ISSN 0254-4725

# Fats and fatty acids in human nutrition

## Report of an expert consultation

FAO
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PAPER

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Food and Agriculture
Organization of
the United Nations

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10 – 14 November 2008
Geneva



FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome, 2010

ISBN 978-92-5-106733-8

# In memoriam

Professor John C. Waterlow died peacefully on 19 October 2010 at the age of 94 at the Chelsea and Westminster Hospital in London. Over the last years his body had weakened but his mind was as sharp as ever up to his last days. With his passing away, the international nutrition community has lost an exceptional nutritionist. FAO will miss this remarkable, knowledgeable, reliable and loyal friend who put all his expertise and wisdom to the service of the hungry and malnourished in different parts of the world.

Professor Waterlow spent approximately twenty years in the Caribbean region, working in Guyana, Trinidad and Tobago and Jamaica, where he established the Tropical Metabolism Research Unit at the University of the West Indies in Kingston, Jamaica and carried out his cutting-edge work on the pathophysiology and treatment of malnutrition. A trademark of his work was to transform complex scientific and technical issues into simple, practical messages such as his "10 easy-to-remember steps" treatment guidelines for hospital staff in treating malnutrition and its related diseases.

When Professor Waterlow returned to the UK and began his long tenure as Professor of Human Nutrition at the London School of Hygiene and Tropical Medicine (LSHTM), a long-standing and strong relationship continued with FAO. Because of his eclectic interests and knowledge, John's contributions ranged from childhood growth and diseases to nutrition requirements, with particular attention to protein, his specialty. He generously gave his time, expertise and prestige to support FAO and WHO in their nutrition programmes from the early 1970's until 2004, chairing a number of expert committees and consultations and participating in numerous seminars and meetings. Even with his retirement from the LSHTM in 1981 he continued to serve selflessly.

Not only did he serve, but the plethora of students he taught, in the United Kingdom and in Jamaica, served with him and then in his place after he did truly retire. He was seen by many, even those who had never studied formally under him, as "the professor". Once in retirement he was reluctant to fill the place of an active scientist in scientific deliberations, noting that he was no longer current with the scientific literature. However, once the deliberations began no one could quite identify those scientific areas in which he was failing. Perhaps his last scientific tour de force was the 2006 revision of the 1978 classic *Protein turnover in mammalian tissues and in the whole body*, which he did the old fashioned way relying on index cards and little on computer searches.

John Waterlow was never interested in pushing his own research or areas of interest except when it was for the welfare of the children in the developing world or, in fact, children everywhere. When the discussion became too esoteric and argumentative, he would remind all, in an even voice and with carefully chosen words, what was the main reason they were discussing these issues and "those who were the object of the discussion" should not be forgotten.

He will be remembered by all of us who had the benefit to work with him, for his extensive knowledge of nutrition, for his dedication for the cause of combating hunger and malnutrition in all its forms, and for his integrity and wisdom during the nutrition deliberations in international fora.

# Acknowledgements

FAO expresses its sincere gratitude to the experts for their contributions before and during the consultation, as well as their dedication in the preparation of this report. Dr Ricardo Uauy deserves special appreciation for his skillful leadership as Chairman of the Expert Consultation and his technical guidance in the preparation of the report. We are thankful to Dr Mariette Gerber, who served as Vice-Chairperson and Drs Murray Skeaff and Petro Wolmarans, who acted as Rapporteurs. We would like to draw attention to the important contributions of the authors of the background papers for the Expert Consultation as well as those who reviewed these papers. FAO is grateful for the essential support provided by Dr Mary L'Abbe and Dr Philip Calder who served as external reviewers during the process of selecting the scientists who participated in the meeting.

Within the Secretariat, the special efforts of Dr Gina Kennedy, who compiled and reviewed draft papers and Dr Robert Weisell who prepared the background papers for publication in the *Annals of Nutrition and Metabolism*, as well as the draft report are gratefully acknowledged.

Each of these outstanding scientists is listed in the annex of this report.

# Acronyms and symbols

| | |
|---|---|
| %E | percent of energy |
| %E fat | percent of energy from fat |
| %FA | percentage fatty acid composition ("wt:wt") |
| AA | arachidonic acid *(trivial name)*<br>20:4n-6 *(IUPAC notation)**<br>5z,8z,11z,14z-eicosatetraenoic acid *(systematic name)* |
| AD | Alzheimer's disease |
| AI | adequate intake (expressed as a range) |
| ALA | alpha linolenic acid *(trivial name)*<br>18:3n-3 *(IUPAC notation)**<br>9z,12z,15z-octadecatrienoic acid *(systematic name)* |
| AMDR | acceptable macronutrient distribution range |
| ANR | average nutrient requirement |
| ARM | age-related maculopathy |
| BC | breast cancer |
| BP | blood pressure |
| CE | cholesterol ester |
| CHD | coronary heart disease |
| CHO | carbohydrate |
| ChREBP | cholesterol regulatory element binding protein |
| CLA | conjugated linoleic acid |
| CLN | conjugated linolenic acid |
| CNS | central nervous system |
| COX | cyclooxygenase |
| CRC | colorectal cancer |
| CVD | cardiovascular disease |
| DG | diacylglycerol |
| DHA | docosahexaenoic acid [cervonic acid] *(trivial name)*<br>22:6n-3 *(IUPAC notation)**<br>4z,7z,10z,13z,16z,19z-docosahexaenoic acid *(systematic name)* |
| DHGLA | dihomo-gamma linolenic acid |
| DPA | n-6 docosapentaenoic acid |
| DRI | dietary reference intake |
| E | energy |
| EAR | estimated average requirement |
| EFA | essential fatty acid |
| EJCN | European Journal of Clinical Nutrition |
| EPA | eicosapentaenoic acid [timnodonic acid] *(trivial name)*<br>20:5n-3 *(IUPAC notation)**<br>5z,8z,11z,14z,17z-eicosapentaenoic acid *(systematic name)* |
| FA | fatty acid |
| FAME | fatty acid methyl ester |
| FAO | Food and Agriculture Organization of the United Nations |
| FBS | food balance sheet |

| | |
|---|---|
| FDA | US Food and Drug Administration |
| FER | fat energy ratio |
| FFA | free fatty acid |
| FID | flame ionization detector |
| GC | gas-liquid chromatography |
| GDP | gross domestic product |
| GLA | gamma linolenic acid |
| HDL | high density lipoprotein |
| HDL-C | high density lipid cholesterol |
| HETE | hydroxyeicosatetraenoic acid |
| HM | human milk |
| HPETE | hydroperoxytetraenoic acid |
| IBD | inflammatory bowel disease |
| IDL | intermediate-density lipoproteins |
| IDS | individual dietary survey |
| IMF | intramuscular fat |
| IUPAC | International Union of Pure and Applied Chemistry |
| JAMA | Journal of the American Medical Association |
| L-AMDR° | lower value of acceptable macronutrient distribution range |
| LA | linoleic acid *(trivial name)*<br>18:2n-6 *(IUPAC notation)**<br>9z,12z-octadecadienoic acid *(systematic name)* |
| LCPUFA | long-chain polyunsaturated fatty acid (>2 double bonds; >18 C atoms) |
| LDL | low density lipoprotein |
| LDL-C | low density lipoprotein cholesterol |
| LOX | lipooxygenase |
| LT | leukotriene |
| MCT | medium chain triglyceride |
| MG | monoacylglycerol |
| MT | metric tonne |
| MUFA | monounsaturated fatty acid |
| NIV | nutrient intake value |
| NOAEL | no observable adverse effect level |
| NRCD | nutrition-related chronic disease |
| OA | oleic acid |
| PC | prostate cancer |
| PG | prostaglandin |
| PGI | prostacyclin |
| PHVO | partially hydrogenated vegetable oils |
| PL | phospholipid |
| PPAR | peroxisome proliferator-activated receptor |
| P/S ratio | polyunsaturated fatty acid/saturate fatty acid ratio |
| PUFA | polyunsaturated fatty acid (2 or more double bonds) |
| RA | rheumatoid arthritis |
| RCT | randomized controlled trial |
| RDA | recommended dietary allowance |
| SDA | stearidonic acid |
| SFA | saturated fatty acid |
| SHGB | sex-hormone-binding-globulin |

| | |
|---|---|
| SL | structured lipid |
| SNP | single nucleotide polymorphism |
| SPE | sucrose polyesters |
| ST | structured triacylglycerols |
| TC | total cholesterol |
| TEI | total energy intake |
| TFA | *trans* fatty acid |
| TG | triacylglycerol |
| TLC | thin-layer chromatography |
| TX | thromboxane |
| U-AMDR° | upper value of acceptable macronutrient distribution range |
| UL°° | tolerable upper intake level |
| UN | United Nations |
| UP | upper level |
| VCAM | vascular cell adhesion molecule |
| VLDL | very-low-density lipoprotein |
| WHO | World Health Organization |

* Note: C:Dn-#, where C=number of C atoms: D=number of double bonds and # = number of C atoms the first double bond is separated from the Methyl group; n-6 (IUPAC notation) = ω6 (Holman notation)

° This term refers either to the upper or lower value of the AMDR range. It is very similar to the use of UCI or LCI for the upper or lower bounds of confidence intervals. Values in excess or lower than the range do not represent risk of excess or deficit respectively.

°° This term was developed for instances where biochemical indicators are needed to confirm risk of adverse effects for intakes that exceed this intake level. In the case of FA, this only applies to TFA.

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# Chapter 1: Introduction

The Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO), in their roles as technical agencies of the United Nations (UN), are charged with providing science-based guidance on food and nutrition to national governments and the international community. The process used to do this involves periodic and systematic reviews of scientific evidence, which often culminates with the convening of joint expert consultations to review the state of scientific knowledge, deliberate on the issues and translate this knowledge into a definition of requirements and corresponding nutrient-based recommendations. The overall goal of these recommendations is to support health and nutritional well-being of individuals and populations. The topics covered during the recent past include energy, protein and amino acids, fats and oils, most of the vitamins and minerals and carbohydrates, with the objective of providing guidance on nutritional requirements and recommended dietary intakes.

The Joint FAO/WHO Expert Consultation on Fats and Fatty Acids in Human Nutrition (hereafter Expert Consultation) was the most recent expert meeting convened, and was held in Geneva from 10 to 14 November 2008. The Expert Consultation was the third to be held on the subject of fats in human nutrition, the first expert consultation on this topic being held in 1977 (FAO, 1978) and the second in 1993 (FAO, 1994).

The timeliness of this Expert Consultation is also tied to the clear recognition of the increasing global burden of nutrition-related chronic disease. Recent work of FAO and WHO in connection with this includes the 2002 Expert Consultation on Diet, Nutrition and the Prevention of Chronic Diseases (WHO, 2003), the 2001 Expert Consultation on Human Energy Requirements (FAO, 2004) and its companion 2002 Expert Consultation on Protein and Amino Acid Requirements in Human Nutrition (WHO, 2007), one 2002 Technical Workshop on Food Energy – Methods of Analysis and Conversion Factors (FAO, 2003), and several Scientific Updates; one by FAO/WHO in 2006 on Carbohydrates in Human Nutrition (Nishida *et al.*, 2007) and another by WHO on *Trans* Fatty Acids (Nishida and Uauy, 2009). These integrated efforts provide, to varying degrees, the scientific basis that guides strategies, programmes and projects of FAO and WHO and their Member Countries.

During the past fifteen years, the changes in diets and lifestyles resulting from industrialization, urbanization, economic development and market globalization have increased rapidly and particularly in the developing countries where major socio-economic changes are occurring. Whereas general improvement in the standard of living has been observed, this has often been accompanied by unhealthy dietary patterns and insufficient physical activity to maintain an optimal energy balance and a healthy weight. The net result has been increased prevalence of diet-related chronic diseases in all socio-economic groups and which now represent the main cause of deaths and disability worldwide.

## SCIENTIFIC DEVELOPMENTS

There have been a number of major developments in the field of fats and fatty acids in human nutrition during the past fifteen years, with the resulting need for an update since the 1994 publication and recommendations. These developments are elaborated