	98.99	35.85	64.15
Eastern Europe + (Total)	44.87	48.65	93.52	47.98	52.02
Australia and New Zealand + (Total)	33.08	70.19	103.27	32.03	67.97
World + (Total)	45.15	29.21	74.36	60.72	39.28

Table 2.6 Estimated EAA availability in selected countries (EAA values are in terms of percentage of availability against the recommended requirement of EAA of adult group)

Countries	Per day per capita total protein intake (g)	Per day per capita vegetable protein intake (g)	Per day per capita animal protein intake (g)	% of Vegetable Protein	% of Animal Protein	Histidine	Isoleucine	Leucine	Lysine	Methionine + Cysteine	Phenylalanine + Tyrosine	Threonine	Tryptophan	Valine
Democratic Republic of the Congo	22.05	19.33	2.72	87.66	12.34	77.3	63.6	60.1	48.2	64.0	88.8	73.9	84.9	58.2
Liberia	34.45	29.79	4.66	86.47	13.53	116.4	99.7	87.9	71.6	104.2	140.3	111.9	140.3	97.4
Mozambique	37.41	33.24	4.17	88.85	11.15	124.8	111.3	109.2	75.1	112.8	157.1	128.7	142.7	103.6
Haiti	40.51	32.89	7.62	81.19	18.81	134.8	120.5	112.1	87.5	109.6	169.5	134.6	142.3	111.0
Guinea-Bissau	41.82	34.2	7.62	81.78	18.22	128.8	120.4	118.8	79.4	119.9	204.5	133.3	155.3	115.4
Burundi	42.77	39.66	3.11	92.73	7.27	183.8	149.9	127.0	116.5	106.7	204.5	173.1	188.2	141.4
Angola	43.05	29.93	13.12	69.52	30.48	154.7	135.4	124.8	108.0	132.9	186.6	156.9	169.7	121.7
Central African Republic	43.11	29.73	13.38	68.96	31.04	149.2	128.8	119.4	107.5	116.8	174.3	152.2	161.5	115.6
Eritrea	43.19	38.55	4.64	89.26	10.74	110.5	123.3	127.3	63.1	103.5	147.9	130.0	136.4	101.7
Comoros	44.05	32.14	11.91	72.96	27.04	174.2	138.5	121.3	114.7	120.0	186.2	154.6	168.8	128.5
Côte d'Ivoire	44.42	36.3	8.12	81.72	18.28	158.2	134.8	124.3	100.9	135.7	195.9	156.9	194.4	130.3
Zambia	44.52	37.25	7.27	83.67	16.33	145.4	126.9	145.9	79.9	127.8	183.4	148.2	132.6	113.6
Uganda	45	34.42	10.58	76.49	23.51	191.1	155.2	136.5	124.2	128.3	208.1	178.1	203.2	144.5
Congo	46.69	31	15.69	66.40	33.60	166.1	140.0	117.9	118.9	143.2	188.4	161.0	188.4	126.6
Rwanda	46.96	43	3.96	91.57	8.43	180.5	160.3	135.2	122.5	114.5	216.8	181.7	202.0	149.0
Solomon Islands	46.98	31.79	15.19	67.67	32.33	180.7	167.4	139.0	133.0	166.7	243.7	196.0	231.5	165.1
Timor-Leste	47	34.01	12.99	72.36	27.64	163.2	139.1	136.9	105.1	136.5	195.3	162.5	157.5	129.7
Togo	47.24	41.35	5.89	87.53	12.47	146.8	136.2	143.1	89.0	125.4	188.4	154.9	154.8	121.5
United Republic of Tanzania	47.46	39.5	7.96	83.23	16.77	174.2	150.9	147.4	107.9	131.9	207.5	170.3	178.0	138.0
Madagascar	48.3	37.03	11.27	76.67	23.33	159.5	145.6	134.0	108.6	146.5	206.8	165.6	187.8	143.5
Bangladesh	49.12	41.34	7.78	84.16	15.84	144.1	142.7	131.8	98.7	145.6	205.4	159.5	181.8	143.7
Sierra Leone	49.5	38.81	10.69	78.40	21.60	163.3	147.3	132.2	113.2	137.4	208.7	163.6	182.6	140.6
Occupied Palestinian Territory	50.04	33.72	16.32	67.39	32.61	149.2	153.2	123.2	109.8	154.8	210.0	164.3	199.5	133.9
Dominican Republic	51.23	23.6	27.63	46.07	53.93	185.0	166.6	138.2	147.0	156.0	213.6	183.8	200.2	144.6
Guinea	51.32	42.92	8.4	83.63	16.37	168.6	150.6	135.6	112.6	144.0	217.0	170.4	202.0	149.2
Cameroon	52.27	42.63	9.64	81.56	18.44	182.6	156.2	153.4	112.6	134.0	208.4	176.4	183.7	140.2
Sri Lanka	52.33	37.85	14.48	72.33	27.67	179.2	166.9	146.4	124.5	163.7	233.6	181.9	209.7	156.8
Ethiopia	52.56	47.13	5.43	89.67	10.33	151.6	153.2	148.9	92.7	136.9	208.7	167.4	170.5	132.0
Tajikistan	52.71	41.5	11.21	78.73	21.27	152.9	149.4	127.9	98.0	161.1	219.9	163.0	201.9	132.2
Suriname	53.13	29.35	23.78	55.24	44.76	180.8	166.3	139.2	142.2	166.5	221.6	185.2	210.4	147.7
Zimbabwe	53.24	43.15	10.09	81.05	18.95	172.1	154.3	168.7	98.8	147.7	221.1	175.0	161.6	134.9
Gambia	53.3	38.72	14.58	72.65	27.35	158.7	154.0	152.6	106.0	149.8	201.7	169.8	197.4	139.8
Bolivia (Plurinational State of)	53.33	32.16	21.17	60.30	39.70	169.0	154.0	135.4	121.3	152.9	210.1	172.0	194.4	137.8
Yemen	53.5	41.87	11.63	78.26	21.74	155.1	154.6	140.9	99.1	154.3	208.5	166.5	191.0	132.6
Guatemala	53.89	38.64	15.25	71.70	28.30	175.3	161.8	164.1	115.2	151.8	224.9	181.4	171.1	141.1
Thailand	54.26	30.12	24.14	55.51	44.49	195.7	170.1	148.9	140.9	176.7	229.4	193.7	209.5	159.5
Democratic People's Republic of Korea	55.01	46.16	8.85	83.91	16.09	164.2	169.4	149.4	118.9	150.2	230.3	184.7	193.6	152.5
Indonesia	55.39	40.12	15.27	72.43	27.57	185.2	166.3	155.2	124.8	171.7	236.7	188.0	210.0	161.3
Malawi	55.95	51.46	4.49	91.97	8.03	185.4	158.0	178.7	101.9	139.9	229.2	182.9	162.9	143.1
India	55.98	45.84	10.14	81.89	18.11	162.5	167.1	147.9	111.9	142.5	232.9	179.0	209.4	153.5

2.4.2 Essential amino acids (EAA)

Among the 40 protein deficient countries, 13 countries are identified where the population has inadequate availability of EAA on a daily basis. Lysine deficiency is especially common in all the countries.^{5, 6}

The protein deficient 40 countries are tabulated in ascending order in Table 2.6 based on 'per day per capita protein supply'. Essential amino acids having supply lower than the requirement are in 'red font' in this table. Essential amino acids whose availability is below 110% are in 'blue font'.

From this table it can be interpreted that the total quantity of protein supply and essential amino acid availability are not directly related. The population in Yemen has an inadequate supply of lysine [$99.1 \% = (99.1 \times 30)/100 = 29.73$ mg/kg body weight/day] compared to the recommended amount to be taken i.e. 30 mg/kg body weight/day (WHO, 2007). On the other hand 21 countries having a lower per day per capita protein supply than Yemen are not deficient in any EAA (table 2.6). So EAA availability depends not only on the quantity of protein intake but also on the variety of food available for consumption. Eritrea is in 9th position in the table 2.6, but the entire EAA supply amount is lower than that of the first 8 countries. This observation supports the concept that quality of protein determines the availability of EAA, not quantity.

⁵ Lysine has a reactive side chain amino group which can react with reducing sugar and produce biologically unavailable lysine derivatives during heat processing of a food or during storage, this factor is not considered in the present study (Moughan, 2003). This factor can increase the number of countries having lysine deficiency in their daily diet. Bioavailability of amino acid for metabolic needs depends on the food matrix in which a protein is consumed. Digestive losses and structural changes of amino acids are caused by numerous anti nutritional factors in foods (Millward et al., 2008). This present study has not covered this aspect to estimate the EAA.

⁶ in this chapter both essential and non essential amino acids are estimated, but in the results and discussion only essential amino acids (EAA) are discussed.

It can also be interpreted from table 2.6 that a population lacking in protein supply can get all the required EAA in the required amounts if the consumed food pattern is designed properly. This finding reflects the comment of Elango et al. (2009) that optimal daily protein intake in the correct proportions will provide all the 20 amino acids (essential and nonessential amino acids) to meet the body's requirements for metabolic functions including intestinal integrity (Wang et al., 2008), modulation of gene expression (Palii et al., 2009), protein synthesis (Suryawan et al., 2009) and regulation of cellular signalling pathways (Flynn et al., 2009).

Burundi is an example of this. In Burundi the per day per capita protein supply from major protein sources is 42.77 g only and still there is a sufficient supply of all the EAA to the population. On the other hand the following countries have a greater supply of protein for consumption than Burundi and still there is a shortage of bio-available lysine: Eritrea, Zambia, Togo, Bangladesh, Ethiopia, Tajikistan, Zimbabwe and Yemen. Table 2.6 has the details of the protein supply and EAA availability of these lysine deficient countries.

2.4.3 Availability of essential amino acids in food items

The amino acid composition of foods varies greatly. Table 2.2 has the list of major protein sources and their amino acid profiles (Souci et al., 2000).

In cereals, such as rice and wheat, lysine concentrations are significantly lower compared to foods of animal origin. Again in legumes, such as peas and soybeans, methionine concentrations are significantly lower compared to animal foods. From this finding it can be interpreted that the nutritional quality of food proteins varies widely, with the animal foods being labelled as “high quality” protein sources when compared with plant proteins (Singh, 2002, Young and Pellett, 1994).

Thus an individual will need to take a greater quantity of low quality protein to meet the recommended requirement of all the essential amino acids.

In this study, lysine has been found to be the main limiting essential amino acid in many countries. Figure 2.2 shows the protein supply pattern of the 13 countries having inadequate supply of EAA (especially lysine) and compared with the protein supply pattern of Burundi. This graph shows that countries where cereals are the major source of protein may have a poor lysine supply (Young and Pellett, 1990). In figure 2.3 the total lysine and bio-available lysine (corrected for true protein digestibility) content of the major protein sources are shown (Souci et al., 2000).

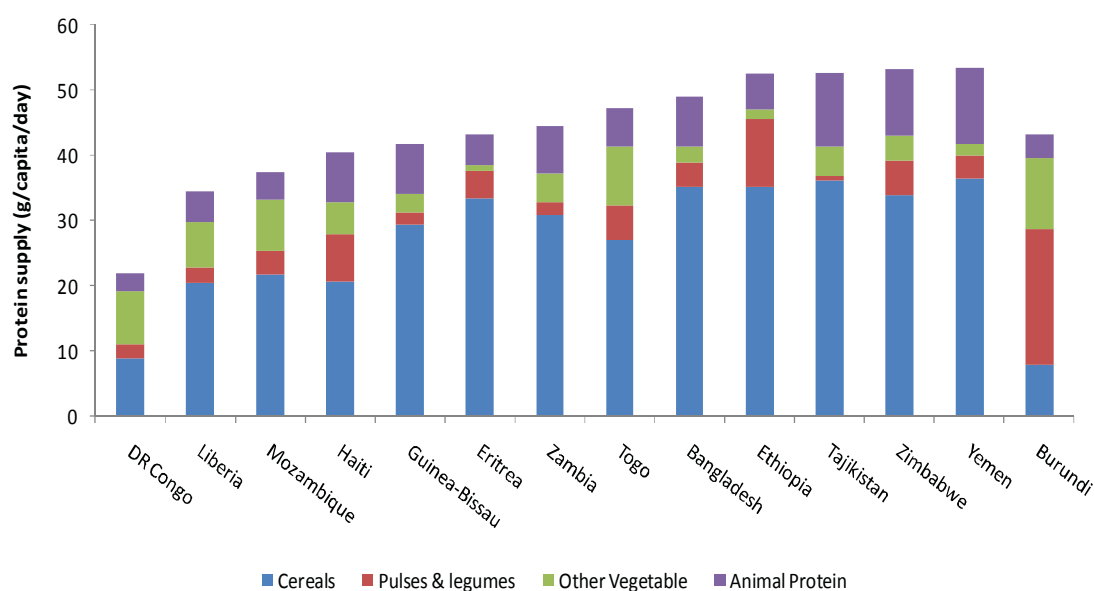


Figure 2.2 Protein supply patterns in countries (mainly lysine deficient) and comparison with Burundi.

g lysine in 100 g of protein vs. g bioavailable lysine in 100 g of protein

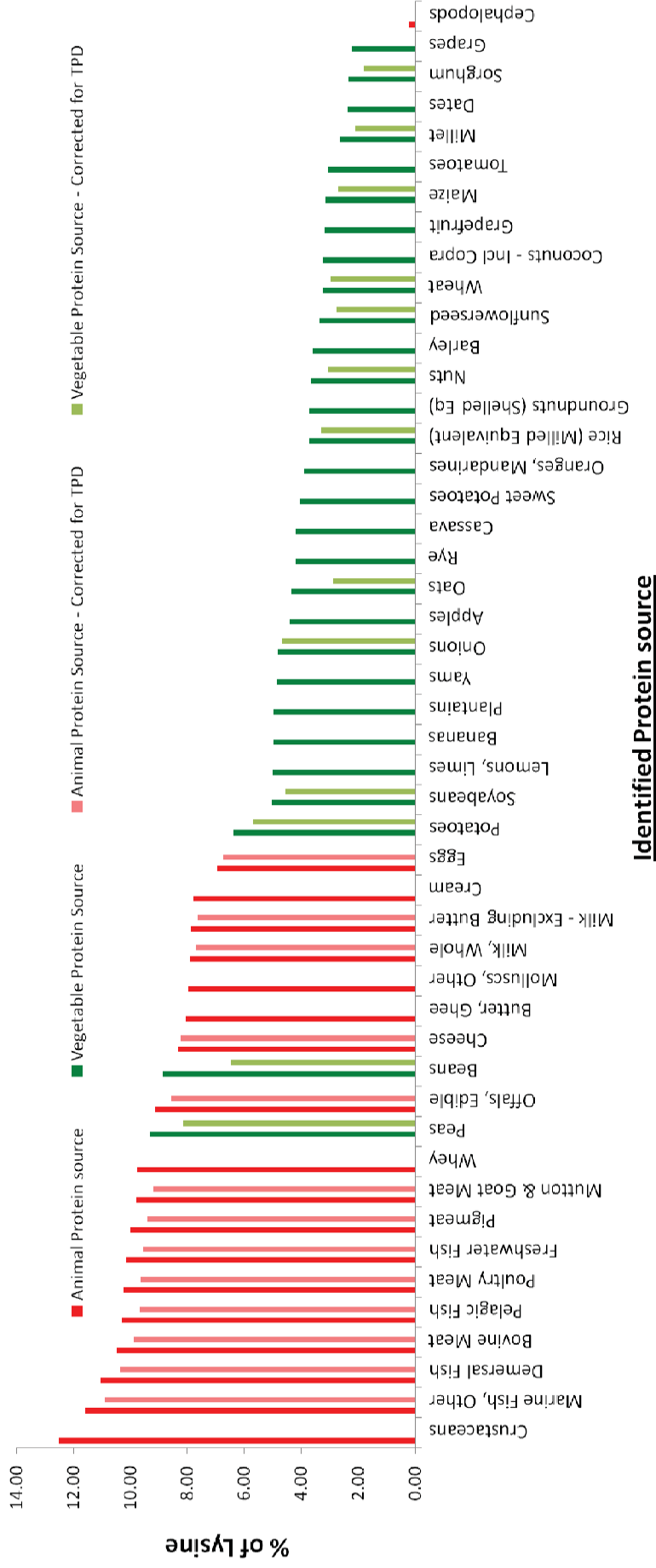


Figure 2.3 g. Lysine and g bio-available lysine in 100 g. of protein in identified major protein sources (Souci et al., 2000)

2.4.4 Countries with limited availability of essential amino acids

The 13 countries deficient in EAA were further studied. These countries are, in ascending order of protein supply: Democratic Republic of the Congo, Liberia, Mozambique, Haiti, Guinea-Bissau, Eritrea, Zambia, Togo, Bangladesh, Ethiopia, Tajikistan, Zimbabwe and Yemen.

The following classification of food groups was used for this study, together with the 2007 protein supply data, downloaded from FAOSTAT. The details can be found in appendix 2.4.

- Cereals - rice, wheat, maize, millet, others (sorghum, barley, oat, rye).
- Pulses - bean, pea, soya bean, pulses other.
- Milk and Milk products – cream, butter, ghee, milk.
- Egg, fish and meat – all type of meat, Cephalopods, Crustaceans, all type of fish, egg.
- Other foods – all vegetables and fruits, cassava, potato, yam.

Democratic Republic of the Congo

The daily protein supply is 22.05 g., 12.33% of which is available from animal sources. This African country has the lowest supply of protein to its population in the world. Its major protein sources are maize, cassava and wheat. These 3 foods contribute more than 55% of its protein supply on a daily basis.

Figure 2.4 shows the protein supply pattern based on the food group classification. Cassava is considered in 'other foods' group and contributes around 21.6% of the protein.

Essential amino acid (EAA) availability status:

The essential amino acid availability in the population can be found in table 2.6, all the EAA supply level is below the recommended requirement for each EAA. Lysine availability is the lowest among all the EAA availability, at 48.2%.

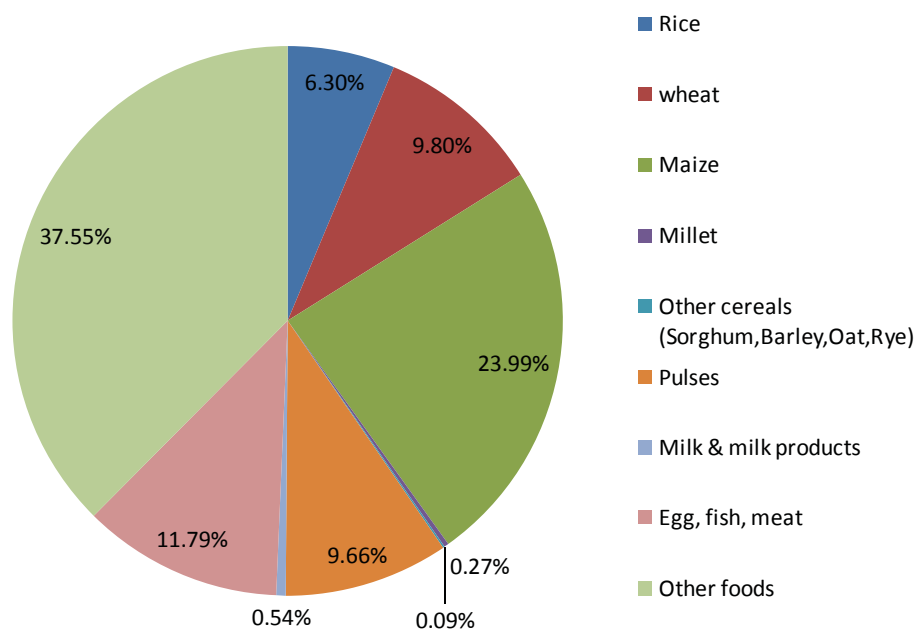


Figure 2.4 Percentage of protein supply from protein sources in Democratic Republic of the Congo

Liberia

Protein supply in this country is 34.45 g. per capita per day of which 13.53 % is from animal sources.

Rice, wheat and cassava are the major sources of protein. Around 60 % of the protein supply depends on cereal. Cassava contributes 10% of the protein.

Figure 2.5 shows the protein supply pattern based on the food group classification.

Essential amino acid (EAA) availability status:

Daily lysine, leucine, isoleucine and valine requirements are not achieved by the available protein (see table 2.7 for details). 'Methionine + cysteine' availability is estimated to be 104% against the recommended requirement of 15 mg/kg body weight/day.

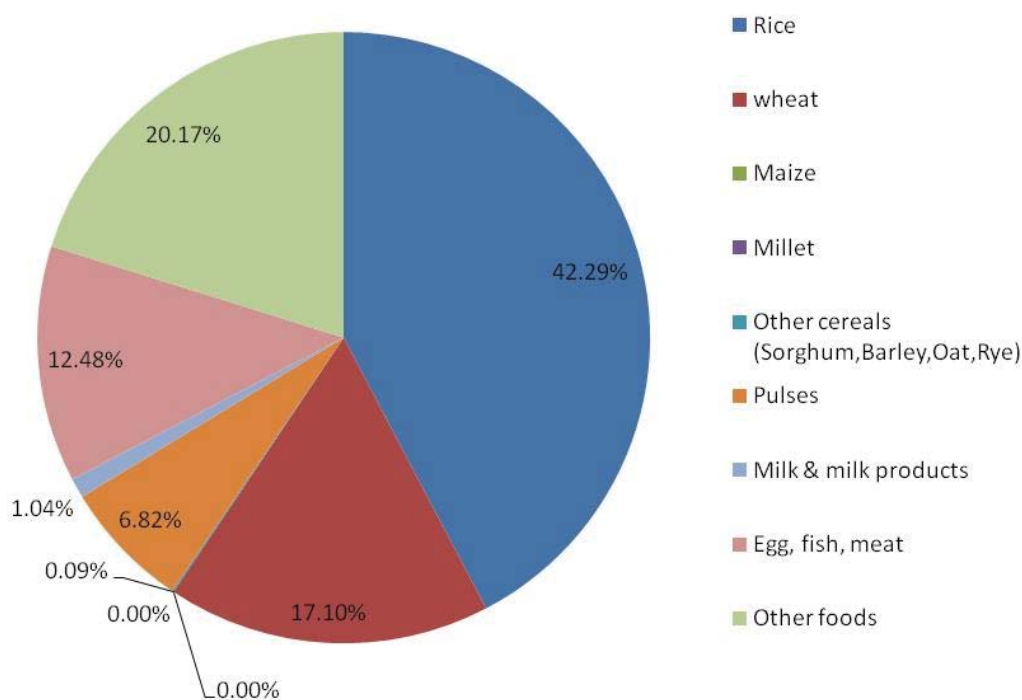


Figure 2.5 Percentage of protein supply from protein sources in Liberia

Mozambique

Protein supply in this country is 37.41 g. per capita per day of which 11.15 % is from animal sources.

Around 58% of protein is contributed by cereals, mainly maize, wheat, rice and sorghum. Apart from cereals, cassava is a major protein source in this country. Figure 2.6 shows the protein supply pattern based on the food group classification.

Essential amino acid (EAA) availability status:

The lysine requirement is not achieved from the available major sources of protein, at 75.1 %. Limited supplies of valine (103.6%) and leucine (109%) are also estimated.

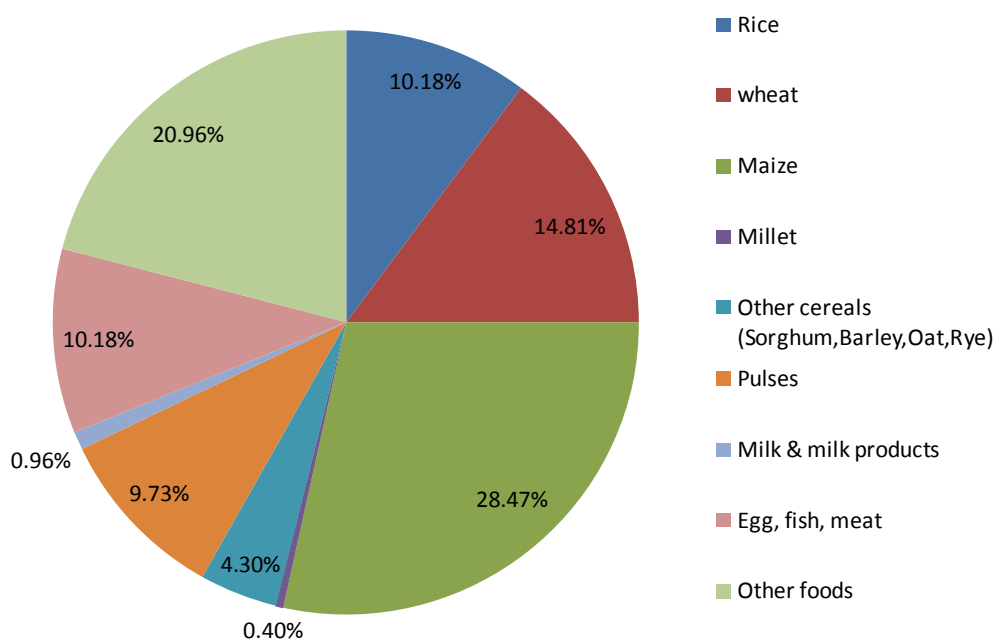


Figure 2.6 Percentage of protein supply from protein sources in Mozambique

Haiti

This is the only South American country where protein deficiency is observed in terms of quantity as well as quality. Protein supply in this country is 40.51 g. per capita per day of which 18.8 % is from animal sources.

More than 50% of the protein supply depends on supply of cereals, mainly rice, wheat, maize and sorghum. Pulses also contribute around 17.75% protein.

Figure 2.7 shows the protein supply pattern based on the food group classification.

Essential amino acid (EAA) availability status:

The lysine requirement is not achieved from the available protein, with only 87.5 % lysine supplied. 'Methionine + Cystine' availability is estimated to be 109.6 %.

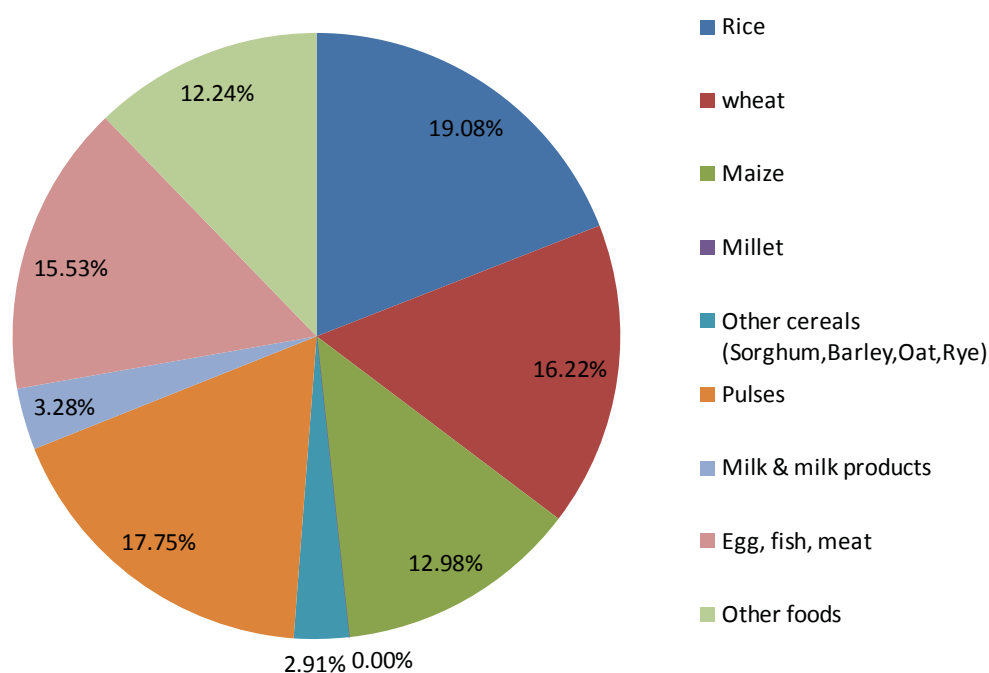


Figure 2.7 Percentage of protein supply from protein sources in Haiti

Guinea-Bissau

The protein supply in this country is 41.82 g. per capita per day. From animal sources, around 18.2 % protein is supplied.

Cereals are the main source of protein, contributing around 70 % of the total supply of protein. Major cereals are rice, millet, maize and wheat. Figure 2.8 shows the protein supply pattern based on the food group classification.

Essential amino acid (EAA) availability status:

In the population lysine is not available at the recommended required amount, at 79.4 %.

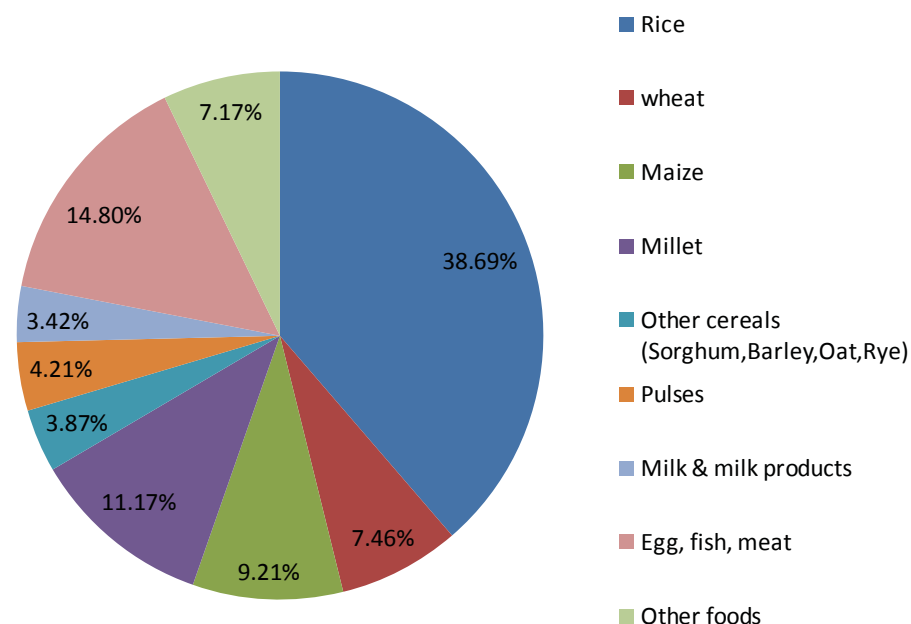


Figure 2.8 Percentage of protein supply from protein sources in Guinea-Bissau

Eritrea

The daily per capita protein supply to the population is 43.19 g., including 10.7% protein from animal sources.

The major source of protein is cereals, mainly sorghum and wheat. Sorghum alone contributes 47.8% of the protein supply.

Figure 2.9 shows the protein supply pattern based on the food group classification.

Essential amino acid (EAA) availability status:

Only 63.1% lysine requirement is achieved from the available protein.

'Methionine + cystine' and valine availability are estimated to be 103.5 % and 101.7% respectively.

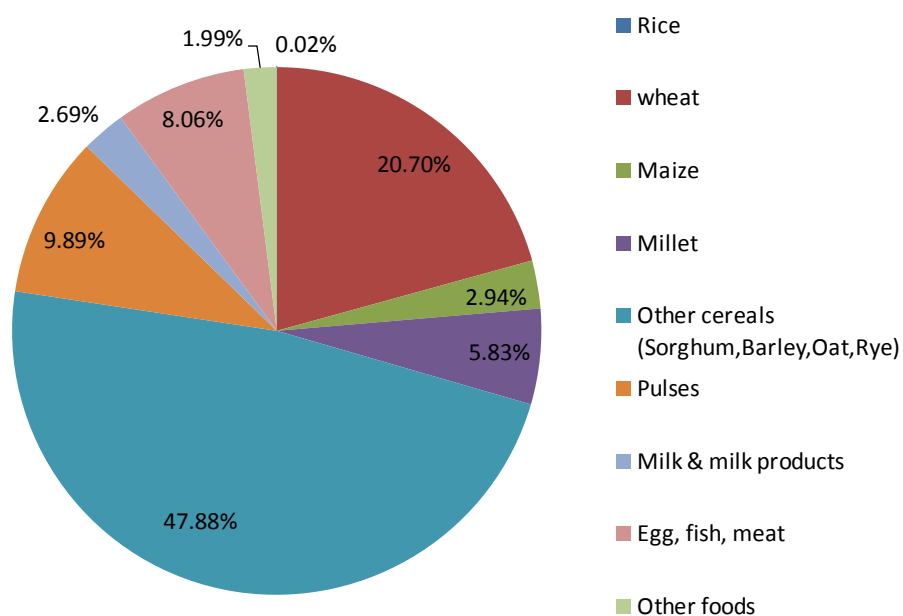


Figure 2.9 Percentage of protein supply from protein sources in Eritrea

Zambia

The protein supply in this country is 44.52 g. per capita per day. Around 9.88 % protein is supplied from animal sources.

The main source of protein is cereals contributing around 70% of total available protein. Maize is the major cereal, providing 57.4% protein.

Figure 2.10 shows the protein supply pattern based on the food group classification.

Essential amino acid (EAA) availability status:

The population of Zambia is getting only 79.9 % of the required intake of lysine.

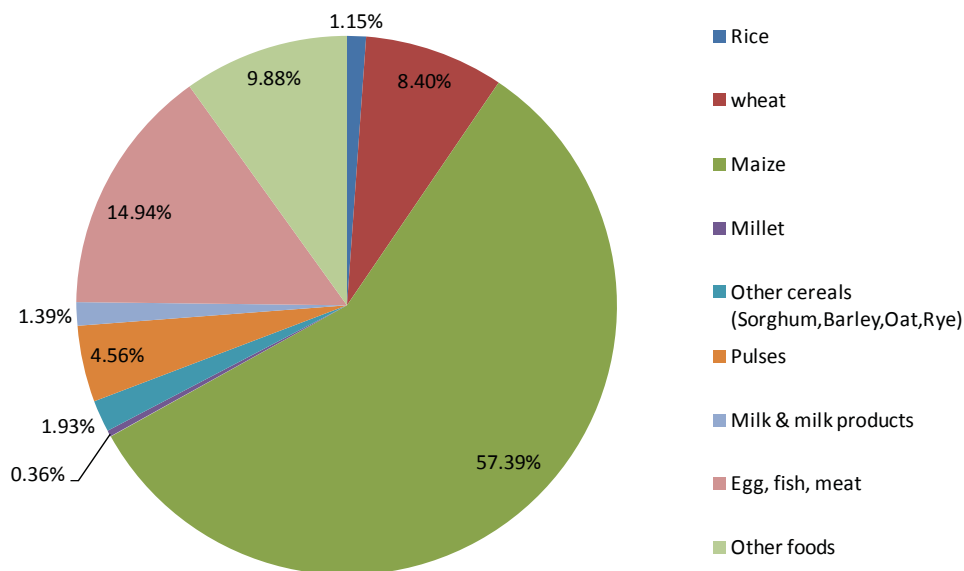


Figure 2.10 Percentage of protein supply from protein sources in Zambia

Togo

The protein supply in this country is 47.24 g. per capita per day with around 12.5 % protein from animal sources.

Around 60% of the protein supply depends on cereals, mainly maize and sorghum. Pulses contribute around 11.26% of the protein.

Figure 2.11 shows the protein supply pattern based on the food group classification.

Essential amino acid (EAA) availability status:

The lysine requirement is not achieved from the available protein, at only 89%.

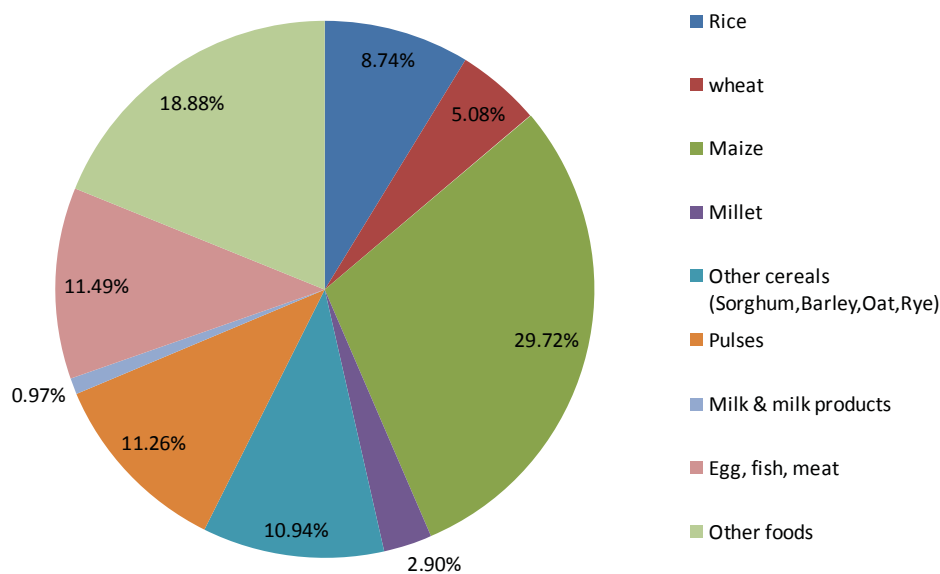


Figure 2.11 Percentage of protein supply from protein sources in Togo

Bangladesh

In this country per day per capita protein supply is 49.12 g. and animal protein contributes 15.8 % of the total available protein.

Cereals contribute around 70 % of the protein supply. Rice is the major cereal, provides more than 60% protein of the daily intake. Fresh water fish is the second major protein source to the population, it contributes around 50% of the animal protein.

Figure 2.12 shows the protein supply pattern based on the food group classification.

Essential amino acid (EAA) availability status:

The lysine requirement is not achieved from the available protein sources in the population, at 98.7 %. The deficiency is of course marginal and better than a number of other poor developing countries.

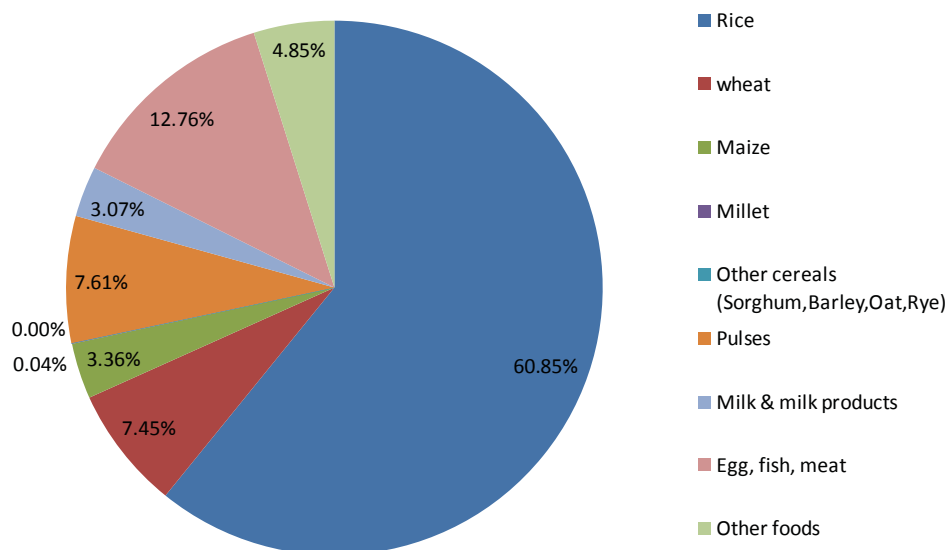


Figure 2.12 Percentage of protein supply from protein sources in Bangladesh

Ethiopia

In this country the per day per capita protein supply is 52.56 g., and animal protein contributes 10.3 % of total available protein.

Cereals contribute around 67 % of the protein. Particularly “other cereals” group, maize and wheat are the major cereals. Pulses are the second major protein source to the population.

Figure 2.13 shows the protein supply pattern based on the food group classification.

Essential amino acid (EAA) availability status:

The lysine requirement is not achieved from the available protein sources in the population, at 92.7 %.

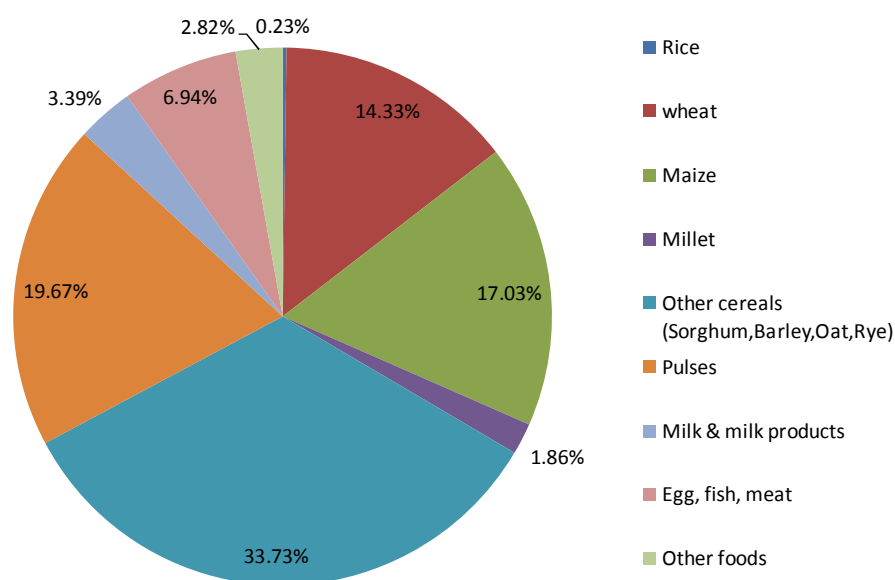


Figure 2.13 Percentage of protein supply from protein sources in Ethiopia

Tajikistan

In this country the per day per capita protein supply is 52.71 g. and animal protein contributes 21.26 % of total available protein

Cereals are the major sources of protein, contributing 68.5 % of total available protein. Wheat is the major cereal in this country and it provides around 61.5% protein. Meat, fish, egg and milk products supply 10.8% and 10.45% of the protein respectively to the population.

Figure 2.14 shows the protein supply pattern based on the food group classification.

Essential amino acid (EAA) availability status:

The lysine requirement is not achieved from the available protein sources in the population, at 98 %.

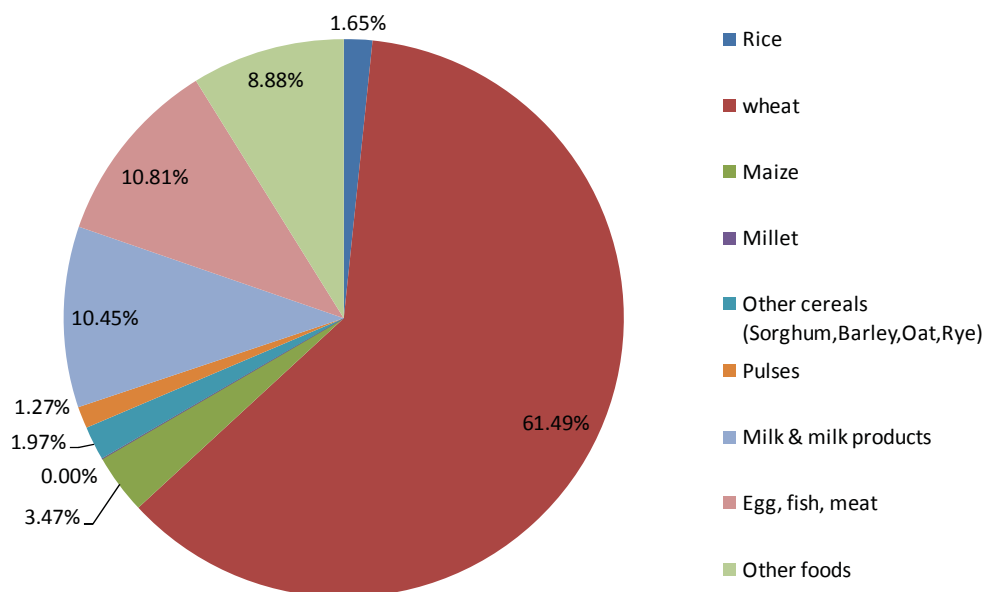


Figure 2.14 Percentage of protein supply from protein sources in Tajikistan

Zimbabwe

Per day per capita protein supply in the population is 53.24 g. including 18.9% from animal protein sources.

Cereals are the main source of protein in this country, providing around 63.6%. Maize and wheat are the major cereals. Pulses supply 9.9% of the protein to the population.

Figure 2.15 shows the protein supply pattern based on the food group classification.

Essential amino acid (EAA) availability status:

The lysine requirement is not achieved from the available protein sources in the population, at 98.8 %.

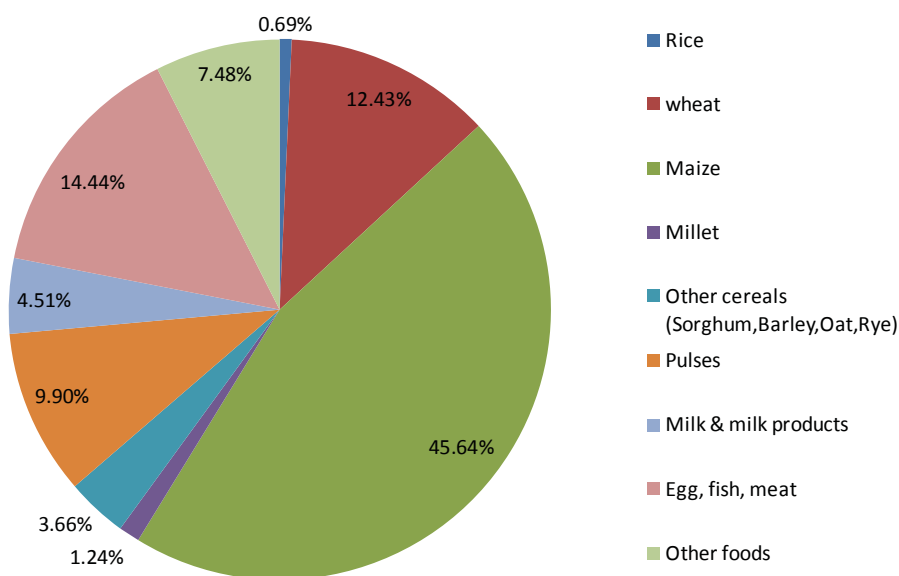


Figure 2.15 Percentage of protein supply from protein sources in Zimbabwe

Yemen

The protein supply in this country is 53.5 g. per capita per day, with around 21.7 % from animal sources.

Wheat, sorghum and meat are the major sources of protein. Around 68 % of the protein supply depends of cereals. Figure 2.16 shows the protein supply pattern based on the food group classification.

Essential amino acid (EAA) availability status:

The daily lysine requirement is not achieved by the available protein intake, at 99.1 %.

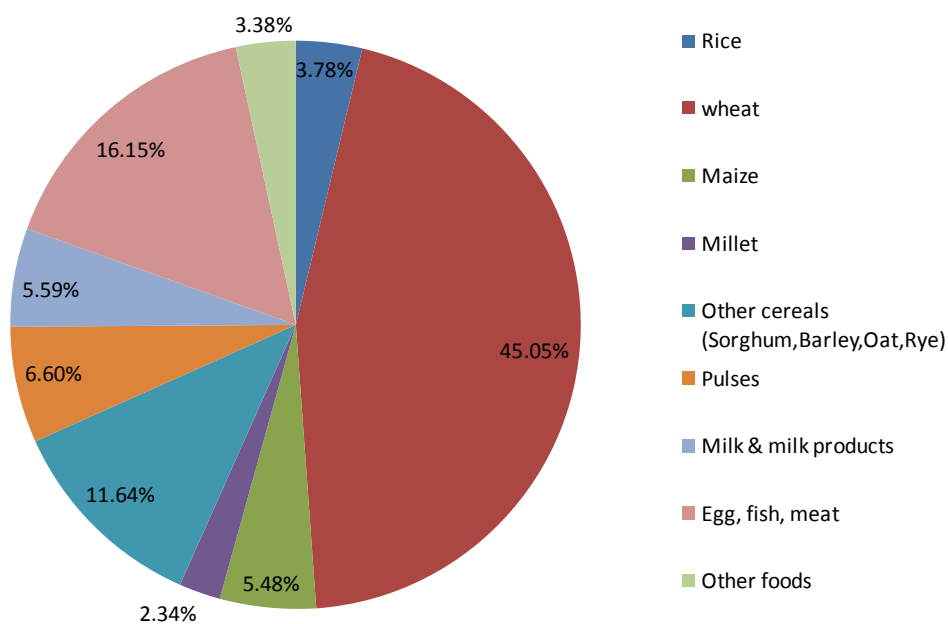


Figure 2.16 Percentage of protein supply from protein sources in Yemen

2.4.5 Sensitivity test

The sensitivity test results show the same trend of EAA availability in different countries, indicating that our results are not greatly affected by the unknown digestibilities of unidentified food sources except for some countries.

Only Malawi is estimated to have inadequate supply of lysine (99.8%).

In countries where the difference of availability of each EAA is found to be more than 5 %, then it is in 'red' font in table 2.7. The food supply pattern of the highlighted countries is further studied to understand the reason for this high difference. Mainly correction of vegetable proteins with assumed true protein digestibility value is responsible for this. Animal proteins have little effect on the changing pattern of estimated EAA while performing the sensitivity test.

The vegetable food items which have the main impact are cassava, ground nut, sweet potato, yam, banana and plantain. This is a limitation of this estimation method and creates the scope for further work in future, where more precise estimation of EAA can be done when the actual TPD values become available.

Table 2.7 EAA availability difference in selected countries (EAA values are in terms of percentage) based on sensitivity test

Countries	Essential Amino Acid								
	Histidine	Isoleucine	Leucine	Lysine	Methionine + Cystine	Phenylalanine + Tyrosine	Threonine	Tryptophan	Valine
Haiti	3	2	2	2	2	3	2	3	3
Democratic Republic of the Congo	8	7	5	7	7	6	7	9	7
Guinea-Bissau	2	1	1	1	1	1	1	1	1
Liberia	6	4	3	4	4	3	4	5	4
Mozambique	5	5	3	6	5	5	5	7	5
Angola	4	3	3	3	4	3	3	5	4
Comoros	5	3	3	3	3	3	3	5	3
Burundi	9	6	5	6	7	6	7	10	7
Central African Republic	4	3	3	3	3	3	3	4	3
Zambia	2	2	1	2	2	2	2	3	2
Eritrea	1	1	1	1	1	1	1	1	1
Uganda	8	5	5	5	5	6	6	8	6
Togo	4	4	3	4	4	4	4	5	4
United Republic of Tanzania	5	3	3	4	3	3	4	5	4
Rwanda	7	4	4	4	5	5	5	7	6
Madagascar	3	2	2	2	2	2	2	3	2
Côte d'Ivoire	7	6	5	6	5	6	6	7	6
Bangladesh	0	0	0	0	0	0	0	0	0
Timor-Leste	1	1	1	1	1	2	1	2	2
Sierra Leone	4	3	3	3	3	4	3	4	3
Congo	4	3	3	3	3	3	3	4	3
Solomon Islands	5	7	6	5	7	7	7	8	7
Tajikistan	1	1	1	1	1	1	1	1	1
Dominican Republic	2	1	1	1	1	1	1	2	1
Occupied Palestinian Territory	1	0	0	1	0	0	1	1	1
Guinea	5	3	3	3	3	3	3	4	3
Yemen	1	0	0	0	0	0	0	1	0
Bolivia	2	1	1	1	1	1	1	1	1
Gambia	2	1	1	1	1	2	1	1	1
Suriname	2	1	1	1	1	1	1	1	1
Zimbabwe	2	1	1	1	1	2	1	2	1
Sri Lanka	2	2	2	2	2	2	2	2	2
Thailand	2	1	1	1	1	1	1	1	1
Malawi	3	2	2	2	2	2	2	3	2
Guatemala	1	1	0	1	0	1	1	1	1
Ethiopia	1	1	1	1	2	2	2	2	2
Indonesia	2	2	2	2	2	2	2	2	2
Korea	1	1	1	1	1	1	1	1	1
cameroon	4	3	2	3	3	3	3	4	3
India	1	1	1	1	0	1	1	1	1

2.5 Limitations of this study

- The nutritional quality of proteins varies and depends on amino acid composition, ratios of essential amino acids, susceptibility to hydrolysis during digestion, and the effects of processing (Friedman, 1996). The effect of processing is not considered in this work, to simplify the estimation method of EAA based on available information.
- Minor protein sources were not considered because of lack of available data on amino acid composition or digestibility, so the estimated food and protein intake for some countries from major protein sources will be somewhat lower than the actual total supply.

For example in Solomon Islands “roots, other” food item supplies 4.27 g. and in Congo “meat other” food item supplies 3.91 g. protein to the population per day. In this study these food items are classified as minor protein sources. Because these countries did not appear as being protein deficient, these were not considered further.

In the case of Ethiopia 7.2 g. protein is supplied from “cereal other” food group. This is also classified as minor protein source. In this case an assumed correction needed to be made, and “cereal other” was assumed to be equivalent to maize.

- It is recognized that income plays a vital role in determining the quantity and quality of the food intake of individuals and households (Chatterjee et al., 2010). The FAO statistical database (FAOSTAT), being based on national data, does not provide information on the distribution of food within countries, or within communities and households. In this chapter this aspect is not studied. In the next chapter we will explore, for a selected country INDIA, the pattern of protein supply, especially in terms of essential amino acids, of households at different levels of expenditure.
- The true digestibility value of all the major protein sources is not available in the literature and 100% digestibility was initially assumed. The effect of this limitation on our results was tested by the sensitivity test in this chapter. The sensitivity test has indicated that our results are generally

robust, but some more countries were highlighted, where some essential amino acid supplies may not be achieving the daily requirements.

There is a need to have more information on the digestibility of these protein sources to estimate the availability of EAA more precisely.

- Dietary requirements for protein and amino acids are characteristics of an individual (WHO, 2007). This study assumes a generic requirement for the population.

2.6 Conclusion

Proteins are an essential component of the diet needed for survival of animals and humans. The basic function of proteins in nutrition is to supply adequate amounts of needed essential amino acids.

With due limitation of the estimation process and a number of assumptions from the present study it can be concluded that:

- The quantity of protein intake is not directly related to supply of essential amino acids. Good combinations of protein sources can fulfil the requirement of EAA even if the total protein intake is less than the recommended amount. The present study has found a number of countries with a lower protein supply to its population and still they are getting enough EAA on daily basis.
- Lysine was the limiting amino acid in diets heavily dependent on cereals mainly in the identified African countries.
- A person on vegetarian diet needs to consume a greater quantity of vegetable protein to maintain the proper balance of essential amino acid availability.

3.0 Impact of economic disparity on food consumption and nutrition in India: estimation of the availability of essential amino acids at different levels of total household expenditure

3.1 Introduction:

In the previous chapter, we discussed and documented the patterns of protein consumption in a large number of countries around the world. Since proteins are made up of a number of essential and non-essential amino acids, the chapter also examined the availability of some of the essential amino acids in the selected countries. This enabled identifying the nature of the protein deficiency many countries are facing, in quantitative and qualitative terms. The detailed database of the FAOSTAT used in the chapter contains valuable information on food available for consumption in the selected countries. This makes the findings reliable and useful. The qualitative aspects are calculated in terms of the availabilities of essential amino acids (EAA) such as lysine, for example.

While this exercise is useful, some of the assumptions on which the calculations have had to be based are not particularly realistic. For example, the available consumption data is based on the average amounts of the food items consumed by each person; it makes no allowance for age or sex, and it assumes an average bodyweight of 70 kg in its consideration of the recommended dietary requirement in respect of the EAA. It must also be remembered that the households' abilities to consume are dependent on their incomes, even if their compositions are, otherwise, identical. Given the FAO dataset, it was not possible to correct the findings for these obvious shortcomings.

In this chapter, we are seeking to address one of these issues in respect of one of the countries of the sample used in the preceding chapter, viz. India. There are several reasons why India is selected for this detailed attention, the main one being the availability of the required data. India is a large developing

country, with a relatively large number of poor people; its economy has been developing rapidly in recent years, and is already the fourth largest economy in the world. All these factors make India a useful candidate for a case study. We focus on the observed patterns of food consumption, not only at their average values, but at different levels of total household expenditure, as given in the National Sample Survey (NSS) statistics, to be detailed below.

3.2 Data description

3.2.1 National Sample Survey Reports, India

On a regular basis, the National Sample Survey Organization (NSSO) conducts a number of socio-economic surveys in India. In this chapter information from the following two reports of the NSSO are extensively used. These reports present useful information on the nutritional intake of the Indian population in particular years. The two reports are:

- The National Sample Survey (Report no 513): Nutritional Intake of India, 2004/2005, 61st round.

This survey covered all the states and Union Territories (UTs) in the country. The data were collected from a sample of 79,298 rural and 45,346 urban households spread over 7,999 villages and 4,602 urban blocks respectively.

- The National Sample Survey (Report no 405): Nutritional Intake of India, 1993/1994, 50th round.

With the exception of Ladakh and Kargil districts of Jammu and Kashmir, some villages in Nagaland and also in the Andaman & Nicobar Islands, the rest of the country was covered in this survey. The data were collected from 115,354 households spread over 6951 sample villages and 4,650 sample blocks. From each selected village/urban block, 10 households were selected.

The NSS reports provide details of the per capita daily availability of protein by different expenditure classes, defined by the Monthly per Capita Consumption Expenditure (MPCE) of the sampled households in urban and rural India. Also reported in the surveys are the percentage contributions of the different food

groups to the total protein consumed. But this report does not have the details of the availability of essential amino acids (EAA) to the population of India. Again, to the best of our knowledge, no significant work has addressed the issue of EAA in relation to the diets of Indians, rural or urban. As the findings of the previous chapter demonstrate, the availability of protein in a generic sense does not necessarily translate into that of the EAAs, which are essential to the nutrition needs. An attempt is therefore made here to examine the nature of the EAA availability of the Indian population, together with the availability of protein.

Monthly per capita consumer expenditure (MPCE)

The definition of the MPCE, as stated in the 61st round of the NSS report (2004/2005), is: *“For a household, this is the total consumer expenditure over all items, divided by its size and expressed on a per month (30 days) basis. A person's MPCE is understood as that of the household to which he or she belongs”*.

MPCE classes

In the 50th and the 61st round reports, 12 MPCE categories were drawn up for the rural and the urban sectors as shown in the table 3.1 below.

Table 3.1 Total consumption spending defining the MPCE classes in rural and urban populations in India (NSS, 1993/1994, NSS, 2004/2005), Rupees (Rs.)

NSS Report (1993-94)			NSS Report (2004-05)		
MPCE level	Rural (Rs.)	Urban (Rs.)	MPCE level	Rural (Rs.)	Urban (Rs.)
1	below 120	below 160	1	0 - 235	0 - 355
2	120 - 140	160 - 190	2	235 - 270	335 - 395
3	140 - 165	190 - 230	3	270 - 320	395 - 485
4	165 - 190	230 - 265	4	320 - 365	485 - 580
5	190 - 210	265 - 310	5	365 - 410	580 - 675
6	210 - 235	310 - 355	6	410 - 455	675 - 790
7	235 - 265	355 - 410	7	455 - 510	790 - 930
8	265 - 300	410 - 490	8	510 - 580	930 - 1100
9	300 - 355	490 - 605	9	580 - 690	1100 - 1380
10	355 - 455	605 - 825	10	690 - 890	1380 - 1880
11	455 - 560	825 - 1055	11	890 - 115	1880 - 2540
12	560 & above	1055 & above	12	1155 & more	2540 & above

3.2.2 Regional variations within India and selection of states for the study

India is the seventh largest country in the world occupying 2.4 per cent of the world land area and slightly more than one-third of the size of the US (CIA, 2011). Population-wise, it is the second largest in the world, after China. India is a union of 28 States and 7 Union Territories, with very wide variations in respect of food habits and general cultural attributes.

Out of the 17 major states⁷ in India, four have been selected in this study, based on their geographical location, climate, and food habits. The states are: Bihar, from the east, Punjab, from the north, Kerala, from the south and Gujarat from the western part of the country (appendix 3.6).

3.3 India's economic growth and changes in the food habits and nutritional pattern of the Indian population

3.3.1 Introduction

After four decades of relatively slow growth, the Indian economy was subjected to a radical policy shift following a short-lived economic crisis in 1990/91. This policy shift involved the opening-up of the economy to greater competition both domestically and, especially, internationally. After a period of adjustment following the introduction of the reform programme, India's total and per capita GDP growth rates rose significantly above the long term trend rates achieved in the past. India's GDP, valued at international exchange rates, is currently the fourth largest in the world, and its GDP per capita has more than doubled in a relatively short period of time (Chatterjee et al., 2010, Subir and Gunjan, 2006).

⁷ 17 States of India which had a population of 20 million or more according to the Census of 2001 are referred as major states. Together, these States accounted for nearly 94.7% of India's population in 2001.

Economic growth of a country usually helps to improve its food supply and nutrition, and reduce its dietary deficiencies - thus achieving an overall improvement in its health status. This has not so far been the case for India. While the 'economic boom' of India has drawn admiring attention of the rest of the world, perhaps a less publicized aspect of India's recent economic evolution has been a significant increase in hunger and malnutrition. India's rank in terms of human development index (which is broadly used as a measure of life expectancy, adult literacy and standard of living) is 119 in 2010, among 169 countries (UNDP, 2011).

The present study helps to underline an important aspect of this issue of nutrition of the Indian population, viz. the availability of EAA and how that has changed over a period of India's rapid economic growth.

3.3.2 GDP (gross domestic product) information

The Gross Domestic Product (GDP) is the market value of all final goods and services produced within a country in a given period. The GDP is measured using one of three methods: production, expenditure and income (Goossens et al., 2007). In time-series studies, estimated GDP figures need to be corrected for price changes over time to obtain real GDP, which is distinguished from nominal GDP.

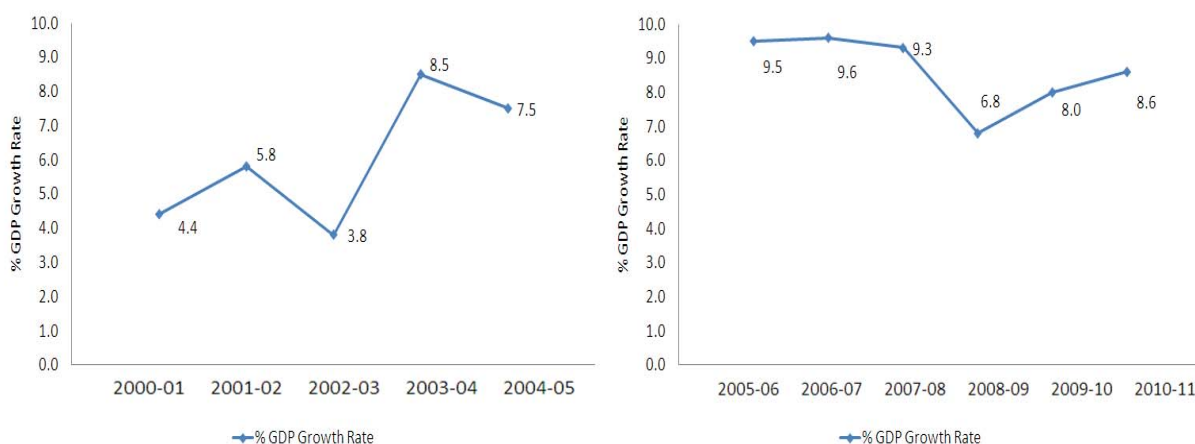


Figure 3.1 India's nominal GDP growth rates 2000/01 to 2010/11 (Ministry of Finance, 2010/2011, Ministry of Finance, 2005/2006)

In figure 3.1 the GDP growth rates of India over two periods have been graphed. Because the prices on which the GDP estimates were based changed in the period under consideration, two separate graphs - one covering the period 2000/01 to 2004/05, and the other 2005/06 to 2010/11 - have been drawn. The earlier series is based on 1999/2000 prices, while the latter on 2004/05 prices. As the graphs show, the Indian economy has grown at high rates in recent years; indeed this has made it one of the fastest growing economies in the world. During the last two decades in particular, the Indian economy has improved its share in the world economy. In 2002, the share of the Indian economy in the world GDP was 6 per cent, which is an increase of several percentage points since the early 1990s. It is estimated that the share of the Indian economy in the world GDP will increase to around 11 per cent by 2025, and further to 14 per cent by 2035 (Subir and Gunjan, 2006). Figure 3.2 shows India's progression in the world GDP shares, estimated in 2002 purchasing power parity prices, in 2015 and 2025, together with the projected GDP shares of China, Germany, Japan and the USA, the other four large economies. According to this projection, by 2025, India will become the third largest contributor to the world GDP after China and US, leaving both Germany and Japan behind (Virmani, 2004).

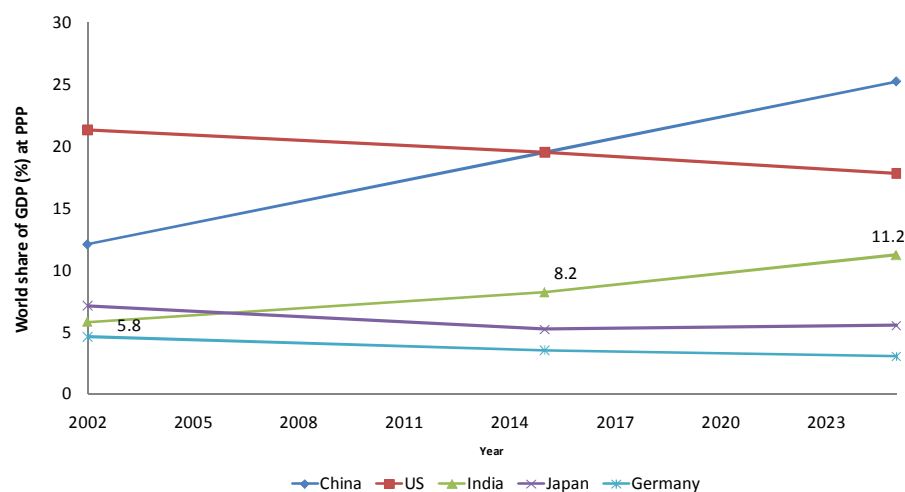


Figure 3.2 Projected shares of world GDP at purchasing power parity 2002 prices of selected economies including India's

Since our interests include the performance of a number of Indian states, it is helpful to remember that there are wide variations in the affluence levels and in those of economic performance of the different states. Figure 3.3 shows the per capita incomes at current prices of India as a whole and of the selected states over the period 1999/2000 to 2005/2006. The figure shows that three out of the four selected states, viz. Punjab, Gujarat and Kerala, have had persistently higher per capita incomes than India as a whole, Bihar's per capita income continues to be lower. The trend of the former three states' per capita income over the period has also been steadily upward, as has that of India as a whole, while Bihar's has been rather flat. These will no doubt have influenced their food consumption and nutrition patterns over time.

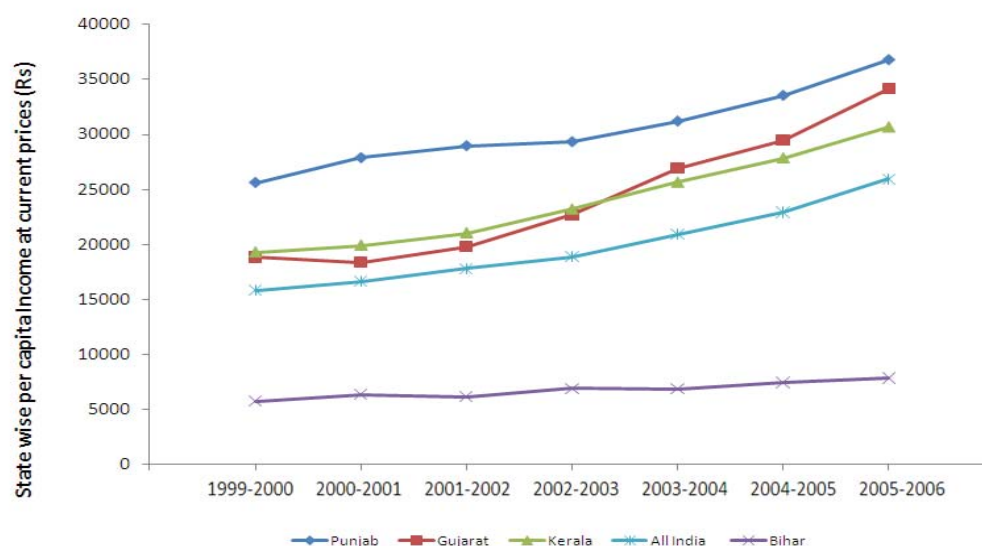


Figure 3.3 Per capita incomes of India and of the selected states at current prices (CSO, 2008)

Figure 3.4 shows the annual real growth rate of the agricultural sector in percentage terms. The year 2000/01 to 2005/06 data is at 1999/2000 prices, and the year 2005/06 to 2011/11 data is at 2004/05 prices. Over the last 10 years, the pattern of agricultural growth has been fluctuating in a major way. For an economy that is still largely dependent on agriculture, such fluctuations cause many adverse knock-on effects both for the consumers and the other sectors of the economy.

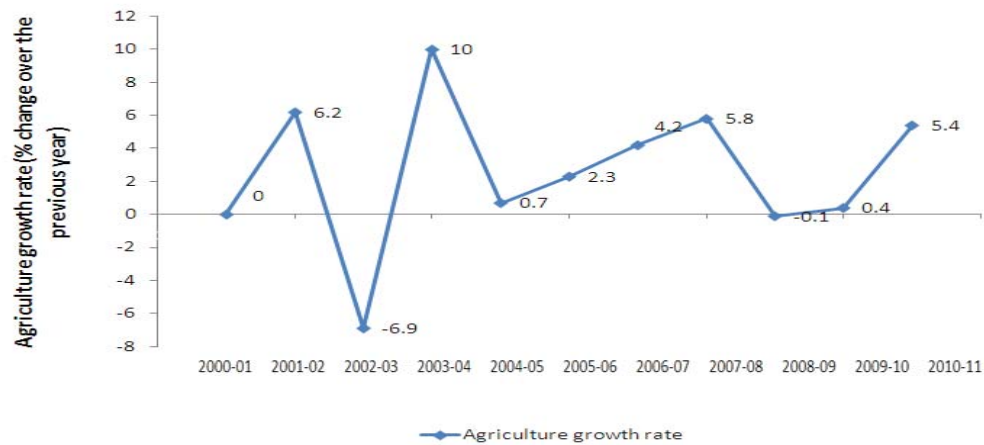


Figure 3.4 Agriculture real growth rates in GDP at factor cost (Ministry of Finance, 2010/2011, Ministry of Finance, 2005/2006)

Figure 3.5 shows the decreasing trend of agriculture's share in Indian GDP. The share of the agriculture sector in India's GDP has declined from 32% in 1990/91 to around 15.7% in 2009/10. The decline in growth of agricultural GDP was primarily due to the fall in the production of some major agricultural crops such as oilseeds, cotton, jute and sugarcane (GK today, 2011). It is also a fact that the other sectors of the economy, especially the service sector, have come to occupy larger shares of India's rapidly growing GDP, but agriculture is still the backbone of the Indian economy. About 65% of the population depends directly or indirectly on agriculture (Share tips info, 2011).

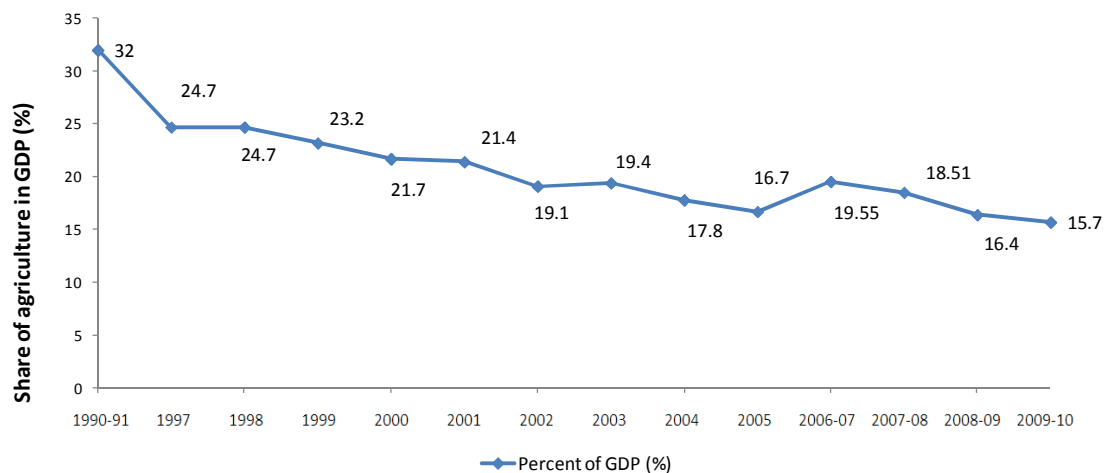


Figure 3.5 Share of agriculture in GDP (Share tips info, 2011, FFTC, 2011).

3.3.3 Cereal production and food supply pattern in India

The daily per capita calories intake has been declining in India for both rural and urban populations (Deaton and Dreze, 2009). For the rural population it has decreased by 4.9 % and for the urban by 2.5% from 1993/94 to 2004/05 (NSS, 2004/2005). Approximately 60% of the daily per capita protein intake of the Indian population derives from cereals (FAOSTAT, 2007), so its decline has significant implications for the nutritional status of the population. Maize production has increased by 97% from 1993 to 2004. During this period, millet, wheat and rice production have also increased moderately, at 49%, 32% and 20% respectively. However sorghum and barley production have decreased by 37% and 12% respectively (figure 3.6).



Figure 3.6 Cereal production pattern in India (FAOSTAT, 2007) – in tonnes/year

Figure 3.7 shows the cereal supply pattern (supply = production + import \pm stock variations – export) to the Indian population. Over the chosen time frame, daily per capita cereal supply has not changed a lot. However, wheat and millet supply has increased by 18.6% and 15.6% respectively, while rice supply has reduced by 8%. In the case of sorghum and barley the daily supply has also reduced by 50%. Rice and wheat are the major cereals in the diet of the Indian people (FAOSTAT, 2007).

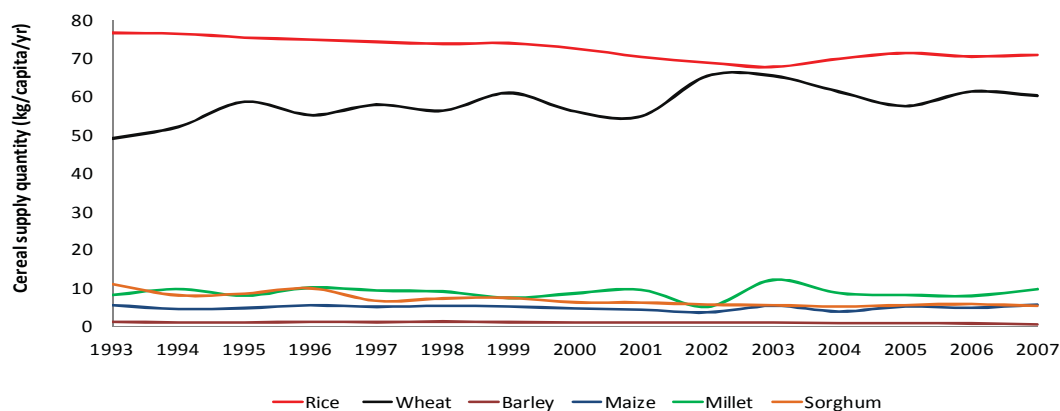


Figure 3.7 Cereal supply pattern in India (kg /capita/year) (FAOSTAT, 2007)

3.4 Availability of essential amino acids in different economic groups in India: method of estimation

The FAOSTAT website has the official information on daily per capita food supply and protein supply for 184 countries in the world, including the Indian population. This required information was downloaded from the FAOSTAT website for the years 1993 and 2004 in terms of ‘gram/capita/day’ (appendix 3.1 and 3.2). In the NSS reports, all the food items consumed by the Indian population are categorised as per table 3.2. The ‘per capita per day intake of protein by MPCE classes in urban and rural India’ and the percentage of total intake of protein, derived from these food groups, are available in the NSS reports based on these food groups.

Table 3.2 Food groups as per the NSS report, India (NSS, 2004/2005)

NSS Report, India			
Year 2004-05		Year 1993-94	
Food Group	cereals	Food Group	cereals
	pulses		pulses
	milk & milk products		milk & milk products
	egg, fish & meat		egg, fish & meat
	other food		

In the NSS report, 1993/1994, the total intake of protein per capita per day from all the food groups is not equal to 100%. The range of the shortfall is from 3.68% in the MPCE class 2 of rural Punjab to 25.14% in the MPCE class 11 of urban Bihar. So in this chapter an extra group had therefore been created for the 1993/1994 data, taking the total to 100%. To match this with the 2004/2005 report, which has a group called “other food”, this assumed group for 1993/1994 was also named the “other food”. The food items available in the downloaded data from FAOSTAT website were grouped in line with table 3.2. For example, barley, maize, millet, rice, sorghum and wheat come under the food group cereals. The amount of food and protein supply from all the food items was summed to give the total supply from each food group. Thus, the totals for all the food items under each food group were calculated. This information is available in appendix 3.1 and 3.2. The NSS Reports do not have the information on the per capita per day intake of food by MPCE classes in urban and rural India, nor the percentage of total intake of food derived from the food groups mentioned in table 3.2. To estimate the availability of the essential amino acids it is necessary to calculate the approximate amount of food intake per capita per day from all the food groups of table 3.2 by MPCE class in urban and rural India in the four selected states. The food supply to protein supply ratio (derived from FAOSTAT data) was used to calculate the required food intake. This ratio, derived from appendix 3.1 and 3.2, is shown in table 3.3 below.

Table 3.3 Ratio of per day per capita protein supply to food supply by Indian population as per food groups of the NSS report, India in 1993 and 2004

	Year	
	1993	2004
Food Group	Ratio	
Cereals	0.079	0.079
Pulses	0.211	0.218
Milk & milk products	0.037	0.035
Egg, fish & meat	0.120	0.117
Other food	0.014	0.0134

To estimate the per capita food intake on daily basis from each food group in each MPCE class, the following formula was used. The calculation steps were:

- At first, per capita per day total protein intake figure from all the food groups by each MPCE class was multiplied by the percentage of total intake of protein of a particular food group.
- This step had generated the amount of protein intake from a particular food item. Then the calculated figure was divided by the ratio of per day per capita protein supply to food supply of the same food group as per table 3.3.
- This second step had generated the per capita per day food intake from the same food group in each MPCE class.

Accordingly, in each MPCE class, using the same method, food intake figures can be calculated. The calculated results are available in appendix 3.3 and 3.4 respectively for year 1993 and 2004.

The equation is,

$$X_a = \frac{A * B_a}{C_a}$$

Where,

X = per capita per day food intake from food group “ a ” by each MPCE class

a = one of the food groups as per table 3.3

A = per day per capita total protein intake from all the food groups by each MPCE class

B = percentage of total intake of protein from food group “ a ” (per capita per day) by each MPCE class

C = ratio of per day per capita protein supply to food supply of food group “ a ” as per table 3.3.

To estimate the availability of essential amino acids it is necessary to identify some food items as reference food items, (i.e. items of food actually consumed) from each of the food groups of table 3.3. This had been done for each selected state of India based on the regional food habits in the particular state. This assumed information on the food items making up the daily diets of the four states as tabulated in table 3.4. For any state it was further assumed that the food habit was the same in both rural and urban areas. In the case of India as a whole it was decided to use the reference food items as per the state of Bihar.

In the case of “other food”, as shown in table 3.3, the ratio suggests that this group provides only 1.34-1.36 g. protein per 100 g. of food items. Also, from appendix 3.1 and 3.2, it can be seen that ‘vegetable others’ and potato are the major contributors of protein for the “other food” group. Vegetable others can have a lot of varieties in the daily diet of the Indian population; so potato was selected as the reference food item as a surrogate estimate of EAA bioavailability. Potatoes are generally the most commonly used vegetable item in Indian diets.

Table 2.3 has the amino acid profile information of all the food items listed in the FAOSTAT website, including the assumed food items in table 3.4 of this chapter. These amino acid profiles were linked with the estimated ‘per capita per day food availability from different food groups by MPCE class’ and the ‘per capita per day protein availability from different food groups by MPCE class’ information to estimate the essential amino acid availability for each state in both their rural and urban areas in 2004 and in 1993. The EAA estimation steps were the same as in chapter 2.

Table 3.4 List of reference food items for each state in India based on the regional food habits

Food Group (as per NSS report)	State			
	Kerala	Bihar	Punjab	Gujarat
Cereals	Rice	Rice	Wheat	Wheat
Pulses	Beans	Beans	Beans	Beans
Milk & milk products	Milk - Excluding Butter	Milk - Excluding Butter	Milk - Excluding Butter	Milk - Excluding Butter
Egg, fish & meat	Freshwater Fish	Freshwater Fish	Poultry Meat	Poultry Meat
Other food	Potato	Potato	Potato	Potato

It is now well recognized that ‘true ileal amino acid digestibility’ is a more accurate representation of bioavailability of protein than ‘true protein digestibility’ (Rutherford et al., 2012). In this chapter, available true ileal amino acid digestibility values of the assumed food items (table 3.5) have been used to correct the protein bioavailability data. In the case of food groups like milk & milk products, egg, fish & meat and other foods, true ileal amino acid digestibility values are not available in the literature. For these food groups, TDP values were used. The TDP details of these food groups can be found in table 2.1, chapter 2.

Table 3.5 True ileal amino acid digestibility values of Indian food items

Food item	True ileal amino acid digestibility value
Rice (cooked rice)	0.74
Wheat (roti)	0.90
Bean (Mung dal)	0.86

3.5 Results and discussion

The calculations reported below are based on the 61st (2004/2005) round of the National Sample Survey (NSS) report.

3.5.1 MPCE class-wise protein supply patterns and estimated EAA availability pattern in the selected states in 2004

The MPCE classes as described in table 3.1 have been grouped further in the following way:

- MPCE class 1 to 4: Lowest group
- MPCE class 5 to 8: Middle group
- MPCE class 9 to 12: Highest group

In this section we proceed to analyze the availability of protein from different food groups and the estimated EAA availability pattern from the protein intake by the different MPCE classes in year 2004. As described in chapter 2, in this chapter also, the recommended EAA values for adults (WHO, 2007) was considered as the reference values and the average body weight of an adult person was assumed to be 70 kg in India. In the all-India case as well as in the selected states, both in the rural and urban areas, the EAA availabilities from different food groups are shown in appendix 3.5, the EAAs having supplies lower than the requirement are in 'red font'. Essential amino acids whose availabilities are below 110% are in 'blue font'. The protein intake figures lower than the recommended intake amount, i.e. 56 g/capita/day, are in 'red' font in this table.

All-India

In all three MPCE groups, both in rural and urban sectors, cereals were the single main source of protein though the percentage of protein obtained from cereals was showing a decreasing trend with increasing income group. The results demonstrate that, with rising incomes, households' dietary preferences shift in favour of non-cereal items of food. This, in turn, has long-term implications for imports of non-cereal protein and other food into India, because of its limited ability to raise domestic production of these goods in a cost-effective way. After cereals, other food and pulses were the main source of protein in all the MPCE groups both in the rural and urban sector. Protein intake from milk and milk products increased with income, both in the rural and urban sector; on the other hand animal protein intake was not improved much.

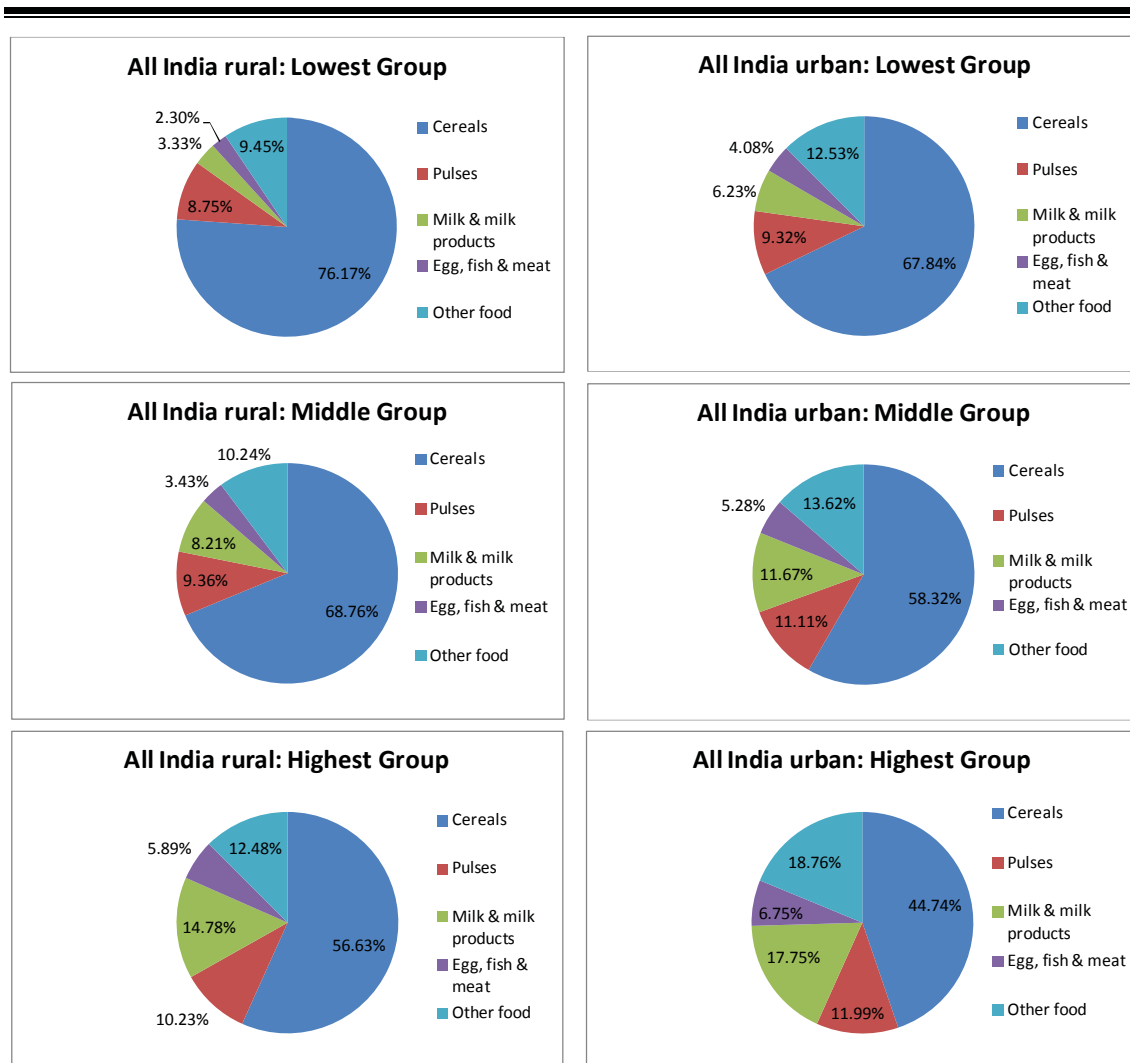


Figure 3.8 Percentage of protein supply from food groups in all-India: rural and urban sector - year 2004

EAA availability status:

In 2004, in the all-India rural sector insufficient supply of lysine was estimated in MPCE class 1 to 6. Interestingly in the MPCE classes 4, 5 and 6 though the protein intake amount was far below the recommended amount (appendix 3.5) only lysine supply was estimated lower than the recommended level; this might be due to the higher consumption of cereals. On the other hand, in the case of the same MPCE classes in all-India urban sector, all the EAAs were estimated to be available to the population in adequate quantity though the protein intake amount was less than 56 g/capita/day. This finding of the urban all-India sector demonstrates that it is the source of the protein that is more critical to the

requirement of the individual amino acids. This finding is in line with the findings on several other countries as reported in chapter 2.

Kerala

In the rural as well as in the urban Kerala cereals and egg, fish and meat were the main sources of protein in all the MPCE groups. In all three expenditure groups, decreased consumption of protein from cereals was observed with increased affluence. Also the urban sector had less protein intake from cereals in each respective MPCE group. Kerala is a coastal state with a relatively large non-Hindu (Muslim and Christian) population, which is not as restrictive in its consumption of animal protein as are many Hindus. The observed high consumption of egg, fish and meat may be a reflection of this cultural aspect.

EAA availability status:

In 2004, in rural areas, due to very low intake of protein, inadequacy of EAAs was observed in most of the lower MPCE classes, up to MPCE class 6. But MPCE class 7, 9 and 10 consuming only 46.1 g, 47.6 g and 51.2 g protein respectively were found to have no deficiency in terms of the supply of EAAs. So, again, the consumption of protein and the adequacy of EAA are not always related in a systematic manner. This finding may be due to the higher consumption pattern of egg, meat and fish protein in the population of Kerala. In the urban sector, a similar situation can be seen (appendix 3.5) which demonstrates again the nature of the relationship between a protein type, rather than quantity, and its essential amino acid contributing ability.

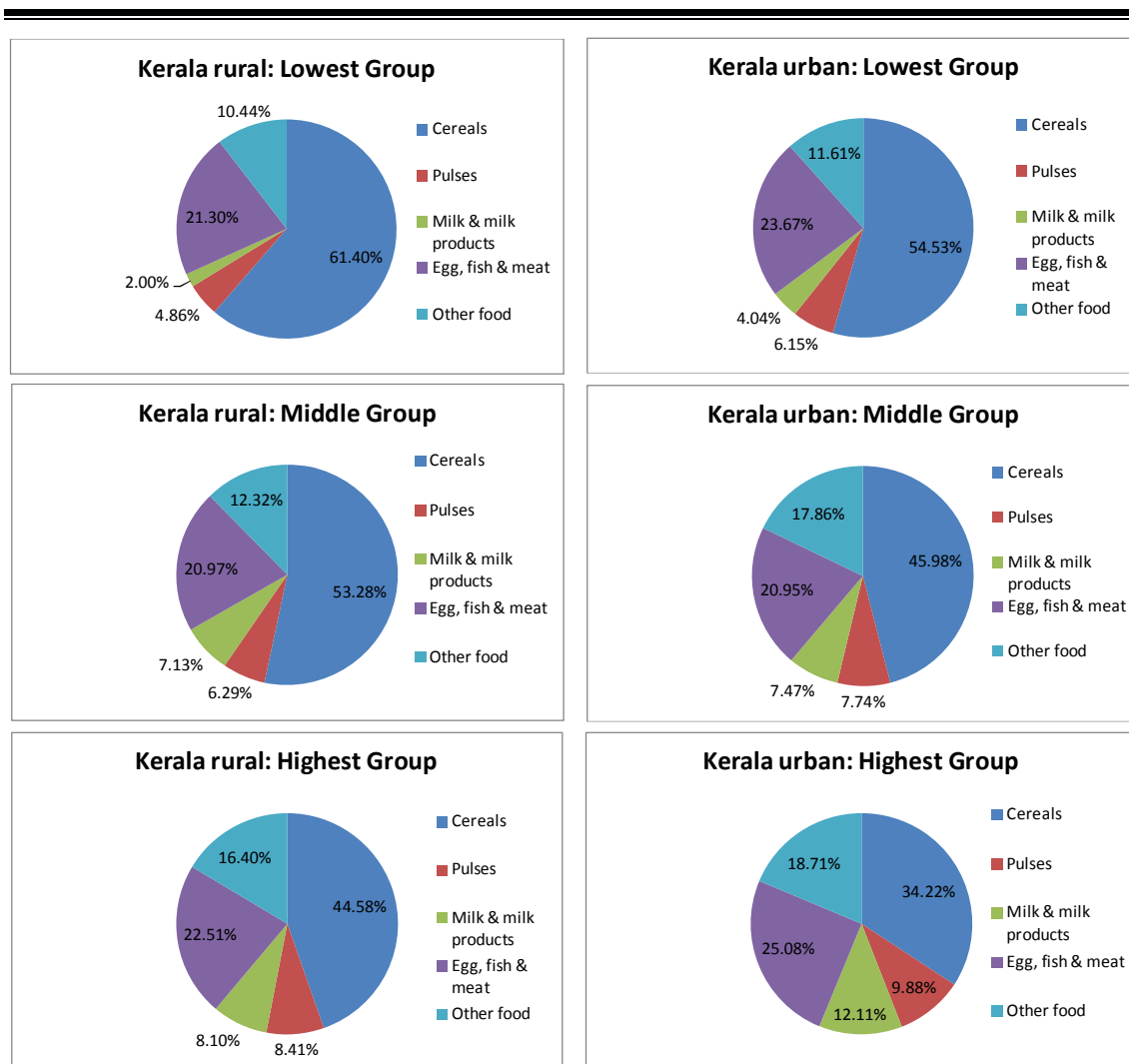


Figure 3.9 Percentage of protein supply from food groups in Kerala: rural and urban sector - year 2004

Gujarat

In the rural as well as in urban Gujarat, in all the MPCE groups, cereals and pulses were the major sources of protein. With increasing income, middle and highest MPCE groups, both in rural and urban sectors, consumed more milk and milk products and other foods and at the same time consumed fewer cereals. The high income households seemed to rely less on cereals, as is to be expected. The other food category being undefined might include eating away from home, with unknown protein content. Egg, fish & meat supply was very limited in the daily diet of the population in both areas of the state. Gujarat is a state in which religions and cultural factors encourage vegetarianism more

than probably in any other state in India. This may help to explain the finding that animal protein does not dominate in the Gujarati diets.

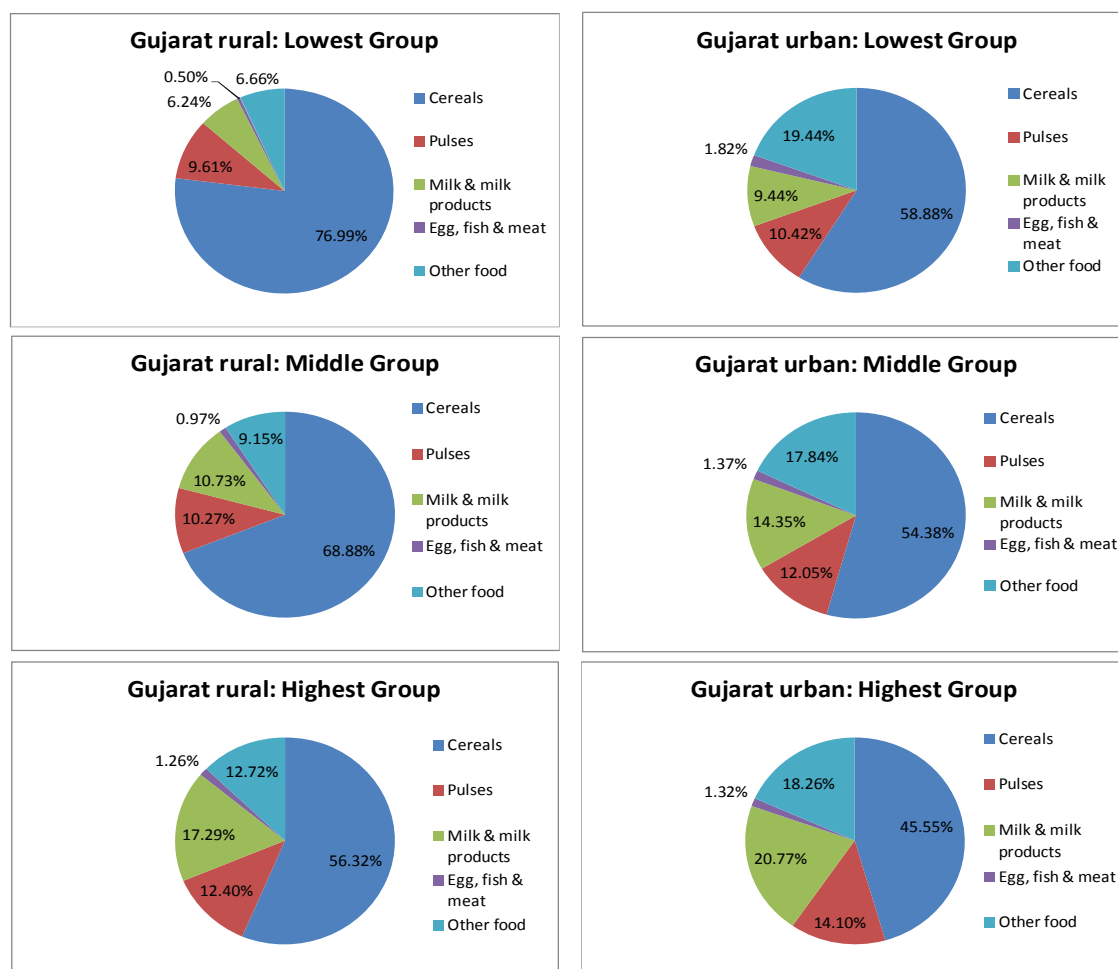


Figure 3.10 Percentage of protein supply from food groups in Gujarat: rural and urban sector - year 2004

EAA availability status:

Mostly inadequate supply of lysine was found to be the case for different MPCE classes in both rural and urban Gujarat. Rural Gujarat was the only region in this study where inadequate supply of lysine was observed for the population in the all-Gujarat average figure (appendix 3.5). MPCE class 12 was estimated to receive 3 times more supply of each EAA than MPCE class 1 supply, a clear example of the most well-off amongst the consumers doing better in a

disproportionate manner, when it came to their intake of the essential amino acids.

Bihar

Bihar, as shown in figure 3.3, was the poorest of the four states being studied here. Cereals, pulses and other foods were the main source of protein in Bihar. Egg, fish & meat supply was very limited in the daily diet of the population in both the areas of the state among all the MPCE groups.

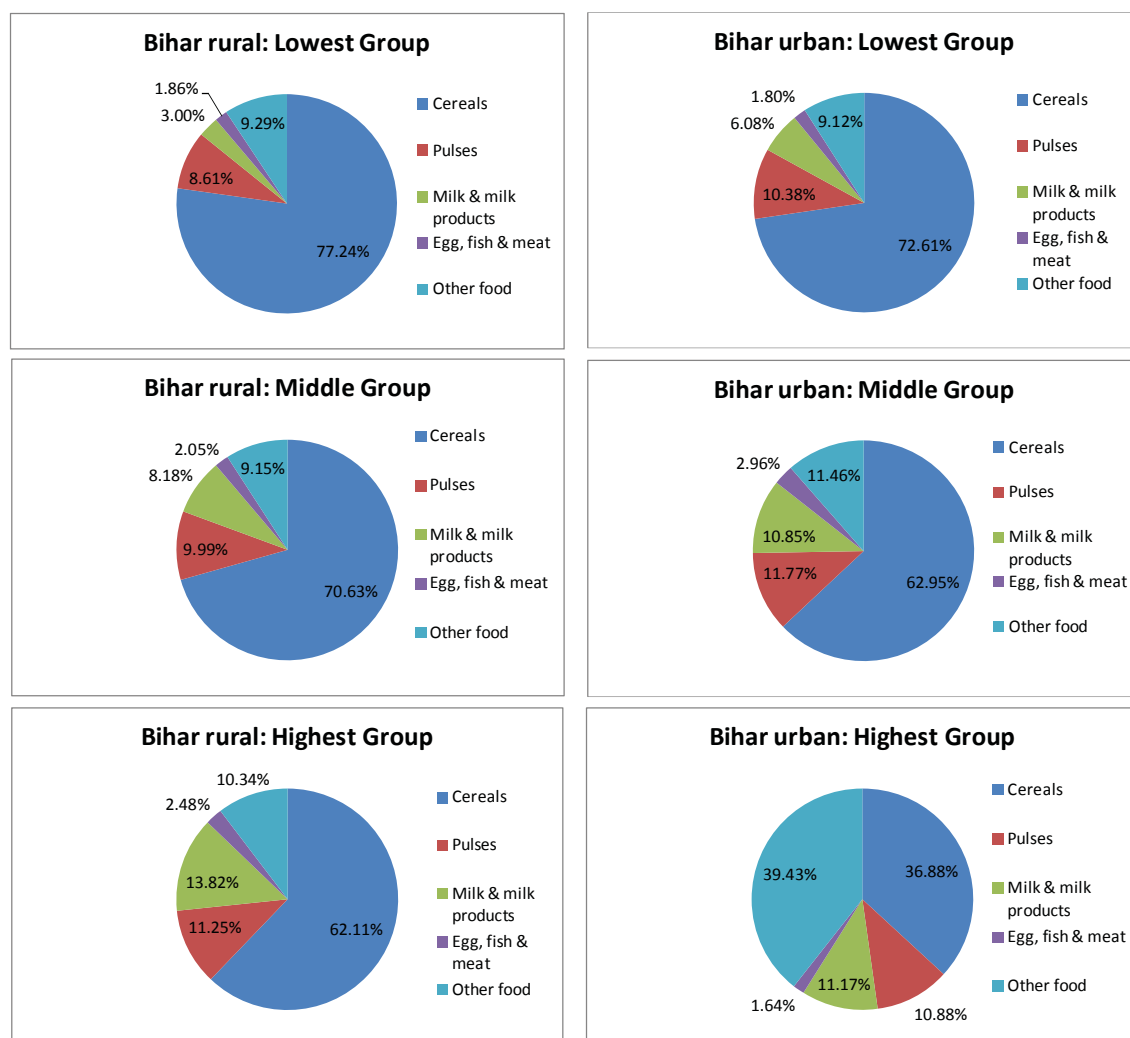


Figure 3.11 Percentage of protein supply from food groups in Bihar: rural and urban sector - year 2004

EAA availability status:

In 2004, the supply pattern of EAAs in both rural and urban Bihar was found to be better than in rural Kerala, Punjab and Gujarat. Though the per capita income in Bihar was lowest among the selected four states, there was less deficiency estimated in the lower MPCE classes in terms of the supply of EAAs. This must be related to the quantity and type of protein consumed in rural Bihar. In urban Bihar, in MPCE class 3, inadequate supply of lysine was estimated though the intake amount of protein per capita per day was higher than the recommended amount i.e. 56 g. This finding showed the opposite relationship between amount of protein intake and availability of individual EAAs to that observed in the case of Kerala. This finding suggested that a person can be deprived of receiving all the EAAs in adequate amount though he is consuming the recommended amount of protein. So quality and combination of EAAs and their bioavailability in a food item is more important for proper nutrition. In the case of Bihar, higher intake of cereal protein might be the reason for this finding.

Punjab

Turning to the state of Punjab now, cereals and milk & milk products were observed to be the major source of protein in both areas. Egg, fish & meat intake was very limited in the daily diet of the population in the rural area as well as in the urban area of the state.

EAA availability status:

Lysine was mainly estimated to have lower supply to the population in rural Punjab among most of the MPCE classes. In 2004 up to MPCE class 7, a lower supply of lysine was observed than the recommended quantity for adults.

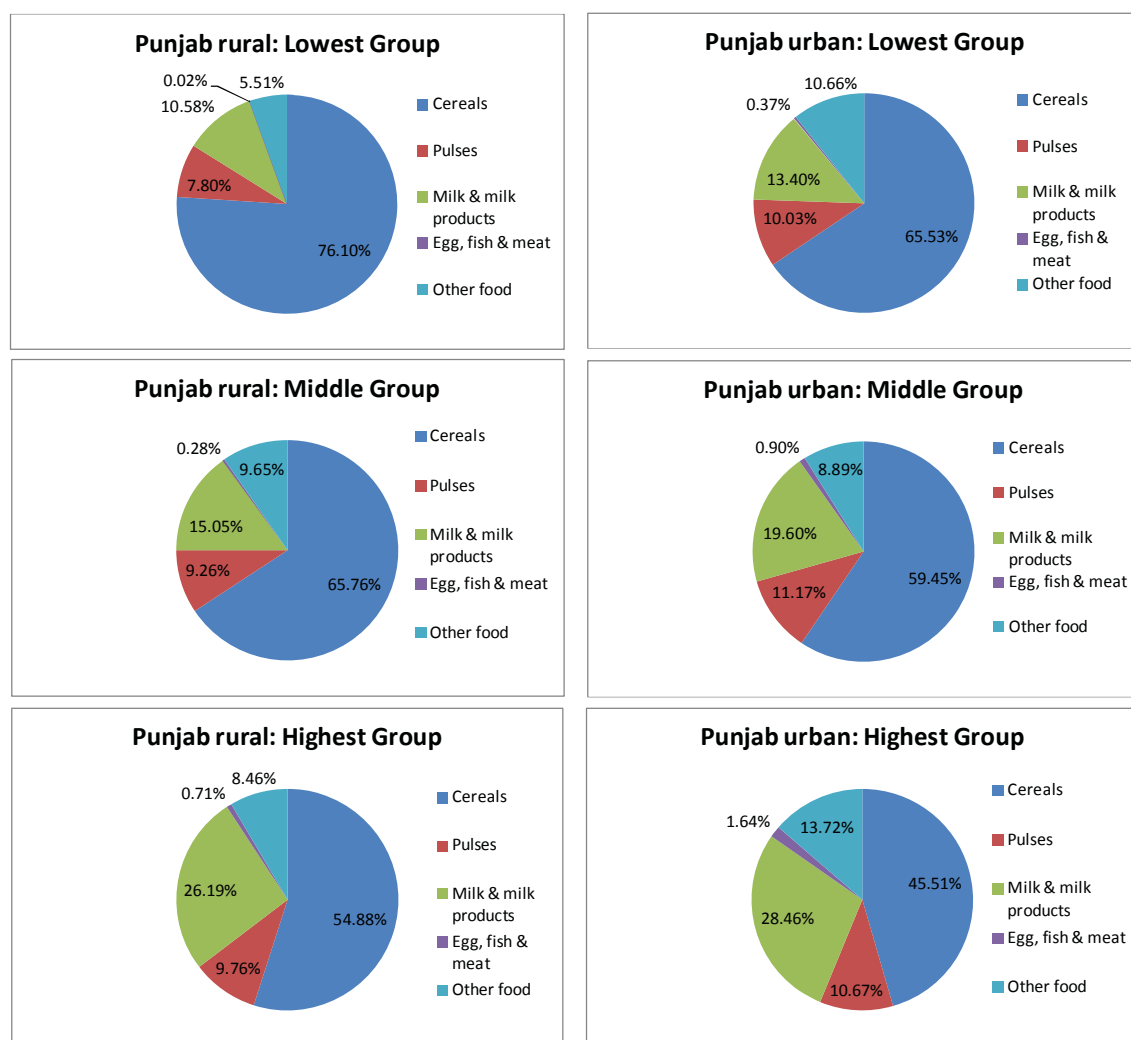


Figure 3.12 Percentage of protein supply from food groups in Punjab: rural and urban sector - year 2004

3.5.2 Lysine availability in the selected states according to the MPCE classes

In all the states, lysine deficiency was mainly estimated in different MPCE classes both in rural and urban sector of the selected states in this study. Figure 3.13 and 3.14 shows the lysine availability status based on the MPCE class in rural and urban sectors in the selected states in year 2004.

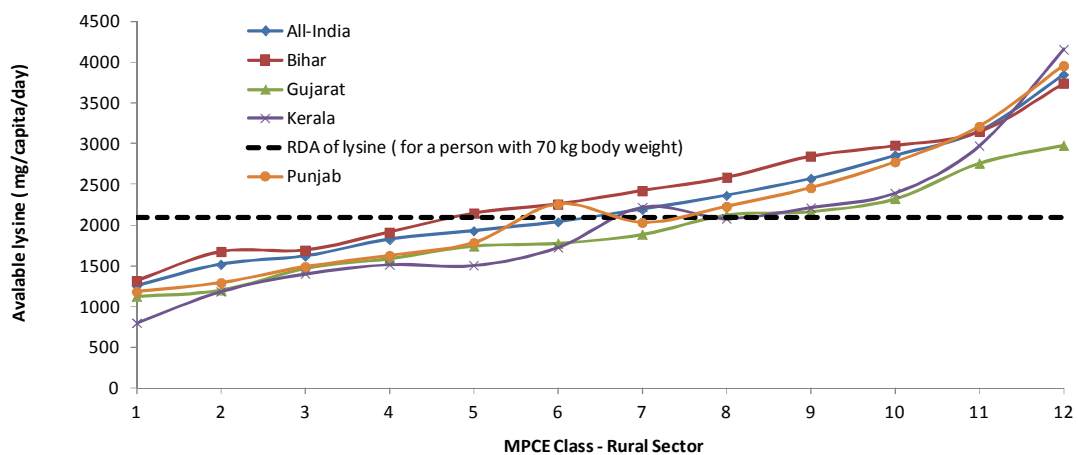


Figure 3.13 Lysine availability vs. MPCE class (rural sector) - year 2004

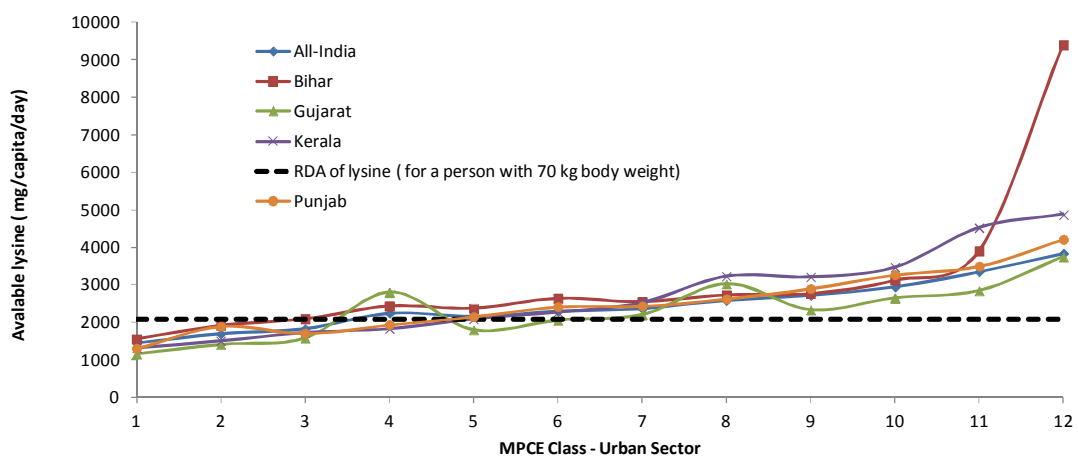


Figure 3.14 Lysine availability vs. MPCE class (urban sector) - year 2004

3.5.3 Changes in protein supply pattern over the years in India

In the case of the per day per capita protein consumption in the urban areas of the all-India population between 1993/1994 and 2004/2005 no change was observed. It was around 57 grams; although during this same time period, in the rural area it had decreased from 60.2 grams to 57 grams (NSS, 2004/2005).

In Kerala, the average supply of protein to the population had increased in both rural and urban areas. However, in the other three states, there had been a decrease in the supply of protein in the rural areas, most noticeably in Punjab, by 10.71%. In these three states the supply of protein in the urban areas had increased over the period (table 3.6). The sharp decline in rural Punjab is not easy to explain, Punjab being one of the more affluent states of India.

Although per capita incomes of both Kerala and Gujarat were higher than the Indian average (figure 3.3), the protein supply in the rural sectors of these two states were below the all-India supply of protein in 2004. In the case of Punjab protein supply was higher than the all-India supply, even though it had declined as noted above. In the case of Bihar the opposite was observed. With a lower per capita income than the Indian average, the state had more protein supply to its population in both the rural and urban sector; mainly cereals contributed more than 72% and 60% of protein to the population in the rural and urban sector respectively.

It is recommended by the WHO that at least 10-15% of the total energy intake must be supplied by protein in an individual person's daily food intake (WHO, 2003a). Protein intake data of all the selected states and the all-India data (both in rural and urban areas), confirmed that the WHO recommended norm was achieved (table 3.6).

In the case of India as a whole, the minimum required calories consumption in urban and rural areas should be 2100 kcal/capita/day and 2400 kcal/capita/day respectively as Deaton & Dreze (2009) states, quoting government sources (Deaton and Dreze, 2009). As per table 3.6, the following observations can be made based on calories requirements and actual calories intake patterns in India:

-
- The all-India intake of calories had fallen over the period by 4.92% and 2.46% respectively in rural and urban areas.
 - In 1993, only Punjab out of the four states in the rural sector had achieved the recommended intake of calories. The other three states had lower intakes than the all-India rural average intake of calories also. The all-India average intake of calories was below the minimum requirement of 2400 kcal/capita/day.

In 2004, the average intake of calories for all the states and for all-India was below the required amount in rural areas. Only rural Punjab and rural Bihar had more calories on a daily basis than the all-India average intake. Only rural Kerala had improved its intake of calories; the other three states had lower intake of calories in 2004 than in 1993. It is somewhat curious that, following a period of faster economic growth, nutritional standards as measured by calories intake have fallen in a number of states.

- In 1993 only urban Bihar had achieved the recommended intake of calories i.e. 2100 kcal/capita/day. The all-India average intake of calories had not achieved the minimum requirement either. Urban Gujarat and urban Kerala had lower intakes of calories even than the all-India average intake. Urban Punjab had a higher supply than the all-India average figure, even though it was lower than the target at 2100 kcal/capita/day.

In 2004, urban Bihar and urban Punjab had achieved the target, whereas India as a whole was managing only 2020 kcal/capita/day intake, having reduced by 51 kcal/capita/day since 1993. Urban Kerala had increased intake of calories in 2004, but in urban Gujarat it had further decreased by 2004.

As detailed in this section, the faster pace of growth of the Indian economy since the mid-1990s has brought in its trail many noticeable changes in the lives of Indians, both rural and urban.

Table 3.6 Daily per capita protein intake (g) and calories intake (Kcal) in selected states in rural and urban area and compared with all-India data

Area	Per capita per day Protein supply (grams)		% of change in supply of protein	Per capita per day intake of Total Calorie (Kcal)		% of change in supply of protein	% of calorie supply from protein	
	Year 1993	Year 2004		Year 1993	Year 2004		Year 1993	Year 2004
India	Rural	60.2	-5.32	2153	2047	-4.92	11.18	11.14
	Urban	57.2	-0.35	2071	2020	-2.46	11.05	11.29
Kerala	Rural	50.8	9.06	1965	2014	2.49	10.34	11.00
	Urban	52.4	8.21	1966	1996	1.53	10.66	11.36
Gujarat	Rural	55.6	-4.14	1994	1923	-3.56	11.15	11.09
	Urban	54.9	4.37	2027	1991	-1.78	10.83	11.51
Bihar	Rural	60.2	-3.99	2115	2049	-3.12	11.39	11.28
	Urban	61.4	1.30	2188	2190	0.09	11.22	11.36
Punjab	Rural	74.7	-10.71	2418	2240	-7.36	12.36	11.91
	Urban	61.8	2.59	2089	2150	2.92	11.83	11.80

3.6 Conclusion

As the evidence suggests, the available food has not been distributed evenly in the selected states of India. The paradox of the increase in food availability and persistent hunger stems from income inequality both in the rural and urban sectors of the selected states. The gap in per capita incomes across the selected states has grown over time. Even in the states where per capita incomes are relatively high, hunger continues to be a major problem, largely due to the skewed income distribution. Furthermore, the low income MPCE classes continue to struggle to purchase nutritionally adequate foods. The uneven pace of India's economic growth, with rising inequalities and unemployment have had significant effects on how people consume food generally, and different types of food specifically.

Interstate migration of people increased over the period of rapid economic growth as labourers moved in search of work from one state to another. They carried with them their food habits which in many cases would be different from those of the native populations of the states to which they had gone. The observed changes to the consumption patterns would at least partly have been influenced by this factor. Even within a state, migration from the rural areas to the urban in search of work has accelerated as agricultural growth has been slow relative to the growth of the industrial and services sector over the period since the 1990s. This has influenced the dietary patterns in line with what has come to be termed 'nutrition transition', as rural migrants adjust to the practices of their urban counterparts (Tripathi and Srivastava, 2011).

The following comments can be made:

- The source of protein and not the quantity of protein necessarily determines the level of availability of EAA to an individual.
- Cereals continue to constitute the main category of food consumed in both rural and urban India. There are large rural-urban and inter-state differences in the monthly consumption of even this basic food item.
- In addition to the specific factors and forces influencing the observed changes in India's dietary patterns discussed above, there are some

other, more general, influences which merit consideration also. First, over many years, in respect of basic food grains, India had maintained a Public Distribution System (PDS) which guaranteed access to the availability of these food items at (subsidised) low prices. Starting in 1997, this scheme was altered and made more 'targeted', by introducing a somewhat arbitrary distinction between what was termed above-the-poverty-line (APL) and below-the-poverty-line (BPL) households. It was the latter that still qualified for cereals at low prices supplied under the PDS. This made many households face higher relative prices of their daily staple food, which would have made them substitute foods of different categories to keep within household food budgets (Ray, 2008)

Considering the expected higher number of vegetarian population in Gujarat than in Punjab and the fact that some plant proteins contain lower proportions of some essential amino acids compared with animal proteins, and the protein digestibility scores for plant proteins are lower than those for animal proteins, it can be concluded that protein nutrition may also be compromised in vegetarians. Vegetarians need to consume more protein daily than the recommended amount suggested by the WHO to support the supply of EAAs in the adequate amount to the body (Kniskern and Johnston, 2011).

4.0 Healthy aging and need of quality protein and essential amino acids

4.1 Introduction

Over the last century, there has been a clear shift in the age distribution of the world's population. The world population is aging globally, in developed as well as in developing countries (UN, 2010, Oeppen and Vaupel, 2002a). According to the latest UN report, globally the population of older persons is increasing at a rate of 2.6% annually, whereas the whole population is growing at 1.2% annually. It is projected that there will be approximately 2 billion elderly people (that is, those aged 60 years or over) in the world in 2050 (UN, 2010). This demographic transition has created a need for a more complete understanding of aging process and the role of nutrition for healthy aging. Aging is a continuous ongoing progressive process of damage accumulation. It is associated with reduction in muscle mass and function, and reduced physical activity. The loss of muscle mass with aging is known as sarcopenia and the loss of muscle mass appears to begin relatively early, at about 30 years of age, and continues. With the ageing of the population globally, the prevalence of sarcopenia is likely to increase. Sarcopenia is accelerated by inadequate diet, mainly due to lack of quality protein in optimal quantity and lack of essential amino acids. Protein is recognized as the key macronutrient responsible for safeguarding against sarcopenia, but the debate over the amount of protein that needs to be consumed on daily basis by an elderly individual is still going on.

In the last two chapters we concluded that the quality of protein is more important than the quantity of it to maintain an adequate supply of essential amino acids to the body. Some of the assumptions made in these two chapters to estimate the availability of essential amino acids to an individual are not particularly realistic. For example, no allowance for age or sex is made, and it assumes an average bodyweight of 70 kg. It must be remembered that an individual's ability to consume is dependent on his/her age, sex, physical condition and income. In chapter three the impact of income and economic

disparity on the consumption pattern of protein and availability of the essential amino acids are discussed and documented. In this chapter, we discuss the nutritional needs of the growing ageing population in terms of the role of dietary protein and essential amino acids with particular reference to sarcopenia.

4.2 Population aging and demographic trends

The population of seniors is not homogenous and depends not only on age but also on gender, lifestyle, health, socioeconomic factors and constitutional influences. Medical advances and improvements in public health, particularly clean water, immunization and antibiotics, and other improvements in lifestyle such as better housing are allowing a growing proportion to survive into the oldest old category, that is, those aged 80 years or over (Partridge, 2010, Shephard, 1997).

“The ageing process is, of course, a biological reality which has its own dynamic, largely beyond human control. However, it is also subject to the constructions by which each society makes sense of old age. In the developed world, chronological time plays a paramount role. The age of 60 or 65 years, roughly equivalent to retirement ages in most developed countries, is said to be the beginning of old age. In many parts of the developing world, chronological time has little or no importance in the meaning of old age. Other socially constructed meanings of age are more significant, such as the roles assigned to older people; in some cases it is the loss of roles accompanying physical decline which are significant in defining old age. Thus, in contrast to the chronological milestones which mark life stages in the developed world, old age in many developing countries is seen to begin at the point when active contribution is no longer possible” (Gorman, 1999).

It is stated in the United Nations latest report ‘World Population Aging 2009’ that *“A population ages when increases in the proportion of older persons (that is, those aged 60 years or over) are accompanied by reductions in the proportion of children (persons under age 15) and then by declines in the proportions of persons in the working ages (15 to 59)”* (UN, 2010).

Both the number and the proportion of older persons are growing in virtually all countries, and these trends are likely to continue worldwide. For example, in 2009 Japan had the highest percentage of population aged 60 or over, at 29.7 %, followed by Italy at 26.4%, whereas in Qatar it was only 1.9%. It is expected that the proportion of population aged 60 or over will be 22% in 2050 compared to 11% in 2009. Figure 4.1 shows the percentage of elderly population in 2050 in major continents. By 2050 it is projected that there will be more than 1.4 billion elderly people in Asia. In figure 4.2, the percentage of elderly population in each continent is shown. Europe will have the highest proportion of elderly people in its total population, at 41.82 %.

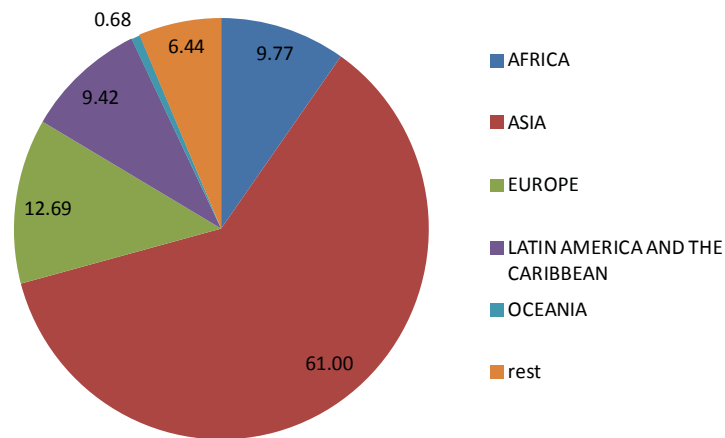


Figure 4.1 Forecast percentage of elderly population in 2050

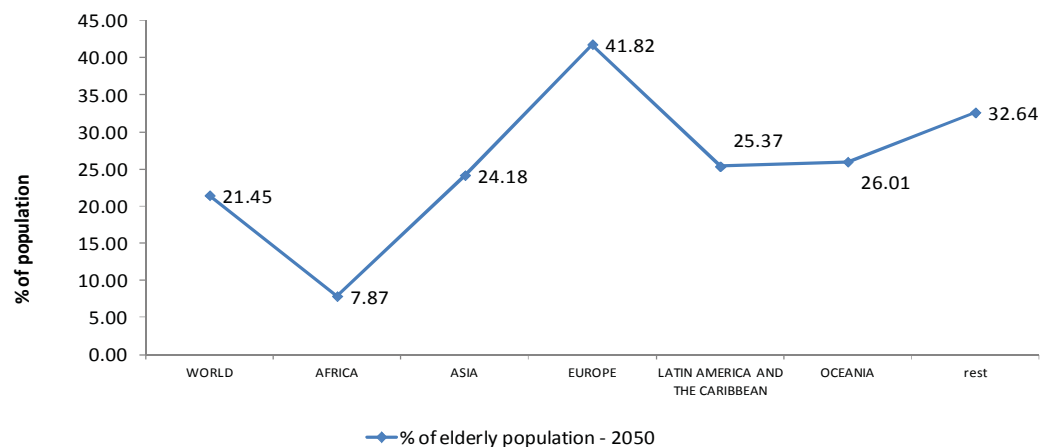


Figure 4.2 Forecast percentage of elderly population in different continents, in 2050

The population of elderly persons is itself ageing. Among those aged 60 years or over, the fastest growing population is that of the oldest-old. It is projected that by 2050, this ratio is expected to increase to nearly 1 person aged 80 years or over among every 5 older persons aged 60 years or over, whereas the present ratio is 1:7 (UN, 2010).

It is reported that globally the total fertility has dropped from 4.9 children per woman in 1950-55 to 2.6 in 2005-2010 and it is projected to be 2.0 children per woman in 2045-2050.

On the other hand mortality has continued to decline. Since 1950, life expectancy at birth increased globally from 46.6 years in 1950-1955 to 67.6 years in 2005-2010 (UN, 2010). This increase in life expectancy is due to a general improvement in living standards and organized efforts to control the spread of infectious disease and further due to reductions in infant and child mortality in the late 19th and early 20th century (Wilmoth, 2000). Over the past 150 years, life expectancy in many developed countries has increased at a relatively constant rate, and the increase in life expectancy is expected to continue (Christensen, 2009). Oeppen and Vaupel (2002) showed that best-practice life expectancy (the highest value recorded in a national population) has risen by 3 months per year since 1840 (figure 4.1) and average life expectancy is forecasted to be 96.4 years in 2050 (Oeppen and Vaupel, 2002b, Christensen, 2009).

Many countries, although experiencing steady increases in longevity, are suffering from stagnation of healthy life expectancy and a greater burden caused by chronic conditions and disability. For example, in the UK between 1991 and 2001, life expectancy increased by 2.2 years but only 0.6 of those years were healthy years (WHO, 2003b, Franco et al., 2009). This population ageing can be seen as a success story for public health policies and for socioeconomic development, but it also challenges society to adapt, in order to maximize the health and functional capacity of older people as well as their social participation and security.

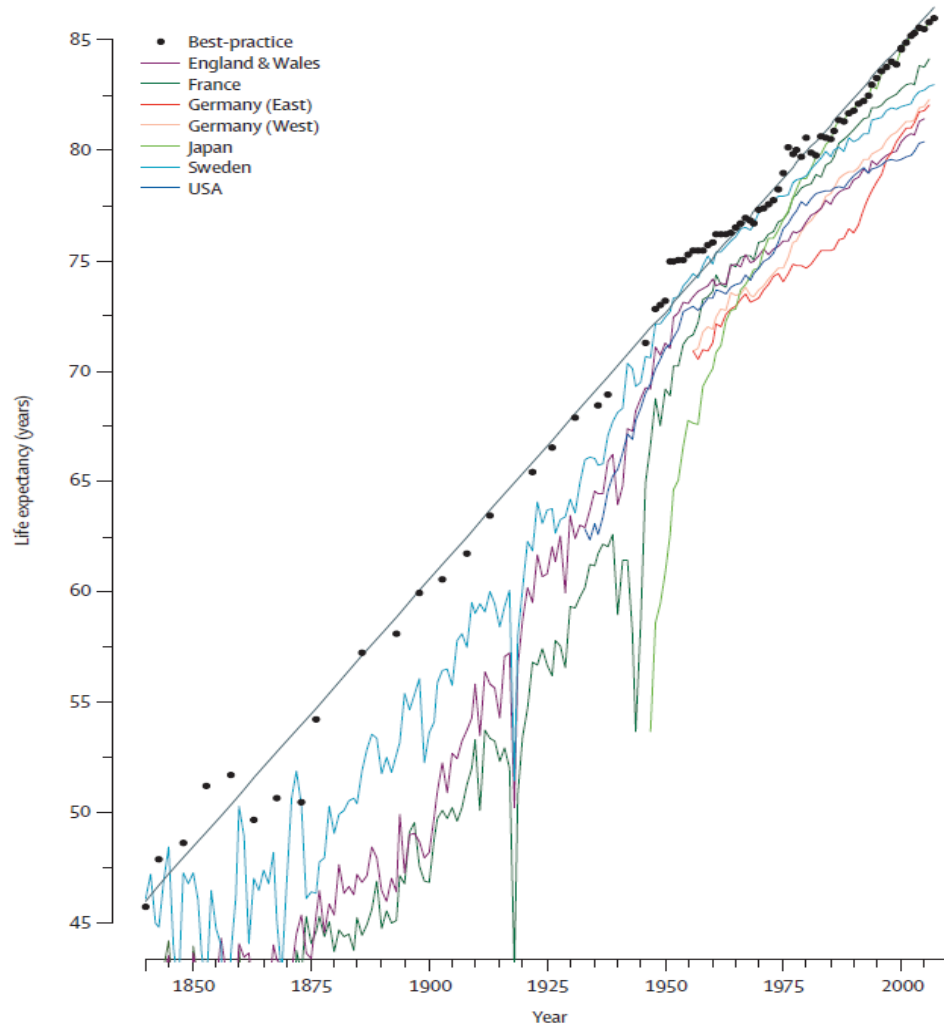


Figure 4.3 Best-practice life expectancy and life expectancy for women in selected countries from 1840 to 2007 (Christensen, 2009)

4.3 Sarcopenia and the aging population

4.3.1 Overview

The human aging process deteriorates the condition of many organs and tissues and also affects many bodily functions and movements. The aging process is characterized by changes in body composition with a progressive loss of muscle and bone mass, strength and metabolic function. The loss of muscle with aging is the result of a chronic imbalance between muscle protein synthesis and breakdown. The age-related loss of muscle protein synthesis is referred as 'sarcopenia'. There are many causes of sarcopenia and an

understanding of the complex mechanism is evolving. This degenerative loss of skeletal muscle occurs at a rate of 3 to 8 percent per decade after the age of 30 and accelerates with advancing age. Chronic muscle loss is estimated to affect 30% of people older than 60 years and 50% of those older than 80 years (Holloszy, 2000, Dutta and Hadley, 1995, Wolfe, 2006, Paddon-Jones et al., 2008, Aniansson et al., 1983, Baumgartner et al., 1998). With the ageing of the population the prevalence of sarcopenia and the resulting burden of disability, are likely to increase. Strategies to prevent sarcopenia are, therefore, of considerable importance. There is a need of public awareness as simple health strategies can be effective.

4.3.2 Understanding of sarcopenia

Normal ageing is accompanied by progressive reductions in muscle quality as well as quantity. There is not only a decrease in muscle cross-sectional area and mass but also infiltration of muscle by fat and connective tissue occurs and the number and size of type 1 and 2 fibres decrease (Lang et al., 2009). The age-related skeletal muscle mass loss is further accelerated by a combined effect of inadequate optimal diet (Campbell and Leidy, 2007) and a sedentary lifestyle (Nair, 2005).

The main causes of sarcopenia, include: (1) reduction in anabolic hormones such as testosterone, oestrogen, growth hormone and insulin-like growth factor-1; (2) increased inflammatory activity as measured by cytokines (IL-6 or TNF-alpha) which contributes to muscle catabolism; (3) accumulation of free radicals with increasing age, which contributes to oxidative stress; (4) changes to mitochondrial function of muscle cells; and (5) increased apoptotic activity in the myo-fibres affecting muscle function (Kamel, 2003, Campbell and Leidy, 2007).

4.3.3 Prevention and treatment

Although the beginning of sarcopenia may be inevitable for some persons, it may be avoidable and reversible for others. Researchers have identified two measures that can play a role to fight against sarcopenia, they are diet and exercise. A number of research works support the efficacy of physical activity and resistance exercise to maintain the muscle mass and bodily functions in

aging populations (Chin et al., 2008, Fielding, 1995, Sugawara et al., 2002). However, in the case of many elderly individuals, the ability to perform exercise is compromised due to disease and disability. In this case, daily high-quality protein intake, having a good combination of EAA, can be helpful to slow down or prevent the muscle protein loss. The need for the right amount of protein intake and ideal EAA combination is discussed in sub point 4.5.

4.3.4 Role of exercise

It is now well recognized that exercise, particularly resistance exercise can be used to counteract age-related muscle loss by increasing the number and cross-sectional areas of skeletal muscle fibres and can increase strength even in very old people (Evans, 2000). A number of studies have evaluated the usefulness of exercise to fight against sarcopenia.

- In postmenopausal women high-intensity strength-training exercises were found to be an effective and feasible means to conserve bone density while improving muscle mass, strength, and balance (Nelson, 1994).
- Long-term weight training was proved to be a safe mode of exercise for the elderly. Continued improvement in dynamic strength was reported in 142 elderly people (60-80 years of age) who did weight training for 42 weeks per annum for two years (McCartney, 1996).
- Some studies have documented that resistance training has benefits even after periods of detraining (Ivey, 2000, Henwood and Taaffe, 2008).
- The influence of resistance training on muscle power was examined on 17 men and women aged 56-66 years, and their responses were compared to 15 men and women aged 21-30 years. This study concluded that individuals can still improve muscle strength at the age of 60 years, with men showing greater gains than women (Jozsi, 1999).

4.4 Quality protein intake and the health of elderly people

Different protein sources were found to stimulate muscle protein synthesis in varying degrees. First and the most important factor is the amount of essential amino acids in the protein, in particular, leucine. Second, differences in

digestibility and bioavailability of certain protein-rich foods may influence muscle protein synthesis (Paddon-Jones et al., 2008). It is reported in many studies that protein intake and efficiency of use decrease with increasing age and the key contributing factors are more expensive food group, increased satiety, dentition and chewing difficulties, changes in the digestive system, gastric emptying and splanchnic uptake (Rousset et al., 2003, Paddon-Jones et al., 2008).

4.4.1 Established recommendations for dietary protein and essential amino acid for the elderly population

Currently, there is no agreement on whether dietary protein needs change with advancing age. For adults (all men and women aged 19 years and older) the recommended dietary allowance (RDA) for protein is 0.8 g protein per kg body weight per day according to the Food and Nutrition Board of the United States National Academy of Science (Wolfe et al., 2008, WHO, 2007). The Institute of Medicine has recommended the same RDA (Paddon-Jones et al., 2008). It is recommended in the report of the FAO/WHO/UNU expert consultation, published in 2007 that the essential amino acid requirement for elderly people should be the same as for adults, as the current acceptable methodologies are not apposite to make a separate set of essential amino acid values for elderly people (WHO, 2007). The recommended EAA pattern for adults as well as for the elderly population can be found in table 2.4, in chapter 2.

4.4.2 New researches and recommendations of higher intake of protein for the elderly population

It has been reported that the RDA of protein was insufficient to meet the metabolic and physiological requirements of elderly and concluded that the dietary protein requirement was determined by the health status of an individual (Campbell et al., 2001). The RDA for protein for the elderly population has been of great interest in the past few years. In many studies it has been recognized that this amount of protein in daily food intake is not enough to promote optimal health or protect aged people from muscle and bone loss, as well as weight loss (Houston, 2008, Wolfe and Miller, 2008, Walrand and Boline, 2005, Rapuri et al., 2003, Kerstetter et al., 2005, Hunt et al., 2009, Arnal et al., 1999). In a 10

year longitudinal study in New Mexico, elderly women with a protein intake of 1.2 to 1.76 g/kg per day were found to have fewer health problems than women consuming the recommended RDA amount of protein i.e. 0.8 g/kg per day (Vellas et al., 1997).

It is suggested in many studies that an intake of 1.0-1.5 g protein per kg body weight per day or about 15-20% of total caloric intake is essential to preserve proper nitrogen balance in the healthy elderly instead of the recommended RDA value (Morais et al., 2006, Wolfe et al., 2008).

Increasing dietary protein intake in humans results in higher urinary calcium (Kerstetter et al., 2003). Previously it was concluded, based on the increased urinary calcium factor, that a high protein diet is detrimental to the skeleton and to bone health (Walker and Linkswiler, 1972, Dawson-Hughes, 2003). Recent studies have concluded that this hypothesis is wrong (Hunt et al., 2009, Kerstetter et al., 2005). Three recent diet-controlled studies have suggested that high protein diets were not detrimental to bone health but rather are beneficial (Hunt et al., 2009, Kerstetter et al., 2005, Roughead et al., 2003).

Moderate protein diets of 1.0 to 1.5 g/kg per day were shown to be associated with normal calcium homeostasis without altering bone metabolism (Kerstetter et al., 2005). It can be concluded that increasing the RDA from 0.8 g/kg per day to 1.5 to 1.6 g/kg per day may result in better muscle and bone health in elderly individuals. Although this level is approximately twice the current RDA, it is still within the acceptable range of intake (10–35% of total calories). It remains unclear whether the relationship between dietary protein and muscle and bone health is linear in the range of 0.8 to 1.6 g/kg per day. Given the available data, increasing the RDA to 1.0 to 1.2 g/kg per day would maintain normal calcium metabolism and nitrogen balance without affecting renal function. Therefore, increasing the RDA to 1.0 to 1.2 g/kg per day for elderly people may help the elderly population to maintain a good health while longer-term protein supplement trials still to be conducted.

4.4.3 Role of essential amino acids

The main amino acid reservoir in the body is skeletal muscle, which contains 50–75% of all proteins in the human body (Timmerman and Volpi, 2008). It is recognized that essential amino acids (EAA) are mainly accountable for the amino acid stimulation of muscle protein anabolism in the aged people (Volpi et al., 2003). According to recent studies it is considered that 15 gram of EAAs is required for maximum stimulation of muscle protein synthesis (MPS) (Wolfe, 2002). This indicates that quality of protein is very important in the diet of elderly.

In another recent study it is recommended to have a moderate amount of protein of high biological value during each meal to maintain muscle mass in the elderly. This is based on the finding that higher doses (10-15 g) of essential amino acids are capable of stimulating muscle protein synthesis in aged people (Katsanos, 2005, Paddon-Jones and Rasmussen, 2009). Preliminary data from a recent randomized controlled trial indicate that it is more important to ingest a sufficient amount of high-quality protein (25–30 g) with each meal rather than 1 large bolus, because more than 30 g in a single meal may not further stimulate muscle protein synthesis (Symons, 2009). It is also recognized in very recent studies that intake of whey protein brings beneficial effects to muscle protein anabolism in the elderly. Further, ingestion of intact whey protein has provided a greater anabolic benefit than ingestion of its essential amino acids alone. These studies have suggested that whey protein is more than just a simple source of essential amino acids with respect to providing a stimulus for enhancing muscle protein anabolism in the elderly (Katsanos, 2009, Katsanos et al., 2008).

There is a general agreement that the essential amino acid leucine increases protein anabolism and decreases protein breakdown (Paddon-Jones and Rasmussen, 2009). Leucine-rich food sources include legumes such as soybeans and cowpea, and animal products such as beef, fish and dairy proteins (whey protein). It is reported that amino acid supplements without adequate leucine do not stimulate protein synthesis (Rieu, 2007, Hayes and Cribb, 2008). Leucine has recently been acknowledged as especially important as a signalling molecule and a building block for muscle. Rat studies show that

leucine can directly stimulate muscle protein synthesis through increasing mRNA translation (Anthony et al., 2000). Insulin and leucine are anabolic stimuli for muscle and both share a common pathway of action via activation of a kinase known as mTOR. mTOR is the main regulator of cell growth and acts by phosphorylating target proteins involved in mRNA translation. Because insulin sensitivity decreases with age, one possible mechanism by which amino acids (mainly leucine) might improve muscle mass is by providing another anabolic stimulus to activate the mTOR controlled pathway (Gaffney-Stomberg et al., 2009).

No differences exist in protein balance in the elderly relative to the young following administration of either 30 g of beef protein or 15 g of essential amino acids (Paddon-Jones et al., 2004). However, when 6.7 gram of EAA is given, the overall protein synthetic response is reduced in the elderly relative to the young (Katsanos, 2005). This anabolic resistance is due to a decrease in leucine sensitivity and may be overcome by increasing the proportion of this amino acid in the diet. For example, when a 6.7-g bolus of EAAs enriched with leucine (46% leucine compared to the normal 26% leucine found in whey protein) is given to the elderly individual, protein synthesis is fully restored (Katsanos, 2006).

4.4.4 Increase of RDA of protein for the elderly and additional protein requirements

The aging population projection in 2050 and increased RDA of protein for the elderly population together will increase the demand of protein for human consumption. Assuming that the weight of an individual elderly person regardless of sex and country is 70 kgs, we can estimate the future extra demand of protein. In 2009, the total world population was 6.8 billion including 11% aged population. Per day all elderly people in 2009 required 41,888 tonnes of protein based on current recommended RDA i.e. 0.8 g/capita/day. In 2050, the projected world population will be 11 billion; including 22% aged population, i.e. 2.4 billion elderly people. Per day all elderly people in 2050 will require 136,293 tonnes of protein based on the current RDA. If the RDA for protein is increased from 0.8 g/capita/day to 1 g/capita/day or 1.2 g/capita/day

for the elderly population, then in 2050, instead of 136,293 tonnes of protein per day, we will require 25% or 50% more protein respectively (figure 4.1).

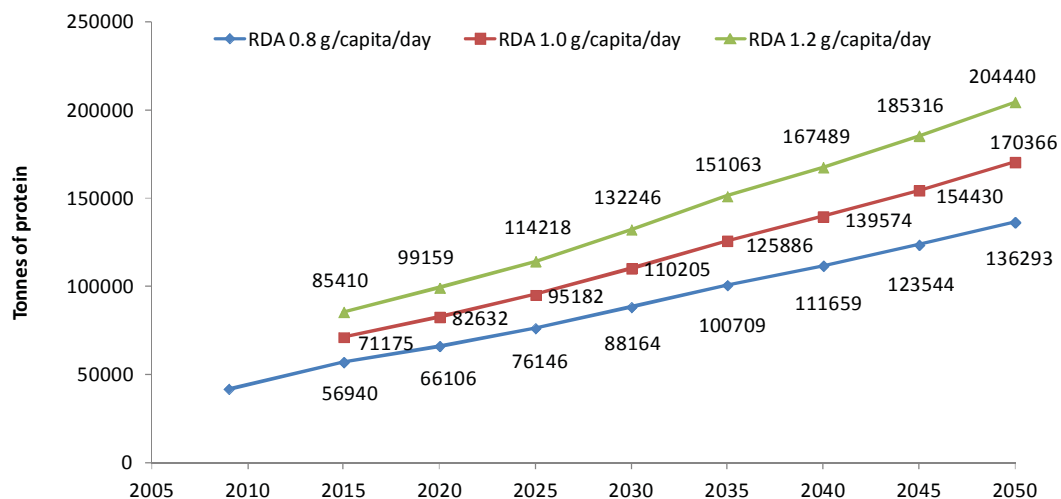


Figure 4.4 Additional requirements for protein in 2050 depending on the RDA value for the elderly population

4.5 Conclusion

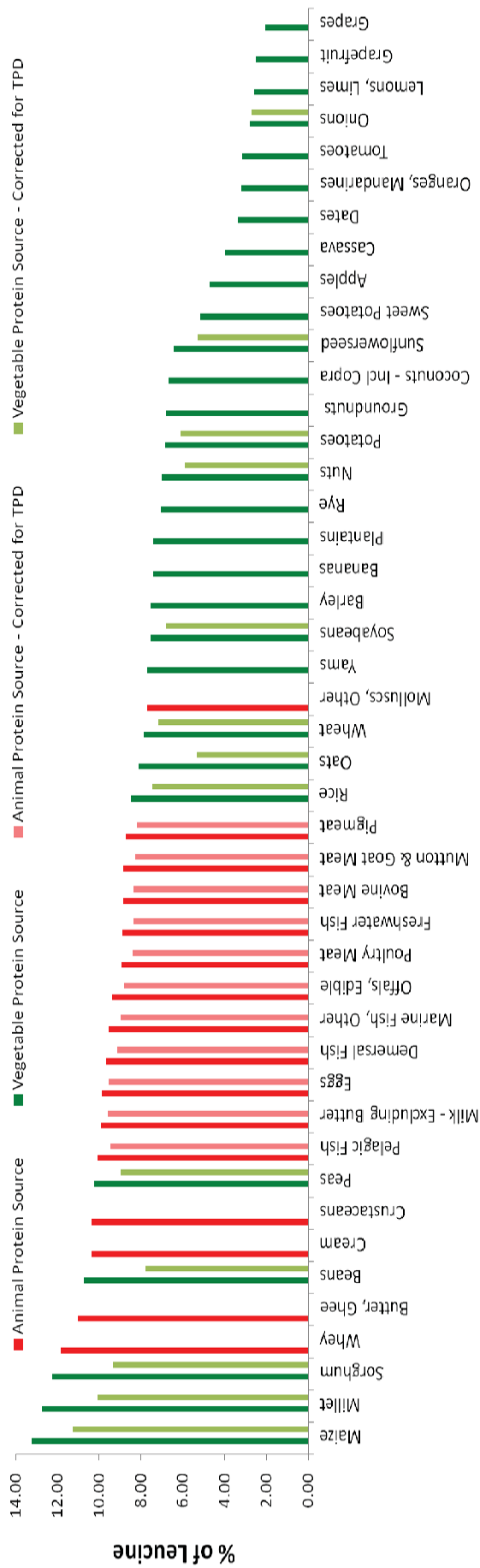
Considering the fact that the proportion of population aged 60 or over will be 22% in 2050 compared to 11% in 2009, the nutritional requirement of elderly generation is of great importance. As populations in the world continue to age, diagnosing, treating, and preventing age related diseases will be progressively more important to the health and well-being of modern societies. It can be concluded from the discussion that

- The current established RDA of protein does not take into account the changes which occur with age, such as reduced muscle mass, increased fat mass, changes in food intake, physical activity and more frequent illness. Increasing the RDA to 1.0 to 1.2 g/kg per day would maintain normal calcium metabolism and nitrogen balance without affecting renal function. Therefore, increasing the RDA to 1.0 to 1.2 g/kg per day for elderly people may help the elderly population to maintain good health.

However long-term protein supplementation trials have still to be conducted.

- Apart from quantity, quality of protein in terms of EAAs availability is especially responsible for increased protein anabolism and decreased protein breakdown in elderly people. Dairy proteins, especially whey proteins, a rich source of branched chain amino acids (mainly leucine), are capable of stimulating muscle protein synthesis, enabling the maximum retention of muscle mass. In figure 4.5, total leucine and bio-available leucine (corrected for true protein digestibility) content of the major protein sources are shown. Interestingly apart from whey (well known source of leucine), vegetable protein sources like maize, millet, sorghum and beans were found to be a rich source of leucine.
- The growing aging population needs special care to maintain a good health. To reduce the chances of sarcopenia proper nutrition needs to be provided to them; also exercise combined with a good food habit can help to reduce the muscle loss and can contribute to enjoy healthy aging.

g leucine in 100 g of protein vs. g bioavailable leucine in 100 g of protein



Identified Protein source

Figure 4.5 g. Leucine and g. bio-available leucine in 100 g. of protein in identified major protein sources (Souci et al., 2000)

5.0 Conclusions

Every human being needs an adequate amount of food. Food is important to individuals as well as to society, as it can provide nutrients and can generate income. Clearly, food production and consumption, technology and society cannot be considered to be independent of one another. It is obvious that food demand will increase with increasing human population, especially urbanization and per capita income growth will increase the consumption of animal, fish and dairy products in future. National diets are hugely different in different countries, mainly depending on cultural values, environmental condition, availability of food and per capita income. In addition, nutritionally optimal diets strongly depend on individual requirements and individual taste preferences. Thus, over 1 billion (~15%) people are currently undernourished (FAO, 2010a) , and 1.6 billion people are overweight (WHO, 2006) and still at the dawn of the 21st century we are a long way from achieving a world free from hunger and poverty.

5.1 Protein and essential amino acid availability and future needs

In chapter 2, we have estimated the availability of essential amino acids to the population in a range of different countries where protein intake is sub-optimal, based on the year 2007 FAOSTAT information about per capita protein intake. This study helps us to understand the present nutritional status of the population in those countries and the results of this study can assist in future planning for sustainable protein production. Cereals are recognized to be the main source of protein in many developing countries in this present study.

In 2007, according to the FAOSTAT information, the total protein supply to the world population was 74.36 g. per capita per day, approximately 18 g. higher than the recommended amount of protein (i.e. 56 g), needed to be consumed by a 70 kg individual. In 2007, in the developed world a higher protein supply was observed than the world average. On the other hand, in 2007, in Asia and Africa a lower protein supply was observed than the world average. Interestingly on average, in all the continents the total protein supply was higher than the recommended amount of protein so it can be concluded that according to 2007 FAOSTAT information, on average there was no shortfall of protein supply to

the 6.5 billion world population. But, this does not tell us the real story of protein. For example, within Africa the highest total protein intake is observed in northern Africa (83.58 g/day/capita) and it is lowest in middle Africa (34.32 g/day/capita). Considering 56 g. total protein per day per capita as the recommended amount to be consumed by an adult person, protein deficiency can be considered to exist in the population of middle Africa (Table 2.5).

In addition total protein does not necessarily meet the need for protein quality in the diet. Protein quality in developed countries is consistently higher than in developing countries. For example, in Australia + New Zealand, animal protein intake was 67.97% in 2007 and in the same year in Africa it was 21.58 % of the total protein consumed on daily basis.

According to the results of this study it is concluded in chapter 2 that a population lacking in protein supply can get all the required EAA in the required amounts if the consumed food pattern is designed properly. Out of the identified 40 countries, having a lower protein supply than 56 g. per day per capita, only 13 countries were estimated to receive an inadequate supply of essential amino acids. It was also possible to identify that lysine deficiency was most common in these 13 countries due to consumption of a high proportion of protein from cereals which are a poor source of lysine, because of both composition and poor digestibility. Thus an individual needs to take a greater quantity of low quality protein such as cereal protein to meet the recommended requirement of all the essential amino acids, particularly lysine.

Burundi was identified in this study as the perfect example of the concept that “the right combination of protein sources in the diet can be helpful to supply adequate levels of all the essential amino acids to a population”. For example, in the case of Togo, if we replace 5 g. protein from maize (the major protein source in the diet) by 5 g. poultry meat protein then an adequate supply of lysine can be achieved. In this study the availability and requirement of non-essential amino acids are not addressed, and it must be noted that the human body needs a minimum supply of total protein to produce the non-essential amino acids by various pathways.

In table 5.1, the additional amount of each bio-available EAA in the identified 13 countries (where an inadequate supply of EAA has been estimated) for the total population is tabulated, based on calculations made in chapter 2.

Table 5.1 The amount of additional bio-available EAA required (in kg per day) in selected countries. Data based on (FAOSTAT, 2007).

Countries	Histidine	Isoleucine	Leucine	Lysine	Methionine + Cystine	Phenylalanine + Tyrosine	Threonine	Tryptophan	Valine
Democratic Republic of the Congo	141.93	455.17	972.92	971.61	337.62	175.06	244.78	37.76	679.50
Liberia		0.22	17.12	30.90					1.51
Mozambique				163.36					
Haiti				36.45					
Guinea-Bissau				9.52					
Eritrea				52.93					
Zambia				74.25					
Togo				20.79					
Bangladesh				61.52					
Ethiopia				172.23					
Tajikistan				4.04					
Zimbabwe				4.48					
Yemen				6.01					
Total	142	455	990	1608	338	175	245	38	681

In table 5.2, in these identified 40 countries, the amount of additional bio-available protein requirement for the total population on a per day basis is tabulated. In this calculation, the assumptions made in chapter 2 and true protein digestibility values (table 2.1) of identified major protein sources were utilized. According to this table it can be concluded that in 2007, an additional 19,416 tonnes of protein per day would be required globally to provide the recommended amount of protein.

Table 5.2 The amount of additional bio-available protein required in selected countries, on a daily basis. Data from (FAOSTAT, 2007)

Countries	Per day per capita total bio-available protein intake (g)	deficiency	Total Population - (Both sexes)	Per day additional requirement of bio-available protein in each country (tonnes)
India	49.41	6.59	1,164,670,000	7675
Indonesia	50.22	5.78	224,670,000	1299
Bangladesh	43.66	12.34	157,753,000	1,947
Ethiopia	44.94	11.06	78,646,000	870
Thailand	49.62	6.38	66,979,000	427
Democratic Republic of the Congo	20.09	35.91	62,523,000	2,245
United Republic of Tanzania	43.02	12.98	41,276,000	536
Uganda	41.47	14.53	30,638,000	445
Democratic People's Republic of Korea	48.14	7.86	23,728,000	187
Yemen	47.28	8.72	22,269,000	194
Mozambique	33.14	22.86	21,869,000	500
Côte d'Ivoire	44.44	11.56	20,123,000	233
Sri Lanka	47.18	8.82	19,882,000	175
Cameroon	45.16	10.84	18,660,000	202
Madagascar	43.31	12.69	18,604,000	236
Angola	39.57	16.43	17,555,000	288
Malawi	48.11	7.89	14,439,000	114
Guatemala	47.4	8.6	13,354,000	115
Zimbabwe	46.79	9.21	12,449,000	115
Zambia	39.11	16.89	12,314,000	208
Dominican Republic	46.71	9.29	9,814,000	91
Haiti	35.45	20.55	9,720,000	200
Guinea	46.15	9.85	9,615,000	95
Bolivia (Plurinational State of)	45.96	10.04	9,524,000	96
Rwanda	40.89	15.11	9,455,000	143
Burundi	36.57	19.43	7,838,000	152
Tajikistan	48.36	7.64	6,727,000	51
Togo	41.04	14.96	6,300,000	94
Sierra Leone	44.03	11.97	5,420,000	65
Eritrea	35.7	20.3	4,781,000	97
Central African Republic	38.76	17.24	4,257,000	73
Occupied Palestinian Territory	45.84	10.16	4,017,000	41
Liberia	31.27	24.73	3,627,000	90
Congo	46.72	9.28	3,551,000	33
Gambia	46.82	9.18	1,616,000	15
Guinea-Bissau	36.64	19.36	1,541,000	30
Timor-Leste	41.48	14.52	1,064,000	15
Comoros	38.73	17.27	830,000	14
Suriname	48.87	7.13	510,000	4
Solomon Islands	42.95	13.05	498,000	6
Per day additional requirement of protein in all the countries (tonnes)				19,416

In table 5.3, additional bio-available amount of the major protein sources (major protein sources were as identified in chapter 2) to supply adequate amount of lysine to each person in the identified 13 countries on daily basis is shown as per 2007 FAOSTAT data. The quantity of any one of the protein sources in this table alone is enough to secure the lysine deficiency gap in the daily diet of an individual in each country. True protein digestibility (TPD) values of each protein source from table 2.1, except for cassava (the TPD value of cassava is not available) was utilized for this calculation.

Table 5.3 The additional bio-available amount of the major protein sources required (in MT per day) in selected countries. Data based on (FAOSTAT, 2007).

Countries	Additional bio-available protein required (in MT per day)			
Democratic Republic of the Congo	Cassava	Maize	Wheat	Freshwater Fish
	23.20	36.26	32.91	10.18
Liberia	Rice	Wheat	Cassava	
	0.94	1.05	0.74	
Mozambique	Maize	Wheat	Rice	Sorghum
	6.10	5.53	4.98	9.14
Haiti	Maize	Wheat	Rice	Sorghum
	1.36	1.23	1.11	2.04
Guinea-Bissau	Maize	Wheat	Rice	Millet
	0.36	0.32	0.29	0.46
Eritrea	Wheat	Sorghum		
	1.79	2.96		
Zambia	Maize			
	2.77			
Togo	Maize	Sorghum	Pulses	
	0.77	1.16	0.32	
Bangladesh	Rice	Freshwater Fish		
	1.88	0.64		
Ethiopia	Maize	Wheat	Pulses	
	6.43	5.83	2.67	
Tajikistan	Wheat	Milk	Bovine meat	
	0.14	0.05	0.04	
Zimbabwe	Maize	Wheat	Pulses	
	0.17	0.15	0.07	
Yemen	Wheat	Sorghum	Poultry meat	
	0.20	0.34	0.06	

During the World Summit on Food Security in 2009, it was recognized that by 2050 there will be a requirement to supply 70% additional food to the global population (FAO, 2009). To meet the future food demand for the rising global population long term plans need to be introduced considering the sustainability of environment. There is a need to develop technology-based approaches as producing the required additional food; especially protein will put pressure on limited resources such as land, energy and water, as well as having an environmental cost. The future demand of food mainly depends on the below mentioned factors:

- Continuing population growth throughout the world and increasing urbanization.
- To provide adequate amount of food to the undernourished people to live a healthy life.
- Utilize science to develop new approaches to increase the essential amino acids in plant crops with emphasis on lysine and leucine and to improve nutrient transfer through new approaches to improve nutrient transport.
- Increased purchasing power and choice of high quality food, individual preference for food.

One of the most important aims for the future is to develop more sustainable protein production methods, such as increasing the efficiency of the present food production systems (for plant as well as animal protein), increasing the yields of crops, developing foods by blending meat and plant protein (lupin, peas) (Linnemann and Dijkstra, 2002). However, these approaches need to be validated by their social acceptance, economic profitability, technological feasibility and environmental sustainability.

5.2 Interrelations between essential amino acid availability and income variation

The impact of income change, specifically rapid per capita income growth on diet over time and by different socioeconomic classes is studied for India in chapter 3. This study suggested that food distribution and ability to purchase

nutritionally adequate foods is dependent on income of an individual person as food prices are primarily determined by food demand, which is determined in turn by world population, income and consumer preferences.

India's food security has seriously deteriorated over the last two decades, as observed in Chapter 4. There are many factors, responsible for this. Agricultural output has stagnated because of lack of investment in the sector. Entitlement to basic food grains, which was long a part of India's search for food security, came to be drastically altered around the mid-1990s when such entitlements were made 'targeted', and many needy consumers found themselves deprived of even basic food-stuffs. With rising affluence of the population as a whole, consumption patterns have been changing – away from cereal-based diets to more animal protein and vegetables and fruits, for example. This has encouraged the use of grains as animal feed, thus further reducing their availability for human consumption. The world-wide inflation of food prices over the period since 2007 has hit India hard, with food price inflation running at twice the general price inflation at times. This has been causing serious problems for the large number of poor people in India.

There is considerable waste of food in India, largely through mismanagement. More than five million tonnes of food stocks rot annually without refrigeration. Nearly 7% of grain and over 30% of fruit and vegetables is estimated to go to waste each year without post-harvest facilities. An astonishingly low 2% of fruit and vegetable production is processed annually in India, compared with 30% in Thailand, 70% in Brazil, 78% in the Philippines and 80% in Malaysia (Murthy, 2010).

It is only to be expected that, as the Indian economy grows, the pattern of diets will keep changing. This will require the agricultural sector to improve its productivity to be able to respond to the increased demand for food and other agricultural products. India's ability to be self-sufficient in respect of protein is very limited, given the paucity of farming land and other required inputs. On the other hand, if India were to depend on imports of food grains on a long-term basis, it would affect world prices in a manner that other importers would suffer too. India has been reluctant to permit new technologies such as genetically

modified organisms (GMO) to be trialled on a wide scale. This may need to change as the capacity to achieve significant improvements in agricultural outputs, especially those that might raise the availability of proteins, must be limited if conventional methods of production only are to be relied upon.

In 2011, a new version of the National Food Security Bill which guarantees highly-subsidised grain to 75% of the Indians was passed by the government. According to this bill:

- All pregnant and lactating women will be given Rs. 6000 for a period of six months.
- Seven kilos of subsidised food grains per person like rice and wheat will be guaranteed every month for "priority households" - which are seen as the neediest.
- The new bill also promises a minimum of three kilos of food grains for the "general category" which consists of Lower Middle Class families. Each family will pay Rs. 3 per kg of rice, Rs. 2 per kilo of wheat, and Rs. 1 per kilo of coarse grain (Prabhu, 2011).

There are issues outside the food sector too that need tackling. Improving employment opportunities, and health care, especially public health, for example, can help reduce the income existing disparities in the distribution of incomes noted in Chapter 4.

5.3 GM Food crops: improving the nutritional value of cereals

Genetically modified food crops are widely grown in many countries today. It was reported that there was an 87 fold increase in the land area used to grow GM crops, from 1.7 million hectares of biotech crops in 1996 to 148 million hectares in 2010 (ISAAA, 2010). In 2010, the number of countries growing GM crops reached 29 (including 19 developing countries), from 6 in 1996. The major countries are USA (66.8 million hectares), Brazil (25.4), Argentina (22.9), India (9.4), Canada (8.8), China (3.5), Paraguay (2.6), Pakistan (2.4), South Africa (2.2) and Uruguay with 1.1 million hectares. Including these 29 countries, a total of 59 countries (where 75% of the world's population live) have granted

regulatory approvals for biotech crops for import for food and feed use, and for release into the environment, since 1996 (ISAAA, 2010).

GM crops having higher nutritional value, such as the high lysine corn, can be helpful to deal with global under nutrition. For example, in Philippines high lysine corn flour is used to prepare Pandesal (breakfast bread widely consumed in the country) and it is expected that it will result in better nutrition as well as cost saving by replacing wheat flour (Business In Sight, 2011).

Golden Rice is recognized to have the potential to improve the lives of millions of the undernourished people in the world and it is recommended as a vitamin A intervention strategy due to rice's unique position as the main food staple in Asia (Dawe et al., 2002). It is reported by IRRI (2011): "*Golden Rice, which is genetically modified, will be available to farmers and consumers only after it has been approved by national regulatory bodies. This project will also generate and collect safety information related to Golden Rice for submission to regulators as early as 2013 in the Philippines and 2015 in Bangladesh. Golden Rice is expected to cost farmers about the same as other rice, and they will be able to save seeds for replanting*" (IRRI, 2011).

Cereals are the major source of protein and calories for nearly half of the world's population including China, India and sub-Saharan African countries. The improvement in the cereals would be helpful to close the inadequacy gaps in protein and essential amino acids in many countries:

Quality protein Maize and high lysine corn

Maize is one of the major staple foods in some countries. Of the 22 countries in the world where maize forms the major percentage of energy in the national diet, 16 are in Africa. Maize lacks an adequate amount of lysine and tryptophan and thus cannot be considered as a balanced source of protein. A new variety of maize with similar protein content, but twice the amount of lysine and tryptophan and with higher bioavailability of protein could be helpful to close the inadequacy gaps in protein and essential amino acids (Nuss and Tanumihardjo, 2011).

In developed countries corn is mainly used as animal feed and corn meal is a poor source of lysine. To overcome this deficiency corn meal is supplemented with soybean meal or crystalline lysine (prepared via fermentation). In corn, α -zein (nutritionally poor corn protein) comprises approximately 40% of the total kernel protein but contains almost no lysine. By reducing this corn protein content other lysine-containing kernel protein content was increased comparatively in experiments. It is also mentioned by the author "*The quantity and digestibility of corn protein in corn grain may also be improved through plant biotechnology. Conventional breeding over the past several decades has made corn one of the most abundant sources for feed and food in the world. Through genetic engineering, the hope is that corn would someday have much greater nutritional value as well*" (Huang et al., 2008).

Inter specific rice hybrid with higher protein content

It was reported in a study in 2008, that a new hybrid of rice showed a protein content of 12.4%, which was 28 and 18.2% higher than those of the parents O.nivara and IR64 respectively (Mahmoud et al., 2008). This kind of rice variety, if approved in countries where rice is the major staple food, will be able to reduce protein deficiency and to improve the supply of lysine.

Africa bio-fortified sorghum (ABS) project

Sorghum is Africa's second most important staple food. The continent produces about 20 million tonnes of sorghum per annum, about one-third of the world crop. However, sorghum protein contains very lower amount of lysine and on cooking it has poor protein digestibility. The average protein content of sorghum is about 11%; this is in the same range as other major cereals, including wheat, maize, rice, barley and millet (table 2.1). However, sorghum contains least amount of lysine among these, 260 mg per 100 g. of sorghum (Souci et al., 2000). The ABS Project has developed the world's first golden sorghum (with yellow/golden endosperm) having an improved protein profile (tryptophan: 10-20%, lysine: 30-120%, threonine: 30-40%) and improved digestibility (Project ABS, 2011). This bio-fortified sorghum could provide a sustainable solution to

protein and essential amino acid deficiencies suffered by the African countries that are dependent on cereals as their main food.

5.4 Nutritional needs of the elderly population

In chapter 4, the nutritional needs of elderly people are reviewed and the effect on future protein demand is discussed. The elderly population in our society is in the most vulnerable condition and they need special attention in terms of good medical service and the right quality of food. Considering the fact that the proportion of population aged 60 or over will be 22% in 2050 compared to 11% in 2009 (figure 5.1), the nutritional requirement of the elderly population is of great importance. As population in the world continues to age, diagnosing, treating, and preventing age-related diseases will be progressively more important to the health and well-being of modern societies.

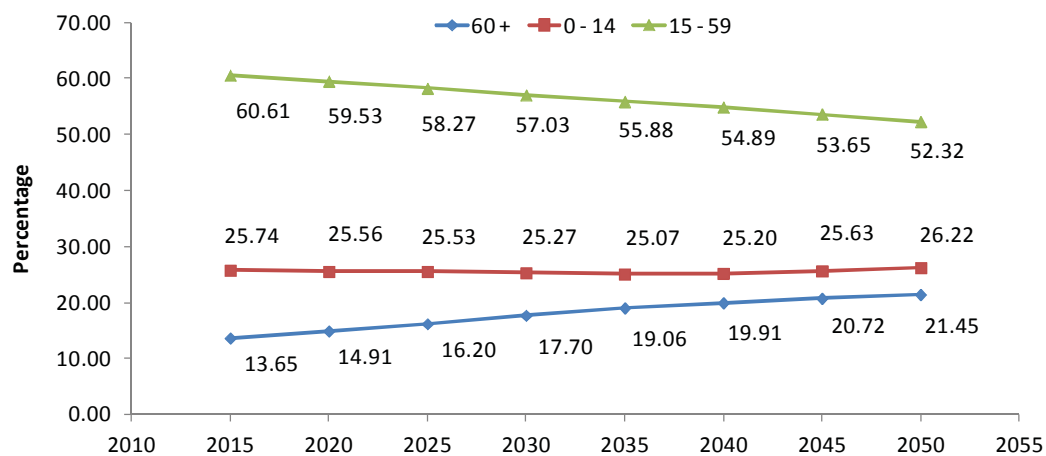


Figure 5.1 Forecast percentage of the different age groups at the world level, 2015 – 2050 (UN, 2011)

As discussed and documented in chapter 4, the need for protein and more specifically the essential amino acid leucine in the diet of the elderly population is of great importance. The current established RDA of protein does not take into account the changes which occur with age, such as reduced muscle mass,

increased fat mass, changes in food intake, physical activity and more frequent illness. Increasing the RDA from 0.8 to 1.0 to 1.2 g/kg per day would maintain normal calcium metabolism and nitrogen balance without affecting renal function. According to the FAO recommendation, an adult person (also an aged person, 60 + years old) needs 39 mg of leucine per kg body weight per day. In this study, out of the 40 identified countries having inadequate protein intake, only 2 countries were estimated to receive lower leucine in their diet. These two countries were DR Congo and Liberia (table 2.6). It can be concluded here, considering the fact that recommended amount of leucine in terms of mg/kg body weight/day is higher than lysine (39 mg and 30 mg respectively), that present food habits in most of the countries were well balanced to provide the required amount of leucine to its people, even if the per day protein intake was as lower as 37.41 g. (as in case of Mozambique). In figure 5.2, the graph of total leucine requirement till year 2050 is shown according to the different age groups. In year 2050 leucine requirement for elderly population will be increased 2.4 times more than the requirement of 2015, and in this time frame it will be 1.55 and 1.31 times more than the requirement of 2015 for 0-14 years age group and 15-59 years age group respectively.

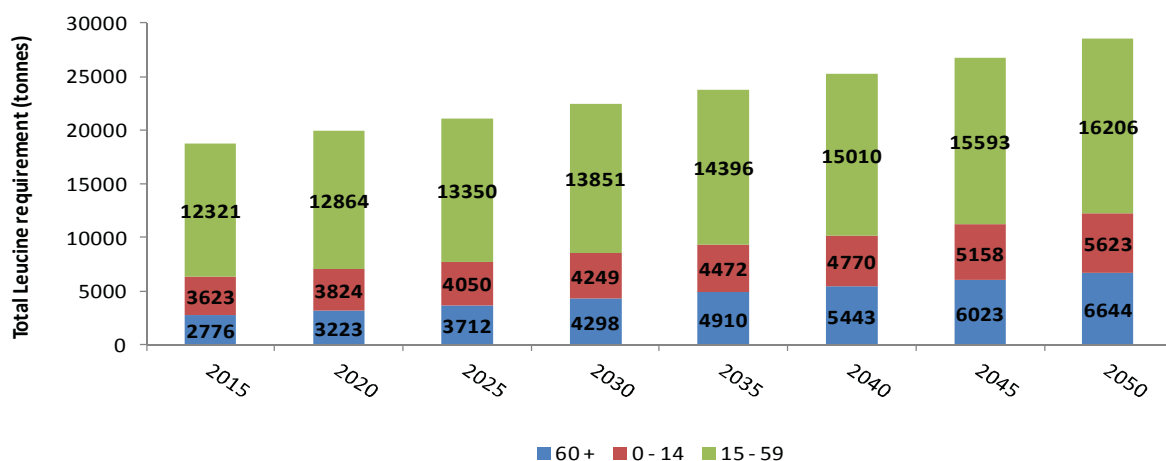


Figure 5.2 Forecast leucine requirements (tonnes) according to the different age groups at the world level, year 2015 – 2050 (WHO, 2007, UN, 2011)

Ageing, globalization and urbanization all create new challenges to be faced in the present world to feed each person a good nutritional amount of food daily. Food has become more affordable in recent years as a result of increase in yield per hectare of agricultural land. However, in the next 40 years 70% more food is required for the global population. The increasing population of elderly group also needs additional amount of protein, considering that the current recommended RDA of protein needs to be increased up to 1.0 to 1.2 g/kg per day for them. One of the options to increase food supply and to decrease the environmental pressure of current food production system is to minimise the waste. It is also important to plan an integrated approach about agricultural innovation and population health which will help us to prepare a matrix to supply the nutritional quality of food to the future world (Godfray et al., 2010).

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CSO (2008) ANNEXURE VIII B: State-Wise Per Capita Income at Current

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Appendix 1.1 Global Hunger index (GHI) (IFPRI, 2010)

“The index ranks countries on a 100-point scale, with 0 being the best score (no hunger) and 100 being the worst, although neither of these extremes is reached in practice. Values less than 5.0 reflect low hunger, values between 5.0 and 9.9 reflect moderate hunger, values between 10.0 and 19.9 indicate a serious problem, values between 20.0 and 29.9 are alarming, and values of 30.0 or higher are extremely alarming.

The Global hunger index is calculated as follows:

$$GHI = (PUN + CUW + CM)/3$$

With,

GHI: Global Hunger Index

PUN: proportion of the population that is undernourished (in %)

CUW: prevalence of underweight in children under five (in %)

CM: proportion of children dying before the age of five (in %)”

Appendix 2.1 True Protein digestibility (TPD)

The term digestibility is defined in terms of the balance of amino acids across the small intestine (from mouth to terminal ileum) or across the entire intestine (from mouth to anus). It is a measure of the dietary intake which is available to the living organism after digestion and absorption (WHO, 2007).

The following formula is used to calculate the TPD of different proteins in humans.

$$\text{True Protein Digestibility (TPD)} = \{I - (F - F_K)\} / I$$

Where I = nitrogen intake, F = faecal nitrogen loss on the test diet, and F_K = faecal nitrogen loss on a protein free diet (WHO, 2007).

Appendix 2.2 Food items and respective Indian food ingredients and their true protein digestibility and true ileal amino acid digestibility values (Rutherford et al., 2012, FAO, 1970, WHO/FAO 1991)

Indian Food Ingredient	Food items	True Protein Digestibility	True ileal amino acid digestibility
Wheat Flour	Wheat	0.909	0.96
Rice	Rice	0.88	0.89
Maize flour	Maize	0.85	0.93
Black gram beans	Beans	0.728	0.31
Refined flour	-	-	0.93
Mung beans	Beans	0.728	0.62
Lentils	Beans	0.728	0.91
Chick peas	peas	0.876	0.87
Kidney beans	Beans	0.728	0.45
Pigeon peas	Peas	0.876	0.58

**Appendix 2.3 List of Food items - amino acid profile not available,
respective assumed foods in the same food group**

Food Item	Food Item - Amino Acid Profile considered
Ground nut	Pea Nut
Nut	Cashew nut
Oranges/Mandarines	Mandarines
Plantains	Banana
Pulses, Other	Beans
Vegetables, Other	Potato
Cheese	Cheddar Cheese
Cream	Whipping cream (Min 40 %
Crustaceans	Lobster
Demersal Fish	Flounder
Fresh water Fish	Salmon
Marine Fish, Other	Cod
Offals, Edible	Ox and Sheep liver
Pelagic Fish	Tuna

Appendix 3.1 Food and protein intake (g/capita/day) information for Indian populations – year 1993, classification of food items as per NSSO report, India (1993/94)

Food item	Food group as per NSS Report, India	Food supply quantity (g/capita/day)	Protein supply quantity (g/capita/day)
Barley	Cereals	3.44	0.21
Maize		15.23	1.14
Millet		22.59	2.04
Rice (Milled Equivalent)		209.85	14.25
Sorghum		30.42	2.89
Wheat		134.19	12.19
Cereals Total		415.72	32.72
Beans	Pulses	8.3	1.78
Peas		1.93	0.43
Pulses, Other		21.93	4.41
Soyabeans		1.13	0.43
Pulses Total	33.29	7.05	
Butter, Ghee	Milk & milk products	3.42	0.01
Cream		0	0
Milk - Excluding Butter		149.72	5.64
Milk & milk products Total	153.14	5.65	
Bovine Meat	Egg, fish & meat	6.22	0.82
Cephalopods		0.05	0.01
Crustaceans		0.88	0.09
Demersal Fish		2.26	0.23
Eggs		3.47	0.37
Freshwater Fish		5.9	0.65
Marine Fish, Other		0.69	0.07
Mutton & Goat Meat		1.87	0.27
Offals, Edible		1.37	0.24
Pelagic Fish		1.45	0.17
Pigmeat		1.34	0.15
Poultry Meat		1.04	0.13
Egg, fish & meat Total		26.54	3.2
Apples		Other food	3.1
Bananas	23.78		0.19
Cassava	15.15		0.05
Coconuts - Incl Copra	17.27		0.26
Dates	0.21		0
Grapefruit	0.23		0
Grapes	1.9		0.01
Groundnuts (Shelled Eq)	1.19		0.26
Lemons, Limes	2.42		0.01
Nuts	1.74		0.09
Onions	10.32		0.16
Oranges, Mandarines	5.08		0.03
Potatoes	40.8		0.65
Sweet Potatoes	3.45		0.03
Tomatoes	13.45		0.11
Vegetables, Other	122.79		1.73
Molluscs, Other	0		0
Other food Total	262.88		3.59
Over All Total	891.57		52.21

Appendix 3.2 Food and protein intake (g/capita/day) information for Indian populations – year 2004, classification of food items as per NSSO report, India (2004/05)

Food item	Food group as per NSS Report, India	Food supply quantity (g/capita/day)	Protein supply quantity (g/capita/day)
Barley	Cereals	2.43	0.15
Maize		10.86	0.81
Millet		23.88	2.16
Oats		0	0
Rice (Milled Equivalent)		191.44	13
Rye		0	0
Sorghum		14.36	1.36
Wheat		167.74	15.25
Cereals Total		410.71	32.73
Beans	Pulses	6.49	1.39
Peas		2.96	0.66
Pulses, Other		20.81	4.16
Soyabeans		2.43	0.92
Pulses Total	32.69	7.13	
Butter, Ghee	Milk & milk products	6.65	0.03
Cream		0	0
Milk - Excluding Butter		174.34	6.22
Milk & milk products Total	180.99	6.25	
Bovine Meat	Egg, fish & meat	4.82	0.63
Cephalopods		0.01	0
Crustaceans		0.81	0.07
Demersal Fish		1.79	0.17
Eggs		5.06	0.54
Freshwater Fish		7.7	0.84
Marine Fish, Other		1.65	0.2
Mutton & Goat Meat		1.71	0.25
Offals, Edible		1.2	0.21
Pelagic Fish		1.06	0.12
Pigmeat		1.16	0.13
Poultry Meat		1.38	0.17
Egg, fish & meat Total		28.35	3.33
Apples	Other food	3.33	0.01
Bananas		32.94	0.26
Cassava		13.94	0.05
Coconuts - Incl Copra		11.13	0.17
Dates		0.61	0.01
Grapefruit		0.32	0
Grapes		3.25	0.01
Groundnuts (Shelled Eq)		1.13	0.25
Lemons, Limes		3.19	0.02
Nuts		2.82	0.14
Onions		16.09	0.24
Oranges, Mandarines		7.17	0.04
Plantains		0	0
Potatoes		50.89	0.82
Sunflowerseed		0	0
Sweet Potatoes		2.75	0.03
Tomatoes		17.99	0.14
Vegetables, Other		117	1.63
Yams		0	0
Molluscs, Other		0.02	0
Other food Total	284.57	3.82	
Over All Total	937.31	53.26	

Appendix 3.3 Estimation of per capita per day food intake from different food groups in Kerala, Gujarat, Bihar, Punjab and all-India in both Rural and Urban areas – year 1993

State	Area	MPCE Class	Per capita per day Protein intake (grams)		Percentage of total intake of Protein per capita per day by MPCE class						Per capita per day Protein intake from different food Sources (grams)								
			Protein intake	(grams)	Cereals	Pulses	Milk & milk products	Egg, fish & meat	Other food	Cereals	Pulses	Milk & milk products	Egg, fish & meat	Other food	Cereals	Pulses	Milk & milk products	Egg, fish & meat	Other food
Kerala	rural	1	19.6	66.2	2.13	2.59	18.81	10.27	12.98	0.42	0.51	3.69	2.01	164.85	1.97	13.76	30.58	147.40	
Kerala	rural	2	24.6	69.03	1.6	1.24	18.18	9.95	16.98	0.39	0.31	4.47	2.45	215.75	1.86	8.27	37.09	179.23	
Kerala	rural	3	28.9	65.34	3.73	2.06	18.87	10	18.88	1.08	0.60	5.45	2.89	239.92	5.09	16.14	45.23	211.62	
Kerala	rural	4	32.7	62.64	4.65	2.46	19.15	11.1	20.48	1.52	0.80	6.26	3.63	260.25	7.18	21.80	51.94	265.79	
Kerala	rural	5	35.7	63.25	4.88	2.89	17.91	11.07	22.58	1.74	1.03	6.39	3.95	286.89	8.23	27.96	53.03	289.39	
Kerala	rural	6	38.1	62.68	4.33	3.76	17.64	11.59	23.88	1.65	1.43	6.72	4.42	303.42	7.79	38.83	55.74	323.35	
Kerala	rural	7	40.4	58.75	6.03	3.88	18.75	12.59	23.74	2.44	1.57	7.58	5.09	301.56	11.50	42.49	62.83	372.45	
Kerala	rural	8	43.9	57.65	5.5	4.19	19.48	13.18	25.31	2.41	1.84	8.55	5.79	321.55	11.40	49.86	70.93	423.68	
Kerala	rural	9	49.6	52.33	6.69	5.93	20.4	14.65	25.96	3.32	2.94	10.12	7.27	329.78	15.67	79.72	83.92	532.09	
Kerala	rural	10	56.8	49.84	6.73	8.09	21.33	14.01	28.31	3.82	4.60	12.12	7.96	359.68	18.05	124.55	100.48	582.71	
Kerala	rural	11	63.9	46.51	7.52	8.79	21.98	15.2	29.72	4.81	5.62	14.05	9.71	377.60	22.69	152.24	116.49	711.23	
Kerala	rural	12	76.7	42.86	7.83	11	22.09	16.22	32.87	6.01	8.44	16.94	12.44	417.67	28.36	228.68	140.52	910.98	
Kerala	rural	All	50.8	51.81	6.5	7.01	20.6	14.08	26.32	3.30	3.56	10.46	7.15	334.40	15.59	96.52	86.79	523.76	

State	Area	MPCE Class	Per capita per day Protein intake (grams)		Percentage of total intake of Protein per capita per day by MPCE class						Per capita per day Protein intake from different food Sources (grams)								
			Protein intake	(grams)	Cereals	Pulses	Milk & milk products	Egg, fish & meat	Other food	Cereals	Pulses	Milk & milk products	Egg, fish & meat	Other food	Cereals	Pulses	Milk & milk products	Egg, fish & meat	Other food
Kerala	urban	1	23.6	62.79	2.93	3.12	18.81	12.35	14.82	0.69	0.74	4.44	2.91	188.27	3.27	19.96	36.82	213.42	
Kerala	urban	2	31.5	63.03	4.53	3.19	18.84	10.41	19.85	1.43	1.00	5.93	3.28	252.26	6.74	27.24	49.22	240.12	
Kerala	urban	3	36.6	56.95	4.31	4.7	24.06	9.98	20.84	1.58	1.72	8.81	3.65	264.83	7.45	46.63	73.03	267.47	
Kerala	urban	4	40.3	55.55	5.76	5.43	22.18	11.08	22.39	2.32	2.19	8.94	4.47	284.43	10.96	59.31	74.13	326.97	
Kerala	urban	5	43.4	55.39	5.99	4.93	19.48	14.21	24.04	2.60	2.14	8.45	6.17	305.43	12.28	57.99	70.12	451.59	
Kerala	urban	6	46.3	51.59	6.82	6.91	19.94	14.74	23.89	3.16	3.20	9.23	6.82	303.48	14.91	86.72	76.57	499.74	
Kerala	urban	7	50.7	51.21	6.81	7.45	20.63	13.9	25.96	3.45	3.78	10.46	7.05	329.88	16.30	102.38	86.75	516.04	
Kerala	urban	8	55.8	47.6	7.44	8.77	22.18	14.01	26.56	4.15	4.89	12.38	7.82	337.47	19.60	132.64	102.65	572.45	
Kerala	urban	9	59.2	46.13	8.17	9.45	21.05	15.2	27.31	4.84	5.59	12.46	9.00	346.97	22.84	151.63	103.35	658.91	
Kerala	urban	10	65.6	41.07	8.21	10.6	21.17	18.95	26.94	5.39	6.95	13.89	12.43	342.31	25.43	188.47	115.18	910.28	
Kerala	urban	11	78.9	34.97	8.16	13.22	22.33	21.52	27.59	6.44	10.43	17.62	16.82	350.56	30.40	282.71	146.12	1231.76	
Kerala	urban	12	84.5	34.07	9.05	14.7	19.35	22.83	28.79	7.65	12.42	16.35	19.29	365.78	36.11	336.68	135.61	1412.62	
Kerala	urban	All	52.4	47.49	7.18	8.63	21	15.7	24.88	3.76	4.52	11.00	8.23	316.17	17.77	122.57	91.26	602.41	

State	Area	MPCE Class	Per capita per day Protein intake (grams)				Percentage of total intake of Protein per capita per day by MPCE class					Per capita per day Protein intake from different food Sources					Per capita per day Food intake from different food Sources				
			Cereals	Pulses	Milk & milk products	Egg, fish & meat	Other food	Cereals	Pulses	Milk & milk products	Egg, fish & meat	Other food	Cereals	Pulses	Milk & milk products	Egg, fish & meat	Other food	Cereals	Pulses	Milk & milk products	Egg, fish & meat
gujrat	rural	1	28	8.63	4.62	0.43	8.36	21.83	2.42	1.29	0.12	2.34	277.34	11.41	35.06	1.00	171.41				
gujrat	rural	2	36.4	9.32	5.48	0.89	8.01	27.77	3.39	1.99	0.32	2.92	352.87	16.02	54.07	2.69	213.50				
gujrat	rural	3	40.9	12.17	6.54	0.61	7.05	30.11	4.98	2.67	0.25	2.88	382.62	23.50	72.50	2.07	211.14				
gujrat	rural	4	45.7	10.59	8.32	1.04	6.62	33.56	4.84	3.80	0.48	3.03	426.36	22.85	103.06	3.94	221.53				
gujrat	rural	5	47.4	10.61	9.13	0.79	6.84	34.43	5.03	4.33	0.37	3.24	437.40	23.75	117.30	3.11	237.41				
gujrat	rural	6	49	11.75	10.43	1	7.82	33.81	5.76	5.11	0.49	3.83	429.57	27.19	138.52	4.06	280.59				
gujrat	rural	7	52	11.83	10.89	1.19	6.98	35.94	6.15	5.66	0.62	3.63	456.60	29.05	153.49	5.13	265.78				
gujrat	rural	8	0	11.59	11.78	1.73	8.27	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
gujrat	rural	9	60.1	12.62	12.44	1.36	8.15	39.32	7.58	7.48	0.82	4.90	499.62	35.81	202.64	6.78	358.67				
gujrat	rural	10	66.2	12.14	15.15	1.29	8.92	41.38	8.04	10.03	0.85	5.91	525.69	37.95	271.84	7.08	432.40				
gujrat	rural	11	76.3	13.27	18.84	1.15	8.8	44.21	10.13	14.37	0.88	6.71	561.68	47.81	389.62	7.28	491.67				
gujrat	rural	12	75.2	13.57	17.22	1.58	10.12	43.25	10.20	12.95	1.19	7.61	549.48	48.19	350.99	9.85	557.26				
gujrat	rural	All	55.6	11.98	12.36	1.24	8.09	36.88	6.66	6.87	0.69	4.50	468.57	31.45	186.27	5.72	329.37				

State	Area	MPCE Class	Per capita per day Protein intake (grams)				Percentage of total intake of Protein per capita per day by MPCE class					Per capita per day Protein intake from different food Sources					Per capita per day Food intake from different food Sources				
			Cereals	Pulses	Milk & milk products	Egg, fish & meat	Other food	Cereals	Pulses	Milk & milk products	Egg, fish & meat	Other food	Cereals	Pulses	Milk & milk products	Egg, fish & meat	Other food	Cereals	Pulses	Milk & milk products	Egg, fish & meat
gujrat	urban	1	29.8	11.25	7.87	0.94	8.29	21.35	3.35	2.35	0.28	2.47	271.28	15.83	63.57	2.32	180.90				
gujrat	urban	2	36.6	10.54	7.08	2.89	7.19	26.46	3.86	2.59	1.06	2.63	336.21	18.22	70.24	8.77	192.70				
gujrat	urban	3	42.9	11.36	8.92	2.49	7.16	30.06	4.87	3.83	1.07	3.07	381.92	23.01	103.72	8.86	224.92				
gujrat	urban	4	45.4	11.9	10.33	4.12	7.82	29.89	5.40	4.69	1.87	3.55	379.72	25.51	127.11	15.51	259.97				
gujrat	urban	5	49.3	11.97	11.03	2.5	9.37	32.11	5.90	5.44	1.23	4.62	407.96	27.87	147.39	10.22	338.26				
gujrat	urban	6	50.6	12.84	13.72	2.15	8.48	31.78	6.50	6.94	1.09	4.29	403.80	30.68	188.17	9.02	314.20				
gujrat	urban	7	57.3	12.64	17.01	1.59	8.37	34.60	7.24	9.75	0.91	4.80	439.65	34.20	264.18	7.56	351.19				
gujrat	urban	8	58.1	13.56	15.5	1.24	12.63	33.16	7.88	9.01	0.72	7.34	421.28	37.20	244.09	5.98	537.33				
gujrat	urban	9	59.6	12.96	17.66	2.36	16.05	30.38	7.72	10.53	1.41	9.57	385.97	36.47	285.28	11.67	700.46				
gujrat	urban	10	66.1	14.48	18.53	1.82	14.32	33.61	9.57	12.25	1.20	9.47	427.05	45.20	331.98	9.98	693.12				
gujrat	urban	11	65.3	14.95	22.23	2.74	13.77	30.24	9.76	14.52	1.79	8.99	384.22	46.10	393.45	14.84	658.43				
gujrat	urban	12	77.7	14.48	21.16	1.95	15.84	36.18	11.25	16.44	1.52	12.31	459.74	53.13	445.63	12.57	901.24				
gujrat	urban	All	54.9	13.01	15.39	2.13	11.32	31.92	7.14	8.45	1.17	6.21	405.61	33.73	229.01	9.70	455.07				

State	Area	MPCE Class	Per capita per day Protein intake (grams)				Percentage of total intake of Protein per capita per day by MPCE class					Per capita per day Protein intake from different food Sources					Per capita per day Food intake from different food Sources				
			Cereals	Pulses	Milk & milk products	Egg, fish & meat	Other food	Cereals	Pulses	Milk & milk products	Egg, fish & meat	Other food	Cereals	Pulses	Milk & milk products	Egg, fish & meat	Other food	Cereals	Pulses	Milk & milk products	Egg, fish & meat
Bihar	rural	1	36.9	8.01	0.9	1.41	7.53	30.31	2.96	0.33	0.52	2.78	385.14	13.96	9.00	4.32	203.46				
Bihar	rural	2	46	8.70	1.36	1.70	7.3	37.23	4.00	0.63	0.78	3.36	473.05	18.90	16.96	6.49	245.89				
Bihar	rural	3	50.8	9.03	2.05	1.79	7.6	40.40	4.59	1.04	0.91	3.86	513.31	21.66	28.23	7.54	282.71				
Bihar	rural	4	0	9.17	3.38	1.66	7.4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00				
Bihar	rural	5	60.3	9.94	4.52	1.78	7.66	45.89	5.99	2.73	1.07	4.62	583.03	28.30	73.87	8.90	338.23				
Bihar	rural	6	63.7	74.82	10	5.55	1.74	47.66	6.37	3.54	1.11	5.03	605.54	30.08	95.82	9.19	368.03				
Bihar	rural	7	68.8	72.96	10.12	1.97	8.28	50.20	6.96	4.59	1.36	5.70	637.77	32.88	124.38	11.24	417.14				
Bihar	rural	8	71.1	71.24	10.43	2.43	8.34	50.65	7.42	5.38	1.73	5.93	643.55	35.02	145.69	14.33	434.21				
Bihar	rural	9	75.3	69.6	10.18	2.27	8.87	52.41	7.67	6.84	1.71	6.68	665.87	36.20	185.32	14.18	489.08				
Bihar	rural	10	80.9	66.45	10.79	2.58	9.65	53.76	8.73	8.52	2.09	7.81	683.02	41.22	230.90	17.31	571.66				
Bihar	rural	11	88.2	63.82	11.34	2.56	11.16	56.93	10.12	9.92	2.28	9.95	723.28	47.76	268.85	18.94	728.94				
Bihar	rural	12	101.7	61.65	11.34	3.91	12.25	62.70	11.53	11.03	3.98	12.46	796.60	54.46	299.08	32.98	912.26				
Bihar	rural	All	60.2	74.78	9.74	1.97	8.15	45.02	5.86	3.23	1.19	4.91	571.97	27.69	87.46	9.84	359.27				

State	Area	MPCE Class	Per capita per day Protein intake (grams)				Percentage of total intake of Protein per capita per day by MPCE class					Per capita per day Protein intake from different food Sources					Per capita per day Food intake from different food Sources				
			Cereals	Pulses	Milk & milk products	Egg, fish & meat	Other food	Cereals	Pulses	Milk & milk products	Egg, fish & meat	Other food	Cereals	Pulses	Milk & milk products	Egg, fish & meat	Other food	Cereals	Pulses	Milk & milk products	Egg, fish & meat
Bihar	urban	1	41.00	8.5	1.7	1.57	7.55	33.08	3.49	0.70	0.64	3.10	420.28	16.46	18.89	5.34	226.67				
Bihar	urban	2	50.20	8.83	3.32	1.96	7.68	39.26	4.43	1.67	0.98	3.86	498.83	20.93	45.17	8.16	282.31				
Bihar	urban	3	54.10	9.19	3.69	2.93	8.17	41.13	4.97	2.00	1.59	4.42	523.53	23.48	54.11	13.15	323.66				
Bihar	urban	4	57.00	70.95	9.96	3.25	9.83	40.44	5.68	3.43	1.85	5.60	513.82	26.81	92.85	15.36	410.29				
Bihar	urban	5	60.00	70.55	10.1	2.49	10.17	42.33	6.06	4.01	1.49	6.10	537.82	28.62	108.80	12.39	446.82				
Bihar	urban	6	63.00	66.11	10.78	3.39	11.16	41.65	6.79	5.39	2.14	7.03	529.17	32.07	146.17	17.71	514.83				
Bihar	urban	7	67.80	65.88	10.08	3.41	11.54	44.67	6.83	6.16	2.31	7.82	567.51	32.27	167.05	19.17	572.93				
Bihar	urban	8	70.60	60.49	10.2	3.64	15.38	42.71	7.20	7.26	2.57	10.86	542.60	34.00	196.91	21.31	795.10				
Bihar	urban	9	72.60	50.8	11.76	4.17	21.87	36.88	8.54	8.28	3.03	15.88	468.58	40.32	224.33	25.11	1162.65				
Bihar	urban	10	80.70	54.81	11.38	4.77	16.57	44.23	9.18	10.06	3.85	13.37	561.98	43.37	272.76	31.93	979.17				
Bihar	urban	11	85.90	46.19	10.34	4.98	25.14	39.68	8.88	11.47	4.28	21.60	504.11	41.94	310.82	35.48	1581.33				
Bihar	urban	12	93.20	43.47	11.94	8.22	21.18	40.51	11.13	14.16	7.66	19.74	514.75	52.55	383.72	63.54	1445.46				
Bihar	urban	All	61.40	66.72	10.16	3.4	11.95	40.97	6.24	4.77	2.09	7.34	520.49	29.46	129.31	17.31	537.28				

State	Area	MPCE Class	Per capita per day Protein intake (grams)				Percentage of total intake of Protein per capita per day by MPCE class					Per capita per day Protein intake from different food Sources					Per capita per day Food intake from different food Sources					
			Cereals	Pulses	Milk & milk products	Egg, fish & meat	Other food	Cereals	Pulses	Milk & milk products	Egg, fish & meat	Other food	Cereals	Pulses	Milk & milk products	Egg, fish & meat	Other food	Cereals	Pulses	Milk & milk products	Egg, fish & meat	Other food
Punjab	rural	1	28.40	7.54	13.77	0	7.75	20.15	2.14	3.91	0.00	2.20	255.97	10.11	106.00	0.00	271.13	317.80	20.00	99.80	1.23	155.43
Punjab	rural	2	44.90	6.31	4.49	0.00	3.68	38.40	2.83	2.02	0.00	1.65	487.87	13.38	54.64	0.00	306.60	395.72	18.67	113.82	1.83	159.70
Punjab	rural	3	44.00	8.19	9.92	0.32	5.27	33.57	3.60	4.36	0.14	2.32	426.54	17.02	118.31	1.17	299.14	407.58	24.57	134.01	2.64	209.11
Punjab	rural	4	50.50	9.58	12.3	0.03	5.04	36.89	4.84	6.21	0.02	2.55	468.70	22.84	168.36	0.13	407.06	399.86	26.01	193.73	2.71	266.98
Punjab	rural	5	49.70	10.6	11.75	0.29	7.45	34.75	5.27	5.84	0.14	3.70	441.45	24.88	158.28	1.20	306.60	434.64	29.87	272.24	1.98	335.49
Punjab	rural	6	52.80	8.94	15.23	0.07	7.93	35.81	4.72	8.04	0.04	4.19	455.03	22.29	217.96	0.31	306.60	428.56	30.20	308.37	2.70	393.30
Punjab	rural	7	57.70	10.24	15.9	0.22	7.08	38.41	5.91	9.17	0.13	4.09	487.95	27.90	248.66	1.05	299.14	451.29	34.60	363.89	5.54	443.79
Punjab	rural	8	63.10	9.5	20.17	0.44	7.67	39.26	5.99	12.73	0.28	4.84	498.82	28.31	344.97	2.30	354.40	473.21	44.86	462.52	7.06	595.99
Punjab	rural	9	69.40	9.06	22.47	1.05	8.01	41.23	6.29	15.59	0.73	5.56	523.85	29.69	422.67	6.04	407.06	437.51	34.45	406.18	6.89	501.75
Punjab	rural	10	76.40	9.16	26.98	0.55	7.63	42.54	7.00	20.61	0.42	5.83	540.48	33.05	558.70	3.49	426.86	473.21	44.86	462.52	7.06	595.99
Punjab	rural	11	86.00	8.98	29.75	0.94	8.54	44.54	7.72	25.59	0.81	7.34	565.89	36.47	693.47	6.70	537.80	484.93	44.25	565.35	16.14	714.40
Punjab	rural	12	102.40	8.91	32.89	1.56	8.43	49.37	9.12	33.68	1.60	8.63	627.23	43.08	912.86	13.25	632.11	627.23	43.08	912.86	13.25	632.11
Punjab	rural	All	74.70	9.17	25.59	0.85	7.91	42.19	6.85	19.12	0.63	5.91	536.05	32.35	518.12	5.27	432.67	536.05	32.35	518.12	5.27	432.67

State	Area	MPCE Class	Per capita per day Protein intake (grams)				Percentage of total intake of Protein per capita per day by MPCE class					Per capita per day Protein intake from different food Sources					Per capita per day Food intake from different food Sources					
			Cereals	Pulses	Milk & milk products	Egg, fish & meat	Other food	Cereals	Pulses	Milk & milk products	Egg, fish & meat	Other food	Cereals	Pulses	Milk & milk products	Egg, fish & meat	Other food	Cereals	Pulses	Milk & milk products	Egg, fish & meat	Other food
Punjab	urban	1	35.2	12.03	10.46	0.42	6.03	25.01	4.23	3.68	0.15	2.12	317.80	20.00	99.80	1.23	155.43	317.80	20.00	99.80	1.23	155.43
Punjab	urban	2	41.7	9.48	10.07	0.53	5.23	31.15	3.95	4.20	0.22	2.18	395.72	18.67	113.82	1.83	159.70	395.72	18.67	113.82	1.83	159.70
Punjab	urban	3	45.4	11.46	10.89	0.7	6.29	32.08	5.20	4.94	0.32	2.86	407.58	24.57	134.01	2.64	209.11	407.58	24.57	134.01	2.64	209.11
Punjab	urban	4	48.1	11.45	14.86	0.68	7.58	31.47	5.51	7.15	0.33	3.65	399.86	26.01	193.73	2.71	266.98	399.86	26.01	193.73	2.71	266.98
Punjab	urban	5	51.1	11.49	16.99	0.65	8.14	32.06	5.87	8.68	0.33	4.16	407.27	27.72	235.32	2.75	304.58	407.27	27.72	235.32	2.75	304.58
Punjab	urban	6	55.4	11.42	18.13	0.43	8.27	34.21	6.33	10.04	0.24	4.58	434.64	29.87	272.24	1.98	335.49	434.64	29.87	272.24	1.98	335.49
Punjab	urban	7	57.2	11.18	19.89	0.57	9.39	33.73	6.39	11.38	0.33	5.37	428.56	30.20	308.37	2.70	393.30	428.56	30.20	308.37	2.70	393.30
Punjab	urban	8	63	11.63	21.31	1.06	9.62	35.52	7.33	13.43	0.67	6.06	451.29	34.60	363.89	5.54	443.79	451.29	34.60	363.89	5.54	443.79
Punjab	urban	9	64.4	11.33	23.27	1.29	10.64	34.43	7.30	14.99	0.83	6.85	437.51	34.45	406.18	6.89	501.75	437.51	34.45	406.18	6.89	501.75
Punjab	urban	10	72.8	13.05	23.44	1.17	11.18	37.24	9.50	17.06	0.85	8.14	473.21	44.86	462.52	7.06	595.99	473.21	44.86	462.52	7.06	595.99
Punjab	urban	11	80.1	11.7	26.04	2.43	12.18	38.17	9.37	20.86	1.95	9.76	484.93	44.25	565.35	16.14	714.40	484.93	44.25	565.35	16.14	714.40
Punjab	urban	12	84.1	10.71	27.66	3.99	13.32	37.27	9.01	23.26	3.36	11.20	473.57	42.53	630.50	27.83	820.28	473.57	42.53	630.50	27.83	820.28
Punjab	urban	All	61.8	11.67	21.14	1.23	9.96	34.61	7.21	13.06	0.76	6.16	439.71	34.06	354.11	6.30	450.72	439.71	34.06	354.11	6.30	450.72

State	Area	MPCE Class	Per capita per day Protein intake (grams)	Percentage of total intake of Protein per capita per day by MPCE class					Per capita per day Protein intake from different food Sources					Per capita per day Food intake from different food Sources				
				Cereals	Pulses	Milk & milk products	Egg, fish & meat	Other food	Cereals	Pulses	Milk & milk products	Egg, fish & meat	Other food	Cereals	Pulses	Milk & milk products	Egg, fish & meat	Other food
india	urban	1	37.6	77.69	8.68	3.61	2.91	7.11	29.21	3.26	1.36	1.09	2.67	371.14	15.41	36.79	9.07	195.76
india	urban	3	47.1	71.17	10.06	5.86	4.44	8.47	33.52	4.74	2.76	2.09	3.99	425.90	22.37	74.81	17.34	292.12
india	urban	4	49.5	68.71	10.67	7.12	4.57	8.93	34.01	5.28	3.52	2.26	4.42	432.13	24.94	95.53	18.76	323.68
india	urban	5	52.3	66.1	11.15	8.43	4.79	9.53	34.57	5.83	4.41	2.51	4.98	439.23	27.54	119.50	20.78	364.97
india	urban	6	55.1	63.8	11.51	9.89	4.92	9.88	35.15	6.34	5.45	2.71	5.44	446.64	29.95	147.70	22.48	398.63
india	urban	7	57.2	60.94	11.79	11.36	5.05	10.86	34.86	6.74	6.50	2.89	6.21	442.88	31.84	176.12	23.96	454.87
india	urban	8	60.1	58.14	12.08	12.62	5.28	11.88	34.94	7.26	7.58	3.17	7.14	443.95	34.28	205.58	26.32	522.82
india	urban	9	63.2	54.53	12.27	14.2	5.79	13.21	34.46	7.75	8.97	3.66	8.35	437.86	36.62	243.25	30.35	611.34
india	urban	10	68.2	50.44	12.43	16.01	5.95	15.17	34.40	8.48	10.92	4.06	10.35	437.07	40.03	295.95	33.66	757.59
india	urban	11	73.5	44.66	12.22	18.27	6.55	18.3	32.83	8.98	13.43	4.81	13.45	417.06	42.41	363.97	39.93	984.92
india	urban	12	82.7	39.9	12.45	19.25	7.64	20.76	33.00	10.30	15.92	6.32	17.17	419.24	48.62	431.50	52.40	1257.18
india	urban	All	57.2	59.41	11.54	11.66	5.29	12.1	33.98	6.60	6.67	3.03	6.92	431.76	31.17	180.77	25.10	506.81

Appendix 3.4 Estimation of per capita per day food intake from different food groups in Kerala, Gujarat, Bihar, Punjab and all-India both in Rural and Urban area – year 2004

State	Area	MPCE Class	Per capita per day Protein intake (grams)	Percentage of total intake of Protein per capita per day by MPCE class					Per capita per day Protein intake from different food Sources (grams)					Per capita per day Food intake from different food Sources (grams)				
				Cereals	Pulses	Milk & milk products	Egg, fish & meat	Other food	Cereals	Pulses	Milk & milk products	Egg, fish & meat	Other food	Cereals	Pulses	Milk & milk products	Egg, fish & meat	Other food
Kerala	rural	1	20.6	69.16	3.58	0.46	15.6	9.42	14.25	0.74	0.09	3.21	1.94	178.78	3.38	2.74	27.36	144.56
Kerala	rural	2	27.3	62.07	2.65	1.67	22.83	10.03	16.95	0.72	0.46	6.23	2.74	212.63	3.32	13.20	53.06	203.98
Kerala	rural	3	32.3	59.5	5.87	1.97	20.96	9.81	19.22	1.90	0.64	6.77	3.17	241.16	8.69	18.43	57.64	236.05
Kerala	rural	4	33.1	55.06	6.26	3.16	22.96	11.56	18.22	2.07	1.05	7.60	3.83	228.69	9.50	30.29	64.70	285.04
Kerala	rural	5	33.9	56.2	6.14	3.52	20.02	12.82	19.05	2.08	1.19	6.79	4.35	239.07	9.54	34.56	57.78	323.75
Kerala	rural	6	38.1	55.4	5.5	3.94	22.25	11.57	21.11	2.10	1.50	8.48	4.41	264.86	9.61	43.47	72.17	328.39
Kerala	rural	7	46.1	47.67	6.15	14.73	19.04	11.38	21.98	2.84	6.79	8.78	5.25	275.76	13.00	196.64	74.73	390.81
Kerala	rural	8	45.2	52.69	6.95	4.48	21.65	13	23.82	3.14	2.02	9.79	5.88	298.85	14.40	58.64	83.31	437.73
Kerala	rural	9	47.6	49.97	6.71	5.97	21.11	14.59	23.79	3.19	2.84	10.05	6.94	298.47	14.64	82.29	85.55	517.35
Kerala	rural	10	51.2	48.92	7.98	6.69	20.03	14.7	25.05	4.09	3.43	10.26	7.53	314.30	18.73	99.19	87.31	560.68
Kerala	rural	11	60.8	43.5	8.18	8.46	22.07	16.05	26.45	4.97	5.14	13.42	9.76	331.88	22.80	148.95	114.24	726.95
Kerala	rural	12	80.7	37.32	9.44	9.59	24.16	18.03	30.12	7.62	7.74	19.50	14.55	377.92	34.93	224.11	165.99	1083.91
Kerala	rural	All	55.4	45.19	7.98	7.8	22.08	15.44	25.04	4.42	4.32	12.23	8.55	314.15	20.27	125.14	104.14	637.21

State	Area	MPCE Class	Per capita per day Protein intake (grams)	Percentage of total intake of Protein per capita per day by MPCE class					Per capita per day Protein intake from different food Sources (grams)					Per capita per day Food intake from different food Sources (grams)				
				Cereals	Pulses	Milk & milk products	Egg, fish & meat	Other food	Cereals	Pulses	Milk & milk products	Egg, fish & meat	Other food	Cereals	Pulses	Milk & milk products	Egg, fish & meat	Other food
Kerala	urban	1	28.8	56.41	4.73	2.05	25.31	10.9	16.25	1.36	0.59	7.29	3.14	203.86	6.25	17.10	62.06	233.85
Kerala	urban	2	33.2	54.93	6.28	4.1	21.5	12.21	18.24	2.08	1.36	7.14	4.05	228.84	9.56	39.42	60.77	301.98
Kerala	urban	3	37.1	52.8	6.21	4.19	24.6	10.46	19.59	2.30	1.55	9.13	3.88	245.81	10.56	45.02	77.70	289.09
Kerala	urban	4	39.1	52.51	6.8	5.17	22.6	12.3	20.53	2.66	2.02	8.84	4.81	257.64	12.19	58.54	75.23	358.27
Kerala	urban	5	44.3	50.28	7.57	6.51	21.78	12.93	22.27	3.35	2.88	9.65	5.73	279.50	15.38	83.51	82.14	426.71
Kerala	urban	6	47.6	48.46	7.16	6.74	21.66	15.25	23.07	3.41	3.21	10.31	7.26	289.45	15.63	92.91	87.78	540.76
Kerala	urban	7	52.6	48.1	8.11	7.5	21.42	14.12	25.30	4.27	3.95	11.27	7.43	317.48	19.56	114.24	95.92	553.28
Kerala	urban	8	65.2	38.39	7.78	8.43	18.97	25.68	25.03	5.07	5.50	12.37	16.74	314.09	23.26	159.17	105.30	1247.29
Kerala	urban	9	62.9	40.24	9.05	10	23.31	16.65	25.31	5.69	6.29	14.66	10.47	317.61	26.10	182.15	124.83	780.17
Kerala	urban	10	66.1	37.07	10.16	12.4	23.71	15.9	24.50	6.72	8.20	15.67	10.51	307.48	30.79	237.35	133.43	782.93
Kerala	urban	11	81.9	31.29	9.61	12.03	28.27	18.25	25.63	7.87	9.85	23.15	14.95	321.57	36.09	285.31	197.11	1113.45
Kerala	urban	12	89.7	29.84	10.28	13.17	23.87	22.25	26.77	9.22	11.81	21.41	19.96	335.88	42.28	342.10	182.29	1486.79
Kerala	urban	All	56.7	41.46	8.56	9.24	23.05	16.98	23.51	4.85	5.24	13.07	9.63	294.99	22.25	151.72	111.27	717.21

State	Area	MPCE Class	Per capita per day Protein intake (grams)		Percentage of total intake of Protein per capita per day by MPCE class					Per capita per day Protein intake from different food sources					Per capita per day Food intake from different food sources				
			Protein intake (grams)	MPCE Class	Cereals	Pulses	Milk & milk products	Egg, fish & meat	Other food	Cereals	Pulses	Milk & milk products	Egg, fish & meat	Other food	Cereals	Pulses	Milk & milk products	Egg, fish & meat	Other food
gujrat	rural	1	36.4	83.16	8.94	2.4	0.12	5.38	30.27	3.25	0.87	0.04	1.96	379.84	14.92	25.30	0.37	145.88	
gujrat	rural	2	35.8	76.1	9.26	6.86	0.46	7.31	27.24	3.32	2.46	0.16	2.62	341.87	15.20	71.12	1.40	194.95	
gujrat	rural	3	43.6	76.04	9.79	6.71	0.43	7.03	33.15	4.27	2.93	0.19	3.07	416.02	19.57	84.72	1.60	228.33	
gujrat	rural	4	45.8	73.68	10.24	8.36	0.89	6.82	33.75	4.69	3.83	0.41	3.12	423.45	21.50	110.88	3.47	232.69	
gujrat	rural	5	49.7	72.6	9.52	9.96	0.53	7.38	36.08	4.73	4.95	0.26	3.67	452.77	21.69	143.35	2.24	273.24	
gujrat	rural	6	49.4	70.08	10.87	9.56	1.08	8.4	34.62	5.37	4.72	0.53	4.15	434.42	24.62	136.76	4.54	309.12	
gujrat	rural	7	50.8	67.26	10.55	12.07	1.19	8.91	34.17	5.36	6.13	0.60	4.53	428.76	24.57	177.56	5.15	337.38	
gujrat	rural	8	57.2	66	10.16	11.23	1.05	11.53	37.75	5.81	6.42	0.60	6.60	473.73	26.64	186.02	5.11	491.30	
gujrat	rural	9	56	62.66	12.1	13.36	1.04	10.83	35.09	6.78	7.48	0.58	6.06	440.32	31.07	216.66	4.96	451.80	
gujrat	rural	10	57.9	59.58	12.25	15.75	1.77	10.64	34.50	7.09	9.12	1.02	6.16	432.88	32.52	264.08	8.72	458.93	
gujrat	rural	11	66.9	56.24	12.14	18.14	1.45	12.02	37.62	8.12	12.14	0.97	8.04	472.13	37.24	351.43	8.26	599.04	
gujrat	rural	12	68.3	48.42	13.02	20.99	0.83	16.72	33.07	8.89	14.34	0.57	11.42	414.99	40.77	415.15	4.83	850.71	
gujrat	rural	All	53.3	65.2	11.09	12.6	1.06	10.04	34.75	5.91	6.72	0.56	5.35	436.08	27.10	194.48	4.81	398.65	

State	Area	MPCE Class	Per capita per day Protein intake (grams)		Percentage of total intake of Protein per capita per day by MPCE class					Per capita per day Protein intake from different food sources					Per capita per day Food intake from different food sources				
			Protein intake (grams)	MPCE Class	Cereals	Pulses	Milk & milk products	Egg, fish & meat	Other food	Cereals	Pulses	Milk & milk products	Egg, fish & meat	Other food	Cereals	Pulses	Milk & milk products	Egg, fish & meat	Other food
gujrat	urban	1	31.4	67.79	11.23	9.01	2.14	9.83	21.29	3.53	2.83	0.67	3.09	267.11	16.17	81.93	5.72	229.94	
gujrat	urban	2	39.2	70.26	12.01	8.13	1.13	8.47	27.54	4.71	3.19	0.44	3.32	345.61	21.59	92.29	3.77	247.34	
gujrat	urban	3	41.2	64.48	11.96	10.8	2.74	10.02	26.57	4.93	4.45	1.13	4.13	333.36	22.59	128.85	9.61	307.53	
gujrat	urban	4	66.6	44.5	8.16	9.57	1.51	36.25	29.64	5.43	6.37	1.01	24.14	371.90	24.92	184.57	8.56	1798.49	
gujrat	urban	5	45.6	61.06	12.54	14.23	1.36	10.78	27.84	5.72	6.49	0.62	4.92	349.39	26.22	187.91	5.28	366.19	
gujrat	urban	6	51.4	59.44	13.02	14.09	1.7	11.71	30.55	6.69	7.24	0.87	6.02	383.38	30.68	209.72	7.44	448.38	
gujrat	urban	7	53.7	56.92	13.28	15.47	1.93	12.38	30.57	7.13	8.31	1.04	6.65	383.56	32.70	240.57	8.82	495.25	
gujrat	urban	8	70.6	44.4	10.09	13.76	0.72	31	31.35	7.12	9.71	0.51	21.89	393.35	32.66	281.32	4.33	1630.39	
gujrat	urban	9	55.1	53.11	13.34	18.04	1.8	13.68	29.26	7.35	9.94	0.99	7.54	367.21	33.70	287.85	8.44	561.52	
gujrat	urban	10	60.3	48.36	13.58	20.95	1.26	15.78	29.16	8.19	12.63	0.76	9.52	365.93	37.54	365.83	6.47	708.84	
gujrat	urban	11	63.1	45.95	13.86	23.37	1.36	15.43	28.99	8.75	14.75	0.86	9.74	363.83	40.10	427.03	7.31	725.31	
gujrat	urban	12	80.4	37.89	15.18	20.42	1	25.46	30.46	12.20	16.42	0.80	20.47	382.27	55.96	475.43	6.84	1524.90	
gujrat	urban	All	57.3	51.39	12.3	15.99	1.43	18.86	29.45	7.05	9.16	0.82	10.81	369.51	32.31	265.32	6.98	805.05	

State	Area	MPCE Class	Per capita per day Protein intake (grams)				Percentage of total intake of Protein per capita per day by MPCE class				Per capita per day Protein intake from different food sources				Per capita per day Food intake from different food sources			
			Cereals	Pulses	Milk & milk products	Egg, fish & meat	Other food	Cereals	Pulses	Milk & milk products	Egg, fish & meat	Other food	Cereals	Pulses	Milk & milk products	Egg, fish & meat	Other food	
Bihar	rural	1	39.10	8.76	1.62	1.57	7.7	31.42	3.43	0.63	0.61	3.01	394.28	15.70	18.34	5.23	224.28	
Bihar	rural	2	48.00	8.13	2.07	1.61	13.14	36.02	3.90	0.99	0.77	6.31	452.04	17.89	28.77	6.58	469.85	
Bihar	rural	3	49.10	8.38	3.3	1.85	8.07	38.50	4.11	1.62	0.91	3.96	483.11	18.86	46.92	7.73	295.18	
Bihar	rural	4	53.90	75.87	4.55	2.29	8.12	40.89	4.93	2.45	1.23	4.38	513.15	22.61	71.02	10.51	326.04	
Bihar	rural	5	58.90	72.92	9.74	2	9.1	42.95	5.74	3.64	1.18	5.36	538.95	26.30	105.41	10.03	399.28	
Bihar	rural	6	61.20	71.81	10.07	1.93	9.03	43.95	6.16	4.38	1.18	5.53	551.47	28.26	126.89	10.06	411.68	
Bihar	rural	7	64.20	69.75	10.26	2.3	9.26	44.78	6.59	5.42	1.48	5.94	561.91	30.20	156.91	12.57	442.87	
Bihar	rural	8	67.60	68.36	9.88	1.97	9.2	46.21	6.68	7.16	1.33	6.22	579.88	30.62	207.31	11.34	463.30	
Bihar	rural	9	71.90	65.13	10.65	2.23	9.18	46.83	7.66	9.20	1.60	6.60	587.62	35.11	266.51	13.65	491.70	
Bihar	rural	10	74.50	63.98	11.21	2.1	9.59	47.67	8.35	9.78	1.56	7.14	598.12	38.29	283.27	13.32	532.23	
Bihar	rural	11	76.80	61.46	11.26	2.54	9.85	47.20	8.65	11.43	1.95	7.56	592.30	39.65	330.93	16.61	563.54	
Bihar	rural	12	89.70	58.71	11.77	2.93	12.31	52.66	10.56	12.82	2.63	11.04	660.84	48.41	371.19	22.38	822.58	
Bihar	rural	All	57.80	72.18	6.98	2.04	9.16	41.72	5.56	4.03	1.18	5.29	523.52	25.49	116.83	10.04	394.41	
Bihar	urban	1	45.20	78.13	9.23	1.72	8.18	35.31	4.17	1.23	0.78	3.70	443.14	19.13	35.73	6.62	275.43	
Bihar	urban	2	53.30	73.53	10.30	1.24	9.26	39.19	5.49	3.02	0.66	4.94	491.79	25.17	87.52	5.63	367.67	
Bihar	urban	3	56.80	71.88	10.73	2.4	9.28	40.83	6.09	3.24	1.36	5.27	512.33	27.94	93.76	11.61	392.66	
Bihar	urban	4	63.90	68.58	10.95	1.79	9.54	43.82	7.00	5.84	1.14	6.10	549.90	32.08	169.13	9.74	454.12	
Bihar	urban	5	61.70	67.37	10.38	2.75	10.81	41.57	6.40	5.36	1.70	6.67	521.60	29.36	155.27	14.45	496.86	
Bihar	urban	6	66.70	65.14	11.18	3.08	10.08	43.45	7.46	7.02	2.05	6.72	545.21	34.19	203.39	17.49	500.86	
Bihar	urban	7	62.20	60.31	12.12	2.83	12.63	37.51	7.54	7.53	1.76	7.86	470.73	34.56	218.13	14.99	585.22	
Bihar	urban	8	65.70	59.1	13.35	3.14	12.38	38.83	8.77	7.90	2.06	8.13	487.24	40.21	228.88	17.56	605.92	
Bihar	urban	9	66.80	59.33	13.76	2.25	11.99	39.63	9.19	8.46	1.50	8.01	497.32	42.14	245.09	12.80	596.65	
Bihar	urban	10	72.80	54.46	14.75	1.84	14.19	39.65	10.74	10.75	1.34	10.33	497.51	49.23	311.17	11.40	769.55	
Bihar	urban	11	86.40	43.32	14.29	2.51	19.43	37.43	12.35	15.91	2.17	16.79	469.67	56.61	460.62	18.46	1250.58	
Bihar	urban	12	197.60	19.66	6.89	0.97	66.39	38.85	13.61	12.01	1.92	131.19	487.48	62.42	347.91	16.32	9772.72	
Bihar	urban	All	62.20	64.02	11.02	2.17	14.18	39.82	6.85	5.32	1.35	8.82	499.68	31.43	154.18	11.49	657.04	

State	Area	MPCE Class	Per capita per day Protein intake (grams)					Percentage of total intake of Protein per capita per day by MPCE class					Per capita per day Protein intake from different food Sources					Per capita per day Food intake from different food Sources				
			Cereals	Pulses	Milk & milk products	Egg, fish & meat	Other food	Cereals	Pulses	Milk & milk products	Egg, fish & meat	Other food	Cereals	Pulses	Milk & milk products	Egg, fish & meat	Other food	Cereals	Pulses	Milk & milk products	Egg, fish & meat	Other food
Punjab	rural	1	39.30	6.62	3.65	0	4.25	33.60	2.60	1.43	0.00	1.67	421.60	11.93	41.54	0.00	124.42					
Punjab	rural	2	37.80	7.85	11.08	0.00	5.98	28.39	2.97	4.19	0.00	2.26	356.22	13.60	121.28	0.00	168.39					
Punjab	rural	3	42.50	7.68	13.06	0	6.33	31.00	3.26	5.55	0.00	2.69	388.94	14.96	160.73	0.00	200.41					
Punjab	rural	4	45.60	71.79	8.89	13.81	5.43	32.74	4.05	6.30	0.03	2.48	410.79	18.59	182.36	0.27	184.45					
Punjab	rural	5	49.50	70.59	8.96	14.17	6.15	34.94	4.44	7.01	0.06	3.04	438.47	20.33	203.12	0.55	226.78					
Punjab	rural	6	59.40	61.43	8.39	12.53	17.24	36.49	4.98	7.44	0.24	10.24	457.88	22.85	215.53	2.07	762.87					
Punjab	rural	7	54.60	67.59	9.89	15.34	6.9	36.90	5.40	8.38	0.15	3.77	463.09	24.76	242.55	1.26	280.65					
Punjab	rural	8	57.90	64.35	9.81	18.11	7.46	37.26	5.68	10.49	0.16	4.32	467.54	26.04	303.65	1.33	321.77					
Punjab	rural	9	61.50	60.87	9.54	21.65	7.58	37.44	5.87	13.31	0.23	4.66	469.75	26.90	385.57	1.99	347.27					
Punjab	rural	10	67.30	57.72	9.74	23.88	8.09	38.85	6.56	16.07	0.38	5.44	487.45	30.05	465.40	3.27	405.59					
Punjab	rural	11	75.40	54.44	9.71	26.88	8.33	41.05	7.32	20.27	0.48	6.28	515.08	33.57	586.91	4.11	467.89					
Punjab	rural	12	88.30	48.92	9.96	30.53	9.46	43.20	8.79	26.96	0.99	8.35	542.05	40.32	780.66	8.42	622.27					
Punjab	rural	All	66.70	9.64	23.15	0.59	8.56	38.73	6.43	15.44	0.39	5.71	485.95	29.48	447.15	3.35	425.33					

State	Area	MPCE Class	Per capita per day Protein intake (grams)					Percentage of total intake of Protein per capita per day by MPCE class					Per capita per day Protein intake from different food Sources					Per capita per day Food intake from different food Sources				
			Cereals	Pulses	Milk & milk products	Egg, fish & meat	Other food	Cereals	Pulses	Milk & milk products	Egg, fish & meat	Other food	Cereals	Pulses	Milk & milk products	Egg, fish & meat	Other food	Cereals	Pulses	Milk & milk products	Egg, fish & meat	Other food
Punjab	urban	1	37.3	10.9	10.16	0.29	5.43	27.31	4.07	3.79	0.11	2.03	342.71	18.64	109.74	0.92	150.88					
Punjab	urban	2	49.2	7.96	12.37	0.05	21.24	28.72	3.92	6.09	0.02	10.45	360.43	17.96	176.24	0.21	778.48					
Punjab	urban	3	45.5	10.51	15.06	0.53	7.34	30.29	4.78	6.85	0.24	3.34	380.08	21.92	198.43	2.05	248.79					
Punjab	urban	4	51.2	10.96	15.28	0.61	7.27	33.73	5.61	7.82	0.31	3.72	423.27	25.73	226.55	2.66	277.29					
Punjab	urban	5	56	10.79	16.52	0.91	6.95	36.31	6.04	9.25	0.51	3.89	455.64	27.70	267.90	4.34	289.89					
Punjab	urban	6	60.3	10.18	18.81	0.93	10.7	35.81	6.14	11.34	0.56	6.45	449.39	28.14	328.46	4.77	480.65					
Punjab	urban	7	59.4	58	20.33	0.89	8.78	34.45	7.13	12.08	0.53	5.22	432.32	32.68	349.70	4.50	388.51					
Punjab	urban	8	62.9	11.67	22.4	0.87	8.97	35.28	7.34	14.09	0.55	5.64	442.72	33.65	408.01	4.66	420.31					
Punjab	urban	9	66	50.62	11.3	26.78	1.23	33.41	7.46	17.67	0.81	6.61	419.23	34.19	511.83	6.91	492.65					
Punjab	urban	10	74	49.68	10.99	27.44	0.9	36.76	8.13	20.31	0.67	8.13	461.32	37.29	588.02	5.67	605.28					
Punjab	urban	11	76.8	46.37	10.12	29.91	1.8	35.61	7.77	22.97	1.38	8.98	446.88	35.63	665.20	11.77	668.81					
Punjab	urban	12	87.8	37.35	10.38	29.28	2.44	32.79	9.11	25.71	2.14	18.04	411.50	41.78	744.46	18.24	1344.10					
Punjab	urban	All	63.4	10.92	22.92	1.1	10.42	34.63	6.92	14.53	0.70	6.61	434.54	31.74	420.80	5.94	492.13					

Area	MPCE Class	Per capita per day Protein intake (grams)	Percentage of total intake of Protein per capita per day by MPCE class					Per capita per day Protein intake from different food sources					Per capita per day Food intake from different food sources				
			Cereals	Pulses	Milk & milk products	Egg, fish & meat	Other food	Cereals	Pulses	Milk & milk products	Egg, fish & meat	Other food	Cereals	Pulses	Milk & milk products	Egg, fish & meat	Other food
All-India	rural	36.9	79.69	8.92	1.49	1.90	7.99	29.41	3.29	0.55	0.70	2.95	368.99	15.09	15.92	5.97	219.63
All-India	rural	43.7	76.99	8.53	2.66	1.95	9.86	33.64	3.73	1.16	0.85	4.31	422.19	17.09	33.66	7.25	320.98
All-India	rural	45.9	76.28	8.65	3.61	2.53	8.92	35.01	3.97	1.66	1.16	4.09	439.35	18.20	47.98	9.89	305.00
All-India	rural	50.1	72.73	8.89	5.00	2.69	10.66	36.44	4.45	2.51	1.35	5.34	457.24	20.42	72.54	11.47	397.85
All-India	rural	52.2	71.73	9.16	6.30	3.01	9.75	37.44	4.78	3.29	1.57	5.09	469.85	21.92	95.23	13.38	379.14
All-India	rural	54.1	69.95	9.48	7.25	3.33	9.95	37.84	5.13	3.92	1.80	5.38	474.87	23.51	113.58	15.34	401.00
All-India	rural	57	68.09	9.39	9.09	3.47	9.92	38.81	5.35	5.18	1.98	5.65	487.02	24.54	150.04	16.84	421.22
All-India	rural	60.2	65.62	9.38	9.89	3.85	11.20	39.50	5.65	5.95	2.32	6.74	495.70	25.89	172.41	19.73	502.27
All-India	rural	63.6	62.69	9.55	11.42	4.46	11.79	39.87	6.07	7.26	2.84	7.50	500.32	27.85	210.33	24.15	558.59
All-India	rural	68	59.13	9.92	13.60	5.38	11.87	40.21	6.75	9.25	3.66	8.07	504.55	30.93	267.81	31.15	601.29
All-India	rural	73	56.00	10.18	16.72	5.35	11.59	40.88	7.43	12.21	3.91	8.46	512.98	34.07	353.45	33.25	630.28
All-India	rural	84.9	50.32	10.97	16.49	7.80	14.18	42.72	9.31	14.00	6.62	12.04	536.09	42.70	405.42	56.38	896.83
All-India	rural	57	66.37	9.47	9.28	3.98	10.84	37.83	5.40	5.29	2.27	6.18	474.72	24.75	153.18	19.31	460.29

Area	MPCE Class	Per capita per day Protein intake (grams)	Percentage of total intake of Protein per capita per day by MPCE class					Per capita per day Protein intake from different food sources					Per capita per day Food intake from different food sources				
			Cereals	Pulses	Milk & milk products	Egg, fish & meat	Other food	Cereals	Pulses	Milk & milk products	Egg, fish & meat	Other food	Cereals	Pulses	Milk & milk products	Egg, fish & meat	Other food
All-India	urban	40.4	74.49	8.48	3.70	3.30	10.01	30.09	3.43	1.49	1.33	4.04	377.63	15.71	43.29	11.35	301.26
All-India	urban	45.6	71.55	9.17	5.71	3.67	9.86	32.63	4.18	2.60	1.67	4.50	409.42	19.17	75.40	14.25	334.94
All-India	urban	47.4	68.13	9.98	6.87	4.72	10.27	32.29	4.73	3.26	2.24	4.87	405.23	21.69	94.30	19.05	362.64
All-India	urban	55.3	59.59	9.47	7.94	4.45	18.51	32.95	5.24	4.39	2.46	10.24	413.51	24.01	127.15	20.95	762.53
All-India	urban	52.7	61.22	10.80	9.81	5.23	12.91	32.26	5.69	5.17	2.76	6.80	404.85	26.10	149.71	23.47	506.83
All-India	urban	55.3	59.84	10.84	10.96	5.51	12.79	33.09	5.99	6.06	3.05	7.07	415.25	27.48	175.51	25.94	526.89
All-India	urban	56.1	58.10	11.52	12.51	5.08	12.74	32.59	6.46	7.02	2.85	7.15	409.00	29.63	203.23	24.26	532.42
All-India	urban	60	54.47	11.22	13.14	5.30	15.82	32.68	6.73	7.88	3.18	9.49	410.11	30.87	228.31	27.07	707.10
All-India	urban	61.3	52.21	11.99	14.94	6.32	14.47	32.00	7.35	9.16	3.87	8.87	401.61	33.70	265.21	32.98	660.78
All-India	urban	64.4	48.03	12.24	17.22	6.19	16.25	30.93	7.88	11.09	3.99	10.47	388.14	36.14	321.14	33.94	779.59
All-India	urban	70.9	43.21	12.13	18.63	6.81	19.15	30.64	8.60	13.21	4.83	13.58	384.43	39.43	382.50	41.11	1011.44
All-India	urban	78.5	37.50	11.64	19.55	7.46	23.79	29.44	9.14	15.35	5.86	18.68	369.39	41.89	444.42	49.86	1391.20
All-India	urban	57	56.16	11.00	12.33	5.47	14.98	32.01	6.27	7.03	3.12	8.54	401.69	28.75	203.52	26.54	636.08

Appendix 3.5 Estimated EAA availability in rural & urban sectors of Kerala, Gujarat, Bihar, Punjab and all-India in 2004 (EAA values are in terms of percentage of availability against the recommended requirement of EAA of adult group, recommended by WHO/FAO)

MPCE classes	Protein intake (g per capita per day)	Histidine	Isoleucine	Leucine	Lysine	Methionine + Cystine	Phenylalanine + Tyrosine	Threonine	Tryptophan	Valine
MPCE 1	20.6	51.77	51.55	46.88	38.13	52.81	73.19	58.84	65.37	53.72
MPCE 2	27.3	72.37	71.42	63.60	56.45	73.57	98.89	82.50	89.71	73.24
MPCE 3	32.3	85.26	84.67	74.98	66.77	84.52	117.00	97.10	104.51	86.09
MPCE 4	33.1	89.55	89.24	77.97	72.13	87.82	122.12	102.55	109.61	89.83
MPCE 5	33.9	89.95	90.39	79.18	71.73	88.13	124.70	103.39	111.80	91.31
MPCE 6	38.1	102.33	102.22	89.43	82.21	100.75	140.14	117.25	126.03	102.99
MPCE 7	46.1	127.21	130.97	112.40	105.75	121.50	177.47	146.38	158.41	128.11
MPCE 8	45.2	122.06	122.70	106.52	99.22	118.34	167.80	140.41	150.38	122.85
MPCE 9	47.6	128.15	129.79	111.89	105.48	123.55	177.15	148.21	159.32	129.32
MPCE 10	51.2	138.19	140.63	120.89	114.02	131.67	191.85	159.88	171.47	139.51
MPCE 11	60.8	167.04	170.51	144.61	141.68	157.53	230.12	194.12	206.70	167.31
MPCE 12	80.7	226.94	232.45	194.07	198.13	210.25	310.21	265.12	279.22	225.34
ALL (Average)	55.4	152.02	154.74	131.78	128.01	144.07	209.28	176.31	187.88	152.35
MPCE 1	28.8	78.40	77.39	67.86	63.06	78.03	105.74	89.58	95.66	78.30
MPCE 2	33.2	89.36	89.58	78.22	71.90	87.38	122.89	102.55	110.21	90.10
MPCE 3	37.1	101.09	100.46	87.42	82.33	98.97	136.45	115.49	122.56	100.54
MPCE 4	39.1	106.94	107.33	93.10	87.23	103.78	146.31	122.79	131.17	107.21
MPCE 5	44.3	121.23	122.45	105.63	99.73	116.41	166.58	139.53	148.94	121.60
MPCE 6	47.6	130.20	132.17	113.37	108.19	124.72	179.78	150.83	161.69	131.09
MPCE 7	52.6	144.76	147.04	126.06	120.29	137.73	199.60	167.19	178.42	145.28
MPCE 8	65.2	176.49	184.49	153.65	153.64	163.76	250.79	210.57	228.77	180.93
MPCE 9	62.9	177.05	181.23	152.36	152.67	165.11	242.80	206.07	217.95	176.27
MPCE 10	66.1	189.05	194.24	162.19	165.02	174.03	258.39	219.74	230.80	186.99
MPCE 11	81.9	239.43	244.86	201.62	215.12	220.07	321.75	279.92	291.09	234.20
MPCE 12	89.7	257.38	267.90	219.38	232.06	232.96	354.89	304.24	320.79	255.95
ALL (Average)	56.7	158.68	162.29	136.78	136.19	148.73	218.06	184.82	196.16	158.45

MPCE classes	Protein intake (g per capita per day)	Histidine	Isoleucine	Leucine	Lysine	Methionine + Cystine	Phenylalanine + Tyrosine	Threonine	Tryptophan	Valine
RURAL GUJARAT (2004)	MPCE 1	97.74	97.28	82.69	53.49	107.46	146.22	103.30	127.22	85.85
	MPCE 2	97.14	98.38	82.77	57.25	104.01	145.66	104.13	126.94	86.67
	MPCE 3	118.53	119.99	100.96	69.89	126.55	177.55	126.96	154.36	105.65
	MPCE 4	125.42	127.56	106.97	75.79	132.53	187.44	134.63	162.70	111.98
	MPCE 5	135.97	138.89	116.37	82.96	143.55	203.91	146.47	177.48	122.07
	MPCE 6	135.66	139.03	115.96	84.70	141.18	203.02	146.78	176.28	122.10
	MPCE 7	140.14	144.67	120.24	89.83	144.60	209.99	152.40	182.66	126.91
	MPCE 8	156.52	162.13	134.37	101.27	161.25	235.71	171.56	206.18	142.87
	MPCE 9	155.20	161.66	133.51	103.20	156.29	232.98	170.36	202.01	141.96
	MPCE 10	161.91	169.69	139.57	110.71	161.28	242.43	178.26	210.20	148.46
	MPCE 11	187.47	198.14	162.34	131.52	184.47	281.76	207.96	244.71	173.53
	MPCE 12	191.41	205.84	166.92	141.97	182.06	290.22	216.55	252.75	181.18
ALL (Average)	53.3	147.16	152.58	126.44	95.89	150.32	220.87	160.82	192.02	133.99
URBAN GUJARAT (2004)	MPCE 1	86.38	88.82	73.71	55.20	89.23	129.02	93.97	112.34	77.94
	MPCE 2	107.71	110.14	91.85	67.05	111.56	160.91	116.43	139.18	96.75
	MPCE 3	114.30	118.26	97.68	75.28	116.34	170.30	124.83	148.04	103.45
	MPCE 4	173.42	189.29	150.56	133.26	168.03	272.09	207.01	249.65	172.21
	MPCE 5	126.97	132.62	109.29	85.62	126.89	190.30	139.57	164.79	116.26
	MPCE 6	143.19	149.94	123.21	97.84	142.07	214.55	157.97	185.84	131.45
	MPCE 7	150.26	158.17	129.54	104.83	147.59	225.18	166.50	195.11	138.56
	MPCE 8	188.08	204.99	163.88	143.98	179.59	292.71	221.46	263.85	184.86
	MPCE 9	154.71	164.31	133.95	111.09	149.75	232.50	172.74	201.69	143.98
	MPCE 10	169.69	182.24	147.77	125.96	161.02	256.36	191.46	222.62	160.00
	MPCE 11	178.99	193.18	156.30	135.22	168.05	270.17	202.32	234.20	169.22
	MPCE 12	223.51	245.23	195.51	178.11	202.21	342.39	260.60	300.05	217.81
ALL (Average)	57.3	158.10	168.85	137.00	114.90	152.99	240.06	179.12	210.72	149.33

MPCE classes	Protein intake (g per capita per day)	Histidine	Isoleucine	Leucine	Lysine	Methionine + Cystine	Phenylalanine + Tyrosine	Threonine	Tryptophan	Valine
RURAL BIHAR (2004)	MPCE 1	39.1	96.81	91.37	62.75	93.45	142.57	106.30	121.57	101.96
	MPCE 2	48	119.92	110.11	79.71	113.27	176.08	132.38	152.36	125.66
	MPCE 3	49.1	122.88	114.06	80.60	117.82	180.16	134.70	154.12	128.68
	MPCE 4	53.9	132.35	126.08	91.15	129.41	199.35	149.71	170.20	142.13
	MPCE 5	58.9	145.70	138.56	102.26	140.76	219.92	165.45	187.71	156.28
	MPCE 6	61.2	152.24	144.67	107.63	146.30	229.74	172.92	195.85	163.00
	MPCE 7	64.2	161.08	152.61	115.52	153.86	242.59	183.22	206.92	171.91
	MPCE 8	67.6	170.37	161.65	123.29	162.33	257.18	194.00	219.64	181.80
	MPCE 9	71.9	183.76	173.69	135.65	172.87	276.67	209.46	235.79	195.02
	MPCE 10	74.5	191.01	180.34	141.86	178.53	287.71	218.00	244.88	202.55
	MPCE 11	76.8	198.81	187.12	149.99	184.69	298.85	227.29	254.72	210.08
	MPCE 12	89.7	232.63	248.00	178.32	214.20	350.00	267.79	299.44	245.96
ALL (Average)	57.8	143.41	149.57	136.33	101.19	138.36	216.47	162.95	184.92	153.71
URBAN BIHAR (2004)	MPCE 1	45.2	109.82	104.97	74.30	107.92	165.92	124.09	141.46	118.45
	MPCE 2	53.3	131.35	125.22	91.61	126.50	198.98	149.16	169.32	141.24
	MPCE 3	56.8	141.31	133.85	99.83	135.47	212.56	160.48	180.93	151.04
	MPCE 4	63.9	160.76	152.35	115.95	152.29	242.64	183.06	206.42	171.54
	MPCE 5	61.7	155.37	163.08	113.17	147.55	233.94	177.59	200.28	165.71
	MPCE 6	66.7	170.24	179.12	125.72	160.01	255.30	194.32	217.75	180.45
	MPCE 7	62.2	160.08	170.06	121.49	147.71	240.96	184.23	205.91	169.63
	MPCE 8	65.7	170.34	180.84	130.03	155.68	255.43	195.83	217.27	179.70
	MPCE 9	66.8	173.05	184.20	131.69	157.55	260.40	198.76	220.72	182.80
	MPCE 10	72.8	190.46	204.76	148.74	170.09	287.72	220.34	244.08	201.05
	MPCE 11	86.4	225.20	246.30	185.90	196.41	341.80	265.22	294.03	237.62
	MPCE 12	197.6	467.75	548.90	425.52	397.41	779.87	630.67	750.16	542.35
ALL (Average)	62.2	156.17	165.29	147.13	115.88	146.36	236.89	180.31	203.58	167.34

MPCE classes	Protein intake (g per capita per day)	Histidine	Isoleucine	Leucine	Lysine	Methionine + Cystine	Phenylalanine + Tyrosine	Threonine	Tryptophan	Valine
RURAL PUNJAB (2004)	MPCE 1	39.3	105.23	89.72	56.36	117.85	157.71	110.75	138.11	92.18
	MPCE 2	37.8	103.21	88.51	61.56	110.64	155.06	110.61	135.36	92.39
	MPCE 3	42.5	116.45	100.17	70.94	123.96	175.16	125.29	153.03	104.77
	MPCE 4	45.6	125.88	108.30	77.49	132.59	188.77	135.26	163.93	113.09
	MPCE 5	49.5	136.64	117.65	85.02	143.30	205.09	147.29	178.26	123.15
	MPCE 6	59.4	160.29	168.38	138.49	164.00	244.74	179.32	217.19	149.74
	MPCE 7	54.6	151.53	156.75	130.67	156.55	227.37	164.15	197.20	137.25
	MPCE 8	57.9	161.59	168.50	139.92	165.04	242.82	176.04	210.75	147.39
	MPCE 9	61.5	172.95	181.89	150.47	174.63	260.08	189.34	225.90	158.76
	MPCE 10	67.3	190.33	201.52	166.07	189.86	286.28	209.38	248.65	175.65
	MPCE 11	75.4	214.68	229.01	188.06	211.63	323.13	237.27	280.69	199.29
	MPCE 12	88.3	253.69	273.66	223.23	245.06	381.98	282.83	332.15	237.66
ALL (Average)	66.7	188.12	199.03	164.02	130.33	188.04	283.15	207.09	246.25	173.67
URBAN PUNJAB (2004)	MPCE 1	37.3	102.85	87.95	62.35	107.90	153.62	110.13	132.54	91.82
	MPCE 2	49.2	131.52	113.94	90.39	133.44	202.49	149.16	181.01	124.68
	MPCE 3	45.5	126.46	108.97	81.50	129.87	189.56	137.23	164.23	114.64
	MPCE 4	51.2	142.61	122.89	92.44	145.78	213.58	154.82	184.72	129.31
	MPCE 5	56	156.63	135.12	102.61	159.68	234.31	170.15	202.74	142.09
	MPCE 6	60.3	168.26	171.19	115.26	168.88	253.45	185.68	221.03	155.25
	MPCE 7	59.4	167.82	176.90	145.63	165.90	251.59	184.52	217.21	154.34
	MPCE 8	62.9	178.30	188.87	155.17	175.30	267.58	196.63	231.28	164.65
	MPCE 9	66	188.59	202.24	165.11	182.21	283.47	209.88	245.72	175.96
	MPCE 10	74	211.15	227.12	185.21	203.51	318.34	235.84	276.51	197.95
	MPCE 11	76.8	219.97	238.29	193.44	210.80	331.49	247.05	289.42	207.20
	MPCE 12	87.8	248.69	274.40	219.33	230.85	378.87	287.59	335.39	240.77
ALL (Average)	63.4	182.16	194.11	158.98	130.34	178.58	274.09	202.12	238.21	169.32

MPCE classes	Protein intake (g per capita per day)	Histidine	Isoleucine	Leucine	Lysine	Methionine + Cystine	Phenylalanine + Tyrosine	Threonine	Tryptophan	Valine
MPCE 1	36.9	89.18	91.55	85.30	59.68	88.22	134.64	100.64	114.88	96.32
MPCE 2	43.7	105.85	109.38	101.07	72.25	104.22	160.34	120.27	137.62	114.51
MPCE 3	45.9	112.15	115.79	106.81	77.07	110.20	169.04	127.12	144.88	120.72
MPCE 4	50.1	123.31	128.20	117.01	86.83	119.91	186.13	140.65	160.08	132.61
MPCE 5	52.2	129.60	134.82	122.74	91.92	125.50	194.91	147.50	167.25	138.73
MPCE 6	54.1	135.31	141.06	127.79	97.13	130.22	203.11	154.17	174.26	144.41
MPCE 7	57	143.69	150.36	135.53	104.45	137.68	215.54	163.87	185.08	152.97
MPCE 8	60.2	152.50	160.17	143.38	112.64	145.31	228.76	174.69	197.10	162.20
MPCE 9	63.6	162.75	171.53	152.35	122.46	153.93	243.51	186.92	210.20	172.44
MPCE 10	68	176.82	186.95	164.55	135.95	165.60	263.18	203.32	227.29	186.07
MPCE 11	73	192.23	204.51	178.65	150.32	178.27	285.97	221.19	246.70	201.46
MPCE 12	84.9	227.05	241.58	207.96	183.35	207.79	334.49	263.14	290.29	236.03
ALL (Average)	57	144.26	151.17	135.61	106.08	137.70	216.10	165.02	186.02	153.37
MPCE 1	40.4	99.08	102.39	93.95	69.04	97.15	149.00	112.71	128.25	106.48
MPCE 2	45.6	113.42	117.69	107.11	80.63	109.93	170.00	129.10	146.04	121.18
MPCE 3	47.4	119.73	124.49	112.21	87.13	114.67	178.34	136.53	153.14	127.00
MPCE 4	55.3	139.24	147.65	129.74	106.70	130.86	210.52	162.88	184.24	149.25
MPCE 5	52.7	135.48	142.49	126.00	102.79	126.97	201.84	155.93	173.98	143.08
MPCE 6	55.3	143.03	150.69	132.80	109.42	133.60	212.74	164.66	183.42	150.67
MPCE 7	56.1	146.10	154.61	135.64	112.73	135.17	217.57	168.27	187.03	153.64
MPCE 8	60	156.42	166.66	144.73	123.25	143.73	233.86	181.84	202.61	164.93
MPCE 9	61.3	162.54	173.09	149.58	129.65	148.13	241.02	188.34	208.02	169.83
MPCE 10	64.4	172.24	184.95	158.14	140.35	155.05	256.16	200.78	221.73	179.87
MPCE 11	70.9	191.03	206.57	174.44	159.63	170.25	284.49	224.63	248.03	199.43
MPCE 12	78.5	212.25	231.58	192.60	182.67	187.28	317.42	252.90	279.99	222.20
ALL (Average)	57	148.20	157.31	137.23	115.75	136.99	221.17	171.82	191.47	156.24

Appendix 3.6 Map of India and selected states

