

Copyright is owned by the Author of the thesis. Permission is given for a copy to be downloaded by an individual for the purpose of research and private study only. The thesis may not be reproduced elsewhere without the permission of the Author.

GLOBAL PROTEIN NUTRITION: ESSENTIAL AMINO ACIDS AVAILABILITY

**A thesis presented in partial fulfillment of the requirements of
the degree of Master of Technology in Food Technology at
Massey University, Palmerston North, New Zealand**

Arnab Sarkar

2012



Massey University

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.

Acknowledgements

I would like to express my sincere gratitude and appreciation to my chief supervisor Dr. Michael Boland and co-supervisors Prof. Srikanta Chatterjee and Dr. Shantanu Das, for their expert guidance, encouragement and constant support. Thanks for your patience and making yourselves available at any time I needed, in spite of your very busy work-schedule.

I am offering my special thanks to the co-directors of the Riddet institute, Prof. Paul Moughan and Prof. Harjinder Singh for approving the financial assistance in the form of the Master Scholarship and project funding.

I would like to show my appreciation and gratitude to the Massey University Scholarship Committee for awarding me with the Catherine Baxter Scholarship.

I am expressing my sincere gratitude to Prof. Jim Harper (United States of America) and Dr. Shane Rutherford for their encouragement, support and valuable discussions during my work.

I thank Mrs. Terri Palmer, Ms. Willi Twight, Mrs. Ansley Te Hiwi, Mr. John Henley King, Ms. Paula MacCool and Mrs. Felicia Stibbards for their administrative support.

I am grateful to all my friends and colleagues in New Zealand Sumon, Dev, Vikas, Anant, Arup, Jinita, Tuli, Shampa, Debjit, Malesh, Amit, Nimmi, Pranav and Shradha for their help and valuable suggestions during my study.

Finally I would like to thank my family for their patience, love and support which enabled me to concentrate and complete my work.

Table of Contents

| | |
|---|-----------|
| Title page..... | i |
| Abstract..... | ii |
| Acknowledgements..... | iv |
| Table of contents..... | v |
| List of figures..... | ix |
| List of tables..... | xii |
| | |
| 1.0 Introduction | 1 |
| 1.1 World hunger scenario..... | 1 |
| 1.1.1 Hunger and the need for food | 1 |
| 1.1.2 Hunger targets..... | 1 |
| 1.1.3 World hunger and under-nutrition status..... | 2 |
| 1.1.4 Global Hunger index (GHI)..... | 3 |
| 1.2 World protein supply | 3 |
| 1.2.1 Protein composition and bioavailability | 3 |
| 1.2.2 World protein supply status..... | 4 |
| 1.2.3 Growing animal protein demand and environmental stress | 5 |
| 1.3 Objective of the thesis and research questions..... | 6 |
| 1.4 The FAO statistical database (FAOSTAT): food and protein supply..... | 7 |
| 1.5 Quality of protein: based on essential amino acid composition and digestibility ... | 8 |
| 1.6 Effect of income disparity on supply of food | 10 |
| 1.7 Population trends and nutritional requirements of the elderly | 11 |
| 1.8 Thesis organization..... | 11 |
| | |
| 2.0 Estimation of essential amino acid (EAA) availability to the world population..... | 12 |

| | |
|--|-----------|
| 2.1 Introduction | 12 |
| 2.2 Methodology | 12 |
| 2.2.1 Protein availability data..... | 12 |
| 2.2.2 Correction for protein bioavailability | 13 |
| 2.2.3 Amino acid profile..... | 16 |
| 2.2.4 Linkage of protein supply data and amino acid data..... | 16 |
| 2.3 Assumptions | 22 |
| 2.4 Results & discussion..... | 24 |
| 2.4.1 Protein..... | 24 |
| 2.4.2 Essential amino acids (EAA)..... | 28 |
| 2.4.3 Availability of essential amino acids in food items | 29 |
| 2.4.4 Countries with limited availability of essential amino acids | 32 |
| 2.4.5 Sensitivity test..... | 46 |
| 2.5 Limitations of this study | 48 |
| 2.6 Conclusion | 49 |
| | |
| 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 | 50 |
| | |
| 3.1 Introduction: | 50 |
| 3.2 Data description | 51 |
| 3.2.1 National Sample Survey Reports, India | 51 |
| 3.2.2 Regional variations within India and selection of states for the study | 53 |
| 3.3 India's economic growth and changes in the food habits and nutritional pattern of the Indian population..... | 53 |
| 3.3.1 Introduction | 53 |
| 3.3.2 GDP (gross domestic product) information..... | 54 |
| 3.3.3 Cereal production and food supply pattern in India..... | 58 |
| 3.4 Availability of essential amino acids in different economic groups in India: method of estimation..... | 59 |
| 3.5 Results and discussion | 64 |

| | |
|---|------------|
| 3.5.1 MPCE class-wise protein supply patterns and estimated EAA availability pattern in the selected states in 2004 | 64 |
| 3.5.2 Lysine availability in the selected states according to the MPCE classes | 73 |
| 3.5.3 Changes in protein supply pattern over the years in India | 74 |
| 3.6 Conclusion | 77 |
| 4.0 Healthy aging and need of quality protein and essential amino acids. | 79 |
| 4.1 Introduction | 79 |
| 4.2 Population aging and demographic trends | 80 |
| 4.3 Sarcopenia and the aging population..... | 83 |
| 4.3.1 Overview | 83 |
| 4.3.2 Understanding of sarcopenia | 84 |
| 4.3.3 Prevention and treatment | 84 |
| 4.3.4 Role of exercise..... | 85 |
| 4.4 Quality protein intake and the health of elderly people..... | 85 |
| 4.4.1 Established recommendations for dietary protein and essential amino acid for the elderly population..... | 86 |
| 4.4.2 New researches and recommendations of higher intake of protein for the elderly population..... | 86 |
| 4.4.3 Role of essential amino acids | 88 |
| 4.4.4 Increase of RDA of protein for the elderly and additional protein requirements | 89 |
| 4.5 Conclusion | 90 |
| 5.0 Conclusions..... | 93 |
| 5.1 Protein and essential amino acid availability and future needs | 93 |
| 5.2 Interrelations between essential amino acid availability and income variation..... | 98 |
| 5.3 GM Food crops: improving the nutritional value of cereals | 100 |
| 5.4 Nutritional needs of the elderly population..... | 103 |
| References: | 106 |
| Appendix 1.1 Global Hunger index (GHI)..... | 123 |

| | |
|--|-----|
| Appendix 2.1 True Protein digestibility (TPD)..... | 123 |
| Appendix 2.2 Food items and respective Indian food ingredients and their true protein digestibility and true ileal amino acid digestibility values..... | 124 |
| Appendix 2.3 List of Food items - amino acid profile not available, respective assumed foods in the same food group | 125 |
| 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)..... | 126 |
| 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)..... | 127 |
| 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..... | 128 |
| 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..... | 133 |
| 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) | 138 |
| Appendix 3.6 Map of India and selected states | 143 |

List of figures

| | |
|---|----|
| Figure 1.1 Undernourishment in 2010, by region (millions)..... | 2 |
| Figure 1.2 Global and regional trends of GHI..... | 3 |
| Figure 1.3 Global and regional protein supply trends | 5 |
| Figure 1.4 Global and regional animal protein supply trends | 6 |
| Figure 2.1 Protein supply patterns in world continents..... | 24 |
| Figure 2.2 Protein supply patterns in countries (mainly lysine deficient) and comparison with Burundi..... | 30 |
| Figure 2.3 g. Lysine and g. bio-available lysine in 100 g. of protein in identified major protein sources | 31 |
| Figure 2.4 Percentage of protein supply from protein sources in Democratic Republic of the Congo..... | 33 |
| Figure 2.5 Percentage of protein supply from protein sources in Liberia..... | 34 |
| Figure 2.6 Percentage of protein supply from protein sources in Mozambique | 35 |
| Figure 2.7 Percentage of protein supply from protein sources in Haiti..... | 36 |
| Figure 2.8 Percentage of protein supply from protein sources in Guinea-Bissau..... | 37 |
| Figure 2.9 Percentage of protein supply from protein sources in Eritrea..... | 38 |
| Figure 2.10 Percentage of protein supply from protein sources in Zambia..... | 39 |
| Figure 2.11 Percentage of protein supply from protein sources in Togo..... | 40 |
| Figure 2.12 Percentage of protein supply from protein sources in Bangladesh..... | 41 |
| Figure 2.13 Percentage of protein supply from protein sources in Ethiopia..... | 42 |
| Figure 2.14 Percentage of protein supply from protein sources in Tajikistan.... | 43 |
| Figure 2.15 Percentage of protein supply from protein sources in Zimbabwe... | 44 |
| Figure 2.16 Percentage of protein supply from protein sources in Yemen..... | 45 |
| Figure 3.1 India's nominal GDP growth rates 2000/01 to 2010/11..... | 54 |

| | |
|--|----|
| Figure 3.2 Projected shares of world GDP at purchasing power parity 2002 prices of selected economies including India's..... | 55 |
| Figure 3.3 Per capita incomes of India and of the selected states at current prices..... | 56 |
| Figure 3.4 Agriculture real growth rates in GDP at factor cost..... | 57 |
| Figure 3.5 Share of agriculture in GDP..... | 57 |
| Figure 3.6 Cereal production pattern in India – in tonnes/year..... | 58 |
| Figure 3.7 Cereal supply pattern in India (kg /capita/year)..... | 59 |
| Figure 3.8 Percentage of protein supply from food groups in all-India: rural and urban sector - year 2004..... | 66 |
| Figure 3.9 Percentage of protein supply from food groups in Kerala: rural and urban sector - year 2004..... | 68 |
| Figure 3.10 Percentage of protein supply from food groups in Gujarat: rural and urban sector - year 2004..... | 69 |
| Figure 3.11 Percentage of protein supply from food groups in Bihar: rural and urban sector - year 2004..... | 70 |
| Figure 3.12 Percentage of protein supply from food groups in Punjab: rural and urban sector - year 2004..... | 72 |
| Figure 3.13 Lysine availability vs. MPCE class (rural sector) - year 2004..... | 73 |
| Figure 3.14 Lysine availability vs. MPCE class (urban sector) - year 2004..... | 73 |
| Figure 4.1 Forecast percentage of elderly population in 2050..... | 81 |
| Figure 4.2 Forecast percentage of elderly population in different continents, in 2050..... | 81 |
| Figure 4.3 Best-practice life expectancy and life expectancy for women in selected countries from 1840 to 2007..... | 83 |
| Figure 4.4 Additional requirements for protein in 2050 depending on the RDA value for the elderly population..... | 90 |
| Figure 4.5 g. Leucine and g. bio-available leucine in 100 g of protein in identified major protein sources..... | 92 |

Figure 5.1 Forecast percentage of the different age groups at the world level, 2015 – 2050.....103

Figure 5.2 Forecast leucine requirements (tonnes) according to the different age groups at the world level, year 2015 – 2050.....104

List of Tables

| | |
|---|-------|
| Table 1.1 List of essential and non essential amino acids..... | 10 |
| Table 2.1 Major protein sources and respective 'True Protein Digestibility' values..... | 15 |
| Table 2.2 Amino acid content (mg of amino acid / 100 g food) of major protein sources..... | 17-18 |
| Table 2.3 Essential amino acid estimation – Burundi..... | 21 |
| Table 2.4 EAA requirement of children, adolescents, teenager, adults (mg per kg body weight per day)..... | 23 |
| Table 2.5 Protein availability in sub continents..... | 26 |
| 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)..... | 27 |
| Table 2.7 EAA availability difference in selected countries (EAA values are in terms of percentage) based on sensitivity test..... | 47 |
| Table 3.1 Total consumption spending defining the MPCE classes in rural and urban populations in India, Rupees (Rs.)..... | 52 |
| Table 3.2 Food groups as per the NSS report, India..... | 59 |
| 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..... | 60 |
| Table 3.4 List of reference food items for each state in India based on the regional food habits..... | 63 |
| Table 3.5 True ileal amino acid digestibility values of Indian food items..... | 64 |
| 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..... | 76 |
| Table 5.1 The amount of additional bio-available EAA required (in kg per day) in selected countries..... | 98 |
| Table 5.2 The amount of additional bio-available protein required in selected countries, on a daily basis..... | 99 |

| | |
|--|-----|
| Table 5.3 The additional bio-available amount of the major protein sources required (in MT per day) in selected countries..... | 100 |
|--|-----|