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MELiSSA FOOD CHARACTERIZATION: PHASE 1

TECHNICAL NOTE: 1.1

ELABORATION OF SYSTEM REQUIREMENTS FOR A FPPS

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List of Abbreviations

BLSS:	Bioregenerative Life Support System
CIP:	Cleaning In Place
DW:	Dry Weight
EMI:	Electromagnetic Interference
EVA:	Extra Vehicular Activity
FPU:	Food Preparation Unit
GU:	Germination Unit
HMI:	Human Machine Interface
HPC:	Higher Plant Chamber
LEO:	Low Earth Orbit
LOI:	Lunar Orbit Insertion
LSS:	Life Support System
PPU:	Plant Production Unit
RDI:	Recommended Daily Intake
SIP:	Sterilization In Place
SOW:	Statement Of Work
SU:	Storage Unit
TBC:	To Be Confirmed
TBD:	To Be Determined
TLC:	Trans Lunar Coast
TLI:	Trans Lunar Injection
VOC:	Volatile Organic Compound

Keywords

Meal	portion of food to satisfy appetite (portion dependent on frequency and timing within a day…).
Dish	Single meal prepared by combining fresh FPPS and/or stabilized products from the FPPS production or re-supplied food items.
Plate	Synonym of dish.
Menu	To be considered as the list of dishes (breakfast, dinner, and supper) available to the crew (and not a single dish or meal) including the way the menu is organized as a function of time.

Menu rotation	A given number of dishes will cover a limited amount of time (corresponding to the menu), after which the same dishes will need to be consumed again by the crew (possibly/likely in the same order). The frequency (weekly, biweekly etc) by which the same (any) dish from the menu will be consumed by the crew.
Menu elaboration	The strategy of: - composing the dishes from fresh or stabilized materials - establishing the menu rotation (and thus variation in time)
Stabilized food	Food processed and conditioned as to allow storage for a reasonable (TBC, dependent on mission scenario for re-supplied items, crop growth period or time between harvest batches for the FPPS products) amount of time.
Semi-finished products	Basic ingredients resulting from limited processing, with ability to be stored for a determined amount of time

Reference documents

Ref 1 NTE-MEL2-TN-007.doc: MELiSSA adaptation for space, phase II; Technical Note 1; Moon Base Mission Scenario Definition & Life Support System Requirements; ESTEC/Contract No. 20104/06/NL/CP.

Ref 2 Statement of Work MELiSSA Food Characterization Phase 1; ESA Directorate of Technical and Quality Management; TEC-MCT/2008/3633/In/CP.

Ref 3 Proposal for MELiSSA Food Characterization Phase 1; HSB University of Gent, Issue date: 12/09/08; RFQ number: RFQ/3-12471/08/NL/JC.

Ref 4 esa-pss-03-401-i1.pdf: Atmosphere quality standards in manned space vehicles; ESA Thermal control and life support division; ESTEC; June 1992.

Ref 5 esa-pss-03-402.pdf: Water quality standards in manned space vehicles; ESA Thermal control and life support division; ESTEC; October 1994.

Ref 6 Advanced Life Support Systems Integration, Modeling, and Analysis Reference Missions Document; JSC-39502; Crew and Thermal Systems Division NASA–Lyndon B. Johnson Space Center Houston, Texas; Document Number CTSD-ADV-383; 5 November 2001.

Ref 7 Advanced Life Support Baseline Values and Assumptions Document; JSC-47804; Crew and Thermal Systems Division NASA–Lyndon B. Johnson Space Center Houston, Texas; Document Number CTSD-ADV-484; 8 May 2002.

Ref 8 HUMEX Technical Note 1, Definition of Reference Scenarios for European Participation in Human Exploration and Estimation of the Life Sciences and Life Support Requirements; ESTEC/Contract No. 14056/99/NL/PA.

Ref 9 MELiSSA Adaptation For Space Phase 2 Technical Note 4, Life Support System Sizing; ESTEC/Contract No. 20104/06/NL/CP; 1.July 2009.

Ref 10 Potential design for a Food Production Unit; Closed Loop Food Systems ST9.1, Technical Note 2; ST9-3000-TN-014-NTE; June 2004.

1 Introduction

This document lists the top level requirements for a Food Production and Preparation System (FPPS) to be used on the Moon or Mars surface. This implies:

- Nutritional needs
- Crop growth system requirements
- Food processing infrastructure
- Recycling ability needs
- Stable functioning and associated control needs (as needed for LSS functionality)
- Interfacing with primary LSS
- In situ resource utilization (sunlight etc.)

Additional needs linked to the top level requirement of functioning under planet surface conditions are listed. Moon surface mission scenarios are defined in the first place. Where applicable, requirements specific to Mars scenarios are mentioned.

Based on these requirements the FPPS functional concept will subsequently be elaborated (WP1200). The FPPS subsystems identified in WP1200 will be assessed individually in WP2000, defining requirements at a higher level of detail, albeit with limited emphasis on functionality under reduced gravity.

Tab. 1 FPPS requirement classes

Requirement Class	Major boundary conditions	Major requirement
Functional requirements	Available resources (energy, waste), MELiSSA loop, contamination	Food production, storage and preparation, quality control
Mission requirements	Duration, environment	Food quantity and quality, menu strategy
Physical requirements	Mass, volume and energy, ALISSE criteria	Minimize weight, volume and power usage, avoid emissions
Environmental requirements	Transit and surface environment	Shielding, safety measures, planetary protection policy
Operational requirements	Mission scenario, crew time, safety, assurance of fine-tuned performance in closed loop	Mission phases, automation, operational modes, predictive control system
Interface requirements	Other LSS elements, function in closed loop, data management and communication,	Compartment interfaces, dedicated information exchange system
Product assurance requirements	Reliability, availability, safety	Efficient troubleshooting approach, man rated safety standards
Human factor requirements	ALISSE criteria, risk, crew time, plant seeding, monitoring and harvesting, processing, menu elaboration	User control decisions - mission control centre assisted, optimize crew time
Logistic requirements	Launcher, transit scenario, maintenance constraints	Appropriate mass and size design, logistic resupply missions, spare part plan
Verification & Validation	Implication of human crew	Validation phase, redundancy

1.1 Naming rules

The hierarchy of the requirement listing in this document is organized in a way to be as close as possible to the logic of the SmarTeam MELiSSA Data Management System. Each requirement obtains a unique identifier which satisfies the syntactic rules given below:

Req.id = <Req.level >-< req.category>- <req.subcategory>-<req.number>

Requirement level: e.g. SYS for system level
Requirement category: e.g. FUNC for functional
Requirement subcategory: e.g. PROD for functional requirement “produce crops”
Requirement number: consecutive numbering

These naming rules ensure that a requirement identifier is unique.

2 FPPS system description

2.1 External view

It is assumed that a Moon/Mars base infrastructure is already in place on the planetary surface, providing power, water and atmosphere. In situ resource utilization can be considered for direct sunlight, water, O_2 and CO_2 harvest. The FPPS system shall integrate with this existing Moon or Mars base.
In a first stage the MELiSSA loop is fully redundant to the primary (physicochemical) LSS. After validation and testing the MELiSSA loop can take over the function of the primary LSS.

2.1.1 Overall objective (black box view)

The objective is to assemble a FPPS as part of the closed loop LSS and to operate it, to partly (see 4.1) fulfill the crews' nutritional needs during the surface stay of the mission as well as possible provisions for the return trip.
The key need is to supply food of sufficient quantity and quality (see Annex 1).

2.1.2 Contextual view

The FPPS is to be considered a part of the MELiSSA loop, and will typically be interfaced to the mission support functions and to the mission control and monitoring systems.
For the FPPS requirements the context of the mission and the overall life support system has to be taken into account (see Fig. 1).

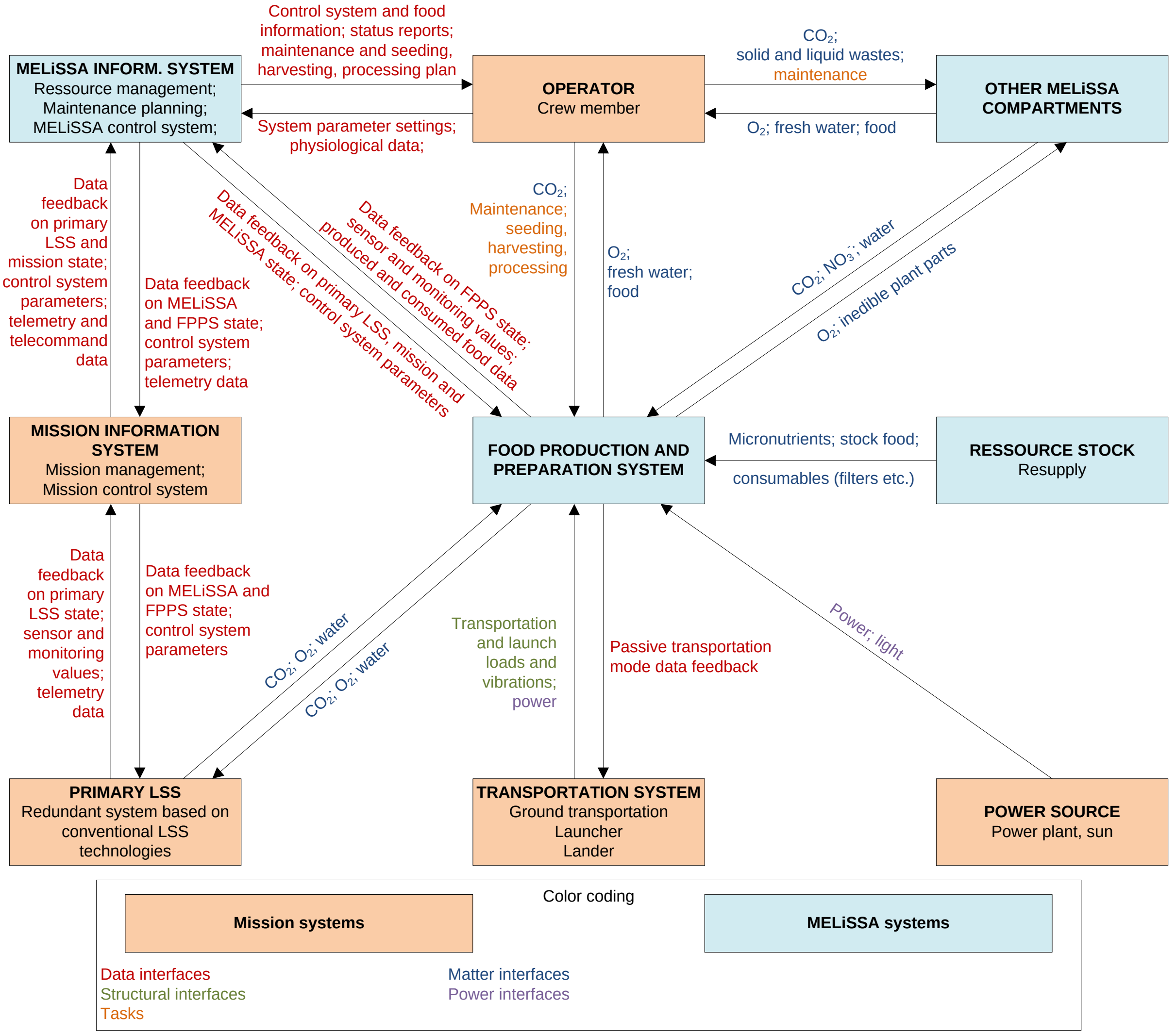

Fig. 1 FPPS context within a closed regenerative life support system

2.2 Internal view

The internal functions to be fulfilled are:

- Food production
- Food processing
- Food storage
- Food quality control
- Menu elaboration management and individual meal composition

The interface functions to be fulfilled are:

- Provision and management of all resources
- Meal, oxygen and water delivery to the crew

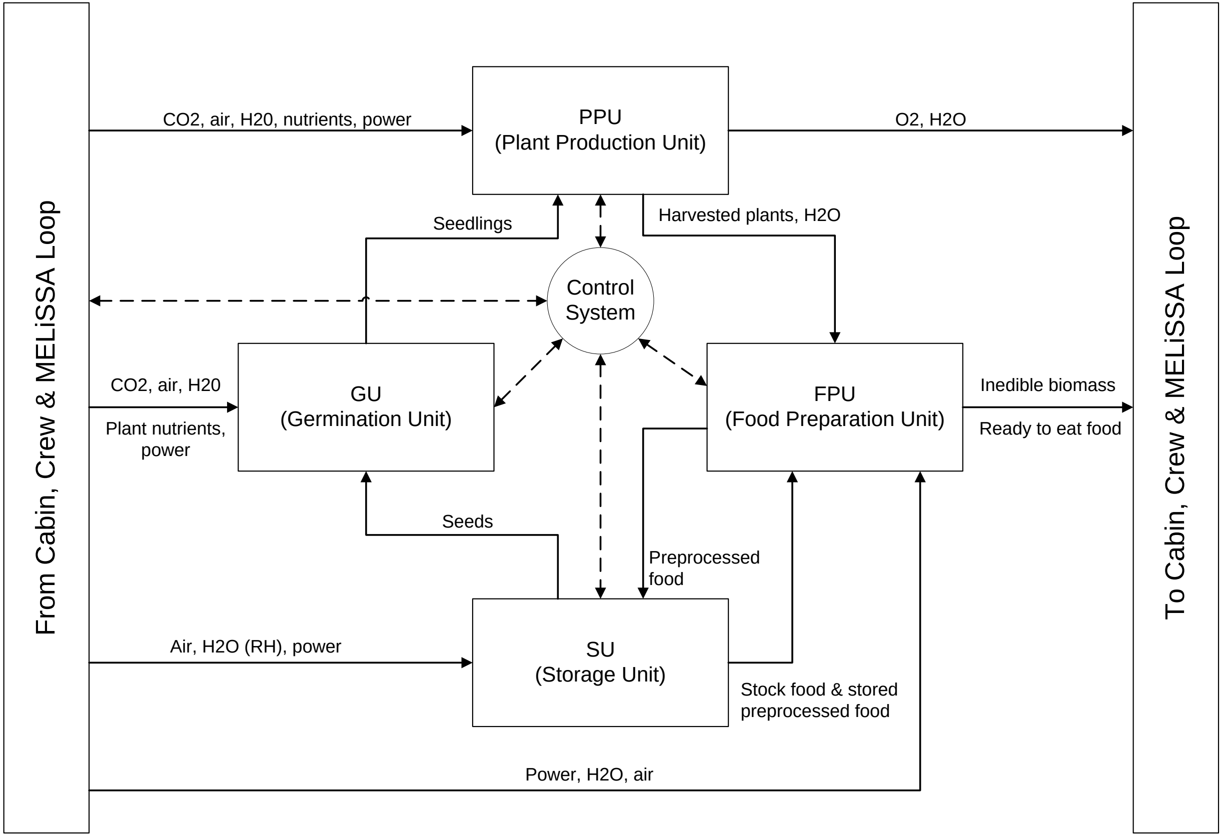

Fig. 2 Internal view of the FPPS

Fig. 2 shows an overview of the internal FPPS structure. Data management and quality control are not displayed for the sake of clarity as they have links to every subsystem similar as the Control system.

2.3 Preliminary crop selection

The MELiSSA Food Characterization project Phase1 concentrates on 4 energy and/or protein rich crop species with widespread usage and ample human nutritional background:

- Potato
- Soybean
- Bread wheat
- Durum wheat

Annex 1 provides an overview of the nutritional characteristics of the 10 proposed MELiSSA food sources:

- 9 Higher plants:
  - 4 Energy crops: Potato, Rice, Soybean and Wheat. Bread wheat (*Triticum aestivum*) and Durum wheat (*Triticum durum*) are 2 separate species.
  - 5 “Salad” crops: Kale, Lettuce, Onion, Spinach and Tomato
- Spirulina (*Arthrospira platensis*)

The crop selection for the food characterization project and the 10 selected MELiSSA crops are not necessarily representative for the first phases of the FPPS deployment. The food characterization crops concentrate on a good nutritional balance and promising efficiencies. The selected crops are however in no means the simplest to grow. Therefore “simple” crops such as lettuce are more likely to be introduces in first FPPS phases. Further details remain TBD.

3 Functional requirements

The FPPS prime function is to provide high quality food (see 4.1) to the mission crew. Associated with this food production, plant growth will generate O_2 (as a first approximation roughly equivalent to the amount of CO_2 fixed).

The FPPS is divided into the following subunits:

- Germination unit (GU) (depending on logistics and crop, in situ germination could be considered)
- Higher Plant Chamber (HPC) also called Plant Production Unit (PPU)
- Food Preparation Unit (FPU)
- Storage unit (SU)

3.1 Produce crops

SYS-FUNC-PROD-1: The FPPS shall provide all the needs for growing (consumable) plants under confined conditions from a stock of certified seeds.

SYS-FUNC-PROD-2: The respective share of each crop shall be determined as a function of the crew nutritional needs and the menu preparation plan.

SYS-FUNC-PROD-3: The amount of each crop to be produced shall take into account the losses that will occur during processing and menu elaboration.

The nutritional quality shall comply with the requirements defined under 4.3. Nutrient content is defined as the composition of meals at the end of the production chain. Recommended Daily Intake (RDI) for each essential nutrient already compensates for the absorption losses after intake. Gender-specific (and age-specific) requirements need to be taken into account. An individualized nutritional software tool allows to provide this functionality (level of control of crewmember food intake is TBD).

3.2 Process crops

SYS-FUNC-PROC-1: The FPPS shall produce fresh or stabilized final food products.

By fresh food, directly harvested and consumed edible biomass is understood (e.g. lettuce). Stabilized food is pre-processed and stored under the correct crop dependent conditions (e.g. bread wheat grains).

SYS-FUNC-PROC-2: The necessary equipment to process harvested crops into a storable state and/or into freshly consumable food shall be provided.

SYS-FUNC-PROC-3: The processing approach shall strive to minimize nutritional losses (vitamins, minerals). Acceptable limits of nutritional losses are TBD.

SYS-FUNC-PROC-4: Pre-processing (harvest) wastes (e.g. stems, roots and leaves) have to be taken into account on a per-crop basis and shall be kept low (see also 8.2). The crop cultivar selection shall include a selection parameter for cultivars with maximal harvest index (high edible versus inedible material ratio). Acceptable limits of waste stream quantity and composition are TBD.

SYS-FUNC-PROC-5:	Processing waste streams shall be consumed if possible as a component of other specific dishes, if needed after storage in the FPPS infrastructure (e.g. soy pulp after soymilk extraction) or recycled to the MELiSSA waste treatment system.

The degree of harvesting automation is TBD. Crew time and automation hardware have to be taken into account.

SYS-FUNC-PROC-6:	The FPPS shall allow the processing, storage and elaboration of edible substrates produced in other MELiSSA compartments (i.e. Arthrospira platensis).

3.3 Prepare food

SYS-FUNC-PREP-1:	The FPPS shall implement the final food products into menus (ready to eat food) incorporating resupply food and edible biomass produced in other MELiSSA compartments (i.e. Arthrospira platensis).
SYS-FUNC-PREP-2:	The produced food shall comply with the nutritional requirements (see Annex 1) and deliver the needed amounts to elaborate the planned menus.

3.4 Store seeds and food

SYS-FUNC-STOR-1:	The FPPS shall store seeds, harvested crops, stabilized and final food products (originating from FPPS grown plants, other MELiSSA compartments (i.e. Arthrospira platensis) and resupply food).
SYS-FUNC-STOR-2:	The seed stock for seedling production shall be kept in the crop specific optimal (T, RH, darkness) conditions till the end of the surface stay of the mission, see SYS-OP-IRES-3. Optimal seed storage conditions are TBD.
SYS-FUNC-STOR-3:	The storage strategy shall imply a safety stock of TBD crewmember day rations in accordance with the production/harvesting schedule.
SYS-FUNC-STOR-4:	The stored food items (resupply as well as FPPS and MELiSSA produced) shall comply with standards (TBD) for acceptability of taste, smell and texture after the maximum intended storage period.
SYS-FUNC-STOR-5:	Sufficient food storage shall be implemented to balance variations in production and consumption.

3.5 Elaborate menus

SYS-FUNC-ELAB-1:	The necessary equipment to prepare meals out of processed and stored food, resupply food and fresh harvest shall be provided.
SYS-FUNC-ELAB-2:	A menu rotation schedule shall be implemented to ensure temporal variability. The schedule is TBD based on psychological and nutritional factors.

SYS-FUNC-ELAB-3: The FPPS menu cycles, processing strategies and storage capabilities shall take into account FPPS produced food, resupply food and food elements produced in other MELiSSA compartments (i.e. Arthrospira platensis).

3.6 Food management

This section describes a software suite providing interconnected capabilities for food and harvest management, nutritional consultancy and storage planning.
The system shall provide the following functionalities:

- Record nutritional uptake
- Treat and incorporate personal data (body temperature, etc.) provided by mission inherent crew physiology analysis tools
- Recommend correction (real time in anticipation of next meal)
- Manage to a TBD extent growth cycles and seeding harvesting times to fulfill the food production needs.

SYS-FUNC-MNG-1: The FPPS shall be equipped with a software tool managing the in-situ FPPS crop production, food elements produced in other MELiSSA compartments (i.e. Arthrospira platensis) and the stored resupply food items taking into account the safety stock (SYS-FUNC-STOR-3) and a maximal storage period (SYS-FUNC-STOR-4).

SYS-FUNC-MNG-2: The software shall provide nutritional consultancy functionalities with 2 levels of operation: crew member basic information and follow-up by nutritional mission scientists to monitor and adjust crew nutritional uptake.

SYS-FUNC-MNG-3: Nutritional uptake shall be monitored in detail but only be controlled to a certain extent. Flexibility according to personal preferences shall be possible within certain (TBD) limits.

SYS-FUNC-MNG-4: Important medical parameters (TBD) of each crewmember shall be taken into account in the meal strategy.

The FPPS itself will not monitor crew medical parameters. This will be done with mission inherent systems. The FPPS shall however identify the necessary input parameters and request these from the system to implement them in the menu and food production strategy.

3.7 Recycle atmosphere

SYS-FUNC-ATM-1: The FPPS shall be sized to recycle a TBD percentage of CO_2 produced by the crew and the other MELiSSA compartments during the surface stay.

SYS-FUNC-ATM-2: The FPPS shall be sized to produce a TBD percentage of O_2 taken up by the crew and other MELiSSA compartments during the surface stay.

The MELiSSA loop is to be sized to provide 100% of the total oxygen demand and to recycle all of the produced CO_2. Other MELiSSA compartments produce oxygen (compartment IVa) and CO_2 (compartment I and II) and consume CO_2 (compartment IVa). The exact share of each compartment has to be specified in more detail.

3.8 Purify water

The FPPS plant growth chambers can be used for water regeneration purposes. Wastewater (grey water and urine) is thereby processed in dedicated LSS equipment (e.g. MELiSSA compartment I, II and III), further adjusted (see 8.2) to comply with the plants' nutritional requirements and then supplied to the root zone. Plants can recycle valuable nutrients from the wastewater stream (e.g., nitrogen from the urine) and take up water through the roots. The plants transpired water is then condensed on appropriate hardware and if required submitted to a post-treatment to comply with water quality standards.

SYS-FUNC-WAT-1:	A TBD fraction of the water produced by the HPC by condensing transpired humidity shall be recycled within the FPPS system or other MELiSSA compartments.
SYS-FUNC-WAT-2:	The water condensate further recycled in the FPPS or other MELiSSA compartments shall be treated after collection if necessary to comply with TBD water quality standards.
SYS-FUNC-WAT-3:	A TBD fraction of the water condensed in the FPPS plant growth chambers shall be used to replenish the potable water stocks.
SYS-FUNC-WAT-4:	The water condensate further used for human nutrition shall be treated after collection if necessary to comply with the water quality standards specified in Ref 5.

3.9 Cleaning in place

A dedicated Cleaning In Place/ Sterilization In Place (CIP/SIP) protocol will be elaborated considering the materials chosen in each sub (sub)-system.

SYS-FUNC-CIP-1:	The FPPS shall comply with standard (TBD) cleaning procedures to manage the microbiological risk in the FPPS.
SYS-FUNC-CIP-2:	CIP/SIP needs shall be considered during hardware material choices, as to avoid any (limits TBD) leaching or off-gassing.
SYS-FUNC-CIP-3:	Cleaning agents and the resulting waste streams shall not interfere with the functioning of the biological processes within the system.

3.10 Quality control

Monitoring approaches for food, air and water composition and microbial contamination are TBD. A redundancy with LSS of the Moon/Mars basis is to be considered. The feasibility with regards to miniaturization into portable devices remains TBD. For further information about microbial safety see section 9.2.1.

SYS-FUNC-QC-1:	The FPPS shall provide a food quality control system.

SYS-FUNC-QC-2:	The FPPS unit shall be equipped with a monitoring system for non-destructive and fast determination of food composition and its possible alteration (TBC if technically possible and level of analysis detail TBD).
SYS-FUNC-QC-3:	The FPPS shall provide an air quality control system.
SYS-FUNC-QC-4:	The FPPS shall provide a water quality control system.

4 Performance requirements

4.1 Food quantity

SYS-PER-QUAN-1a: The system shall provide 3 meals a day for a crew of 4 during the surface stay for the moon scenario. Every possible gender composition shall be taken into account (individual crew member nutritional needs assessment, details TBD).

SYS-PER-QUAN-1b: The system shall provide 3 meals a day for a crew of 6 during the surface stay for the mars scenario.

SYS-PER-QUAN-2: The quantity of food produced in the FPPS and other MELiSSA compartments (i.e. Arthrospira platensis) shall amount globally to at least 40% DW of the crew needs

The food production ratio between different MELiSSA compartments is TBD but the largest fraction is FPPS food.

SYS-PER-QUAN-3: The food produced shall cover 100% of the vegetable protein needs; see also Annex 1 regarding amino acid availability from the produced crops.

SYS-PER-QUAN-4: The food produced shall cover a maximum of the vitamins needs, as specified on a case-by case basis in Annex 1.

SYS-PER-QUAN-5: The food produced shall cover at least TBD% of micronutrient needs. Higher values are favorable to assure optimal bioavailability, see also Annex 1.

4.2 Temporal food availability

The main requirement is to ensure meal availability to the crew. Therefrom other requirements derive:

SYS-PER-TEMP-1: The production strategy shall provide the amount of food at each specific time required to satisfy the crew needs as defined by the menu.

SYS-PER-TEMP-2: The production strategy shall also take into account replenishment of the storage with fresh food and/or processed food according to a TBD menu and storage strategy.

SYS-PER-TEMP-3: The cropping strategy shall obtain the required amount of fresh food per each crop to satisfy both, the direct consumption (SYS-PER-TEMP-1) and the stock replenishment (SYS-PER-TEMP-2).

SYS-PER-TEMP-4: Production schedules are to be monitored and coordinated by the use of a predictive modeling approach. It remains TBD at which extent predictive modeling is implemented.

SYS-PER-TEMP-5: The composition of the globally produced 40% DW edible FPPS products can be chosen freely and distributed over the daily meals as needed to minimize the total re-supplied food mass.

4.3 Food quality

The FPPS shall provide the crew with food compliant to TBD quality standards. For the nutritional composition, the requirements stated in Annex 1 and its associated calculation sheets shall be used. The main requirements are:

SYS-PER-QUAL-1: The food shall be of sufficient quality to not provoke any ill-being, poisoning, wounding at any level of severity during the whole mission.

SYS-PER-QUAL-2: The food shall correspond to psychological acceptability of the crew (taste, smell, texture, presentation, helping to maintain crew well-being).

Psychological issues due to the fact that recycled material is consumed are not considered within this study. Based on the main requirements, derived requirements are defined:

SYS-PER-QUAL-3: The food quality shall be monitored. Monitored parameters and level of detail are TBD (see 3.10).

The strategy for monitoring microbial food quality at the end of the processing chain (ready to eat meal) is described in chapter 9.2.1. Microbial and nutritional aspects are the 2 key parameters for food quality (see chapter 3.10).

5 Physical requirements

5.1 ALISSE criteria

The maximum values for mass and energy consumption were fixed in the Annex 1 to the FC1 SOW (Ref 2). All values mentioned below are extracted from this document.

Note: The other ALISSE criteria reliability, risk and crew time allocation are assessed in chapter 9.1, 9.2 and 10.1 respectively.

All values below are defined for a 6 membered-crew scenario. For a 4 membered-crew (Moon scenario), the respective values shall be scaled down, yet taking into account higher average values due to non-linear downscaling (TBD).

5.1.1 Mass

SYS-PHS-MASS-1: The FPPS equipment weight shall be equal or below 17 metric tons.

This is a preliminary estimation based on Ref 2 and Ref 10. It includes 12 tons for the HPC (including water), 1 ton for processing equipment, 1 ton for the germination unit, 1 ton for storage and 2 tons margin. The mass of the external module structure is not included. Equipment generally refers to all hardware parts contributing to the functioning of the system.

SYS-PHS-MASS-2: The total water content of the FPPS shall be defined to provide sufficient buffer capacity to compensate nominal flux variations between different compartments and a TBD safety stock (e.g. 1 day water consumption).

5.1.2 Volume

SYS-PHS-VOL-1: The total volume of the equipment and the liquid tanks shall be equal or below 184 m^3. These include crop production, food processing, storage and menu elaboration infrastructure.

Ref 9 proposes a HPC distributed over 4 modules with an (approximate) diameter of 4.3 meter and a length of 8.4 meter each. The maximum share of the allowable volume/weight for each sub-compartment will be determined during the course of the study.

5.1.3 Energy

SYS-PHS-ENRG-1: Both steady state and peak level power consumption shall be described.

SYS-PHS-ENRG-2: The peak level consumption shall be below or equal to 142 kW for the whole FPPS.

5.1.4 Efficiency

SYS-PHS-EFF-1: Food processing efficiency shall be maximized, in a trade-off with nutritional quality; including the minimization of vitamin and mineral losses, with prioritization of particular compound preservation (TBD). Multi-parameter assessment with weighing factors remains TBD.

5.2 Containment of emissions

SYS-PHS-EMM-1:	The FPPS (especially the Food Preparation Unit (FPU) kitchen hardware and by extension the kitchen compartment) shall not emit vapor, VOCs or dust into the mission compartment crew modules above TBD limits.
SYS-PHS-EMM-2:	The FPPS shall not transmit levels of noise, vibration and radiation that exceed the levels as accepted for the TBD mission scenario.

5.2.1 Vapor, VOC, dust, particulate matter

SYS-PHS-EMM-3:	Vapor, VOC, dust, and particle emissions shall be avoided at process level. Where emissions cannot be prevented at process level, appropriate containment shall be provided. Acceptable levels are TBD.

5.2.2 Heat/energy dissipation

Energy conservation strategies shall be applied at process level (sub-sub-system) and at global level where possible and efficient.

5.2.3 Radiation

SYS-PHS-EMM-4:	Any application employing micro-waves, UV-radiation or other electromagnetic radiation shall not emit levels of radiation that can be harmful to the crew (acceptable levels TBD) or have a negative impact on the functioning of other equipment (TBD based on base module environment).

5.2.4 Sound

SYS-PHS-EMM-5:	Noise (sound, vibrations) shall be confined at FPPS level, according to TBD mission level regulations. Countermeasures shall be applied at a case per case (equipment solution level) basis.
SYS-PHS-EMM-6:	Transmission of ultrasounds from processing or cleaning equipment shall be suppressed to TBD levels.

5.3 Limitation of electromagnetic interference

SYS-PHS-EMI-1:	The FPPS shall not interfere electromagnetically with surrounding hardware (other base compartments).

Tolerable limits are TBD.

6 Environmental requirements

6.1 Surface transit

The surface transit describes the transit from the earth surface to the Moon/Mars surface. This includes launch to LEO (Low Earth Orbit), TLI (Trans Lunar Injection), TLC (Trans Lunar Coast), LOI (Lunar Orbit Insertion), lunar descent and landing. Until now the final launch systems are not yet defined. NASA is developing the ARES launcher fleet for the Project Constellation. These will most likely be the only systems providing cargo and crew transport opportunities in the near future. Thus all design factors shall be derived from ARES specifications. Since the system is still under development, detailed specifications are TBC.

SYS-ENV-TRANS-1: The FPPS (in a non-operational and possibly partly disassembled state) shall withstand all orbital and transit conditions towards the targeted mission extraterrestrial surface. This includes the TBC launch vibrations and accelerations, docking procedures and landing.

SYS-ENV-TRANS-2: The FPPS structure (disassembled) shall be compliant to volume and mass requirements of the selected launchers (TBD e.g. ARES V).

SYS-ENV-TRANS-3: At mission level, critical FPPS subsystems (TBD) shall be shielded from radiation (including Van-Allen radiation belts).

More details on the mass and volume requirements for launch and transit can be found in chapter 11.

6.1.1 Acceleration

SYS-ENV-TRANS-4: Being the worst case scenario for continuous acceleration, the launch shall be taken as the design driving factor.

As a first approximation, the accelerations provided by an Ariane 5 ES launcher can be assumed for launch.

SYS-ENV-TRANS-5: For shock acceleration, the landing loads (TBC) shall be the design driving factor.

More details (accelerations in X,Y,Z directions, final launcher etc.) are TBD.

6.1.2 Vibrations

As for the acceleration loads, the launch is the design driving factor for vibration loads.

SYS-ENV-TRANS-6: Vibrations transmitted by an Ariane 5 ES launcher shall be used for a first design estimation.

6.1.3 Radiation

For the moon scenario, the total dose received during transit is small compared to the surface stay due to the short exposure. However, depending on the logistic of the mission scenario, some elements (electronic racks, subsystems, seed stock etc.) might have to be transported separately from the main (shielded) base modules.

SYS-ENV-TRANS: Sufficient radiation shielding shall be provided for the transit to avoid hardware failure and degradation of biological material.

6.2 Food production environment on extraterrestrial surface

SYS-ENV-SURF-1: In a nominal operation mode, the FPPS shall function under the conditions of the chosen environment for the whole mission intended time (TBD).

SYS-ENV-SURF-2: The system is to be designed to function only on the Moon respectively Mars surface. Microgravity applications are not envisaged for now.

SYS-ENV-SURF-3: The FPPS and its associated module shall shield detrimental impact of the surface mission conditions on the food quality (acceptable levels TBD).

Note: The FPPS is contained inside one or more man rated modules. Requirements concerning the shell of the base module are only summarized briefly in this document The FPPS is submitted to the environmental conditions present inside these base modules. For further details see Ref 1.

If the higher plant chamber relies on direct sunlight an accommodation in a separate module could be needed. More detail on the PPU housing is TBD.

6.2.1 Surface environmental parameters under confined conditions

SYS-ENV-SURF-4: The FPPS shall be functional within the base module which provides a stable atmosphere and shielding from surface conditions.

6.2.1.1 Gravity

SYS-ENV-SURF-5: The FPPS shall be functional under the reduced gravity present on the planet surface. Moon: 1.63 m/s^2 (0.167 g). Mars: 3.69 m/s^2 (0.376 g).

6.2.1.2 Radiation

The FPPS will be housed inside a base module which is in principle human-rated. But since most likely not all areas of the modules are evenly shielded (areas where astronauts spend more time are usually better shielded), it has to be taken care that sufficient radiation shielding is especially present in the storage and growth compartments. As in growth and storage modules living matter for human consumption is kept over prolonged periods, negative effects due to radiation must be avoided.

SYS-ENV-SURF-6: The module structure shall provide the protection of the FPPS subsystems or components against harmful radiation levels based on human and plant radiation sensitivity guidelines (TBD), and food safety and storage regulations (TBD).

SYS-ENV-SURF-7: Taking into account the residence time in space associated with the relevant mission scenarios, an acceptable limit on radiation exposure (TBD) shall guarantee that no food components will be degraded into possibly harmful components, and that nutritional losses stay within acceptable limits (trade-off TBD).

SYS-ENV-SURF-8: The radiation level in the FPPS shall be below the limit for food alteration (taking into account a TBD safety margin).

The radiation environment has to be defined (GCR – galactic cosmic rays, SEP – solar energetic particles). The possible usage of radiation for biocidal applications is TBD.

6.2.1.3 Micrometeorites

As described for radiation in chapter 6.2.1.2, the base modules provide the required structural means to protect from micrometeorite impacts. Again, this has to be especially taken into account for a transparent module scenario.

SYS-ENV-SURF-9: The base module structure shall provide the protection against micrometeorite impacts.

6.2.1.4 Pressure, Temperature and atmosphere composition

SYS-ENV-SURF-10: The FPPS shall be functional under the following conditions:
Pressure: 1000 to 1027 hPa nominal.
Temperature: 18.5 to 26.8 ºC.
Humidity: 25 to 80% RH.

These values are TBC and are based on Ref 1. The atmosphere composition range remains TBD. Most likely, a composition range breathable by humans without special equipment will be required.

SYS-ENV-SURF-11: The system shall provide safety measures in case of rapid module depressurization (e.g. pressure release valves) as well as the means to restore nominal values (see Ref 1 page 11/12).

SYS-ENV-SURF-12: The crew shall have access to all (plant growth, processing, storage) compartments without special precautions or equipment.

6.2.2 Surface environmental parameters under partly confined conditions

The benefits of having custom separate closed environments for storage and processing will have to be assessed by trade-offs on a per subsystem basis. Associated risks to the crew have to be excluded. Large-scale (module-level) application of environments not suitable for human presence will be included for future consideration.

6.2.2.1 Temperature

SYS-ENV-SURF-13: Partial connection with the space vacuum for cooling purposes shall exclude risks of excessive atmosphere and energy loss (e.g. vacuum or low temperature storage). Providing a level of containment by means of external radiators is to be favored.

6.2.2.2 Pressure

The same constraints as for 6.2.2.1 apply.

SYS-ENV-SURF-14: Implementation of low-pressure areas (defined as a pressure lower than the standard crew compartment atmosphere pressure) for processing shall consider only (sub)-subsystems where no human operator presence is needed.

SYS-ENV-SURF-15: Exposing food or other biological material directly to the space vacuum shall be avoided due to the high off gassing rates.

6.2.2.3 Vibration

Inherent planet surface vibrations (quakes) are likely of less concern than FPPS, and Moon/Mars basis generated vibrations (see 5.2.4), TBC.

6.3 Planet protection

SYS-ENV-PROT-1: The FPPS system shall comply with the COSPAR planetary protection policy.

SYS-ENV-PROT-2: No organic-constituent or biological contamination shall be released to the planetary surface.

7 Operational requirements

For the Moon scenario, the BLSS is to be considered experimental at a first stage. It is intended to be 100% redundant to the primary mission LSS (likely physicochemical process based). During that first period, the mission LSS keeps the role of a primary LSS. After extensive evaluation the BLSS might take over the status of the primary LSS. For more information see Ref 1 chapter 2.

If the validation on the moon is successful, the BLSS will become the primary LSS. For the Mars scenario the BLSS will certainly be the primary LSS. In that case it is sufficient to size the physicochemical LSS to provide only a short term (TBD) full redundancy to the PPU oxygen and water production.

7.1 Operational mission description

7.1.1 Mission phases

1. Transit earth – surface:
   The FPPS and the crew will be transported on separate transportation systems. Crew and system arrival do not necessarily need to be planned at the same time. The FPPS can be transported disassembled and stowed (according to the logistics approach).
2. Surface stay:
   Since the MELiSSA LSS is considered as a secondary system for the first mission, the FPPS does not necessarily need to be operational at crew arrival. A staggered assembly can be planned through several assembly phases. For Mars TBD.
3. Transit surface – earth:
   Only the crew travels back to earth. The FPPS stays on the surface and is either shut down or put in a standby mode. No return transport for the base modules is intended.

7.1.2 Mission duration

For the moon and mars different scenarios are specified. The moon scenario defined in Ref 1 mentions permanent mission with a 4 member crew (mixed genders) cycled every 6 months (or longer). A transfer flight to the moon lasts between 3 to 5 days depending on the selected launch window.

For the Mars scenario three mission phases are defined:

1. Transit to Mars:
   As stated in 7.1.1 the FPPS shall be designed only for surface stay at a first stage. Functioning during the Mars transit is TBD.
2. Surface stay:
   Operational phase of the FPPS with approximately 500 day’s surface stay.
3. 6 months return
   As stated in 7.1.1 only the crew travels back. The FPPS is left behind.

7.1.3 Crew size

Moon scenarios are considering 4-membered crews. The system is to be designed to provide enough resources for every possible gender combination (see Ref 1).

Scenarios of missions to Mars are considering 6-membered crews. Today, the impact of the crew-size on the design of the FPPS considered in the present document is not well known. Therefore, for this study, a 6-membered crew of mixed gender for all phases of the mission is considered.

Nonetheless, this topic will be further analyzed in the course of the study when additional information becomes available (TBD).

7.2 Required resources

7.2.1 External resources needed by the FPPS

The FPPS can request a maximum level of energy from the Moon/Mars basis energy system, equal to the amount defined in chapter 5.1.3.

SYS-OP-ERES-1: CO_2 shall be provided by the crew compartment and the MELiSSA compartment I (liquefying compartment) and II (photoheterotrophic compartment).

SYS-OP-ERES-2: Air (nitrogen and oxygen) shall be provided by the crew compartment.

SYS-OP-ERES-3: Plant nutrients shall be provided by the MELiSSA bioregenerative system (micronutrients availability TBD).

SYS-OP-ERES-4: Water resupply shall be provided by the MELiSSA loop.

7.2.2 Internal FPPS resources

SYS-OP-IRES-1: The FPPS design has to distribute/balance the available energy to the different subsystems, as to comply with the key productivity requirements (40% DW of the crews' nutritional needs).

SYS-OP-IRES-2: The FPPS shall provide the resources to support the growth, from seeding to harvest, of the crops selected for the mission (note: the crop growth requirements specifications will be elaborated within the course of the Food Characterization project).

SYS-OP-IRES-3: Seed to seed production is not considered within this study; hence the seed-stock shall be considered a critical FPPS subsystem and shall be protected from possible detrimental effects.

SYS-OP-IRES-4: The FPPS shall provide the resources to support the processing of the crops into stabilized and final food products (Note: the requirements specifications for the processing steps will be elaborated within the course of the Food Characterization project).

SYS-OP-IRES-5: The FPPS shall provide resources to support the storage of preconditioned and fresh food products.

SYS-OP-IRES-6: Resource efficiency shall be considered, including the possibility of maximum energy recuperation (e.g. heat from processing).

Definition of specific resource utilization and timing is TBD.

7.3 Automation degree

SYS-OP-AUT-1: A preliminary trade-off shall be made between crew time availability and prioritization versus increased mass/energy needs for automation related hardware. The latter can only be proposed for tasks where feasibility can be based on documentation of existing technology (harvest, product transport).

For further details see chapter 10.1.

7.4 Operational modes

Four operational modes are defined:

7.4.1 Calibration mode

SYS-OP-MOD-1: At start-up, a defined sequence of steps shall be executed as defined in a testing and calibration procedure, involving all equipment. PPU an FPU will first be considered separately.

7.4.2 Routine, nominal operation - Functioning in closed loop system

SYS-OP-MOD-2: Adjustment of processing capacity and crop production capacity to crew consumption needs shall be provided by a central planning software application, accessible from an earth based ground control station and by the crew. The interface shall in both cases be provided by a HMI (human-machine interface).

7.4.3 Degraded, suboptimal operation mode

SYS-OP-MOD-3: A suboptimal operation mode shall guarantee a subsequent return to nominal operation by keeping the systems in a safe mode (if needed, off mode) while the subsystem equipment malfunction is diagnosed and corrected. Typically this implies low light, lower temperature, minimum nutrient flow etc. Maximum duration of suboptimal operation mode without irreversible damage to biological matter is TBD.

SYS-OP-MOD-4: Safeguarding of seed stock shall be assured under all circumstances since no seed to seed culture is envisaged.

7.4.4 Maintenance operational mode

7.4.4.1 Preventive maintenance mode

SYS-OP-MOD-5: Risks to the crew linked to FPPS malfunction shall be avoided by a preventive maintenance plan.

The time, frequency and length of maintenance are limited by crew time availability. TBD on an equipment by equipment basis. Built-in redundancy (with base LSS) avoids risks to the crew concerning water and oxygen production shortages.

7.4.4.2 Corrective maintenance mode

SYS-OP-MOD-6: The mission supervision system in which the FPPS monitoring system will be integrated shall provide real-time parameter output that can be monitored for derivations from optimal performance (by mission control and the crew). All parameters shall be logged for a TBD period of time to enable tracing of errors.

SYS-OP-MOD-7: Food production shall be adjusted as a function of food needs and crew time availability by using corrective maintenance planning.

7.5 Control system strategy

SYS-OP-CONT-1: The FPPS control system shall be integrated into the MELiSSA top level control system strategy.

SYS-OP-CONT-2: The control strategy shall be of predictive nature (based on physical models; e.g. plant physiological model, as an ultimate goal).

SYS-OP-CONT-3: No black box control system shall be used.

Since the FPPS (as the whole MELiSSA loop) will have many direct interfaces with the crew, a high degree of monitoring and control is needed. Further details remain TBD.

8 Interface requirements

8.1 Interface to conventional LSS

The FPPS as part of an experimental bioregenerative LSS (MELiSSA) will be redundant with the Moon base primary LSS (largely physicochemical). Upon maintenance of the FPPS during a limited timeframe the primary LSS can provide backup capacity. In later evolution stages the BLSS can be adapted to become the primary LSS (e.g. for Mars scenario). Both systems will have to be interfaced to some extent. The general nature of these interfaces is presented in Fig. 1. Further details on these interfaces remain TBD.

The mission storage system needs to have the capacity to temporary store the amounts of water, air, plant nutrients and waste streams related to crop production, food harvest and processing, to allow these processes to start and function for the planned amount of time, and to link to the MELiSSA system with a predefined load (as a function of time).
Specifically start-up of each plant culture will likely require some specific interfaces within the BLSS, e.g. nutrient solution provision with composition corresponding with plant growth requirements, after temporary storage (accumulation over a TBD amount of time).

8.2 Interface with other BLSS elements

SYS-IF-BLSS-1:	The FPPS shall interface with the other MELiSSA compartments for waste fluxes (TBD, e.g. waste water, crop processing wastes, food preparation wastes), resource fluxes (TBD, e.g. CO_2, water, MELiSSA processed nutrients) and all valuable output from PPU-based crop production (O_2, condensed plant transpiration water).
SYS-IF-BLSS-2:	The FPPS shall interface with the food galley of the mission.

8.2.1 BLSS control system interface

SYS-IF-BLSS-3:	The FPPS control system shall be integrated into the Moon/Mars base system control strategy (as part of the MELiSSA bioregenerative system). It shall be interconnected to other MELiSSA compartments to provide predictive functioning.

Interfaces to earth based mission control are TBD.

8.3 Interfaces within FPPS

The PPU and the FPU, as well as the storage area for fresh and (semi) processed food need to be interconnected. As a first approach handling of the harvest and intermediate products by crew members based on a predefined yet flexible schedule under supervision of a dedicated software system (and control centre operator supervision) is considered (see 10.1).

The different processing steps within the FPU can be either carried out by single or multifunctional devices, depending on the results of a trade off (using ALISSE criteria) to be carried out (TBD).

SYS-IF-FPPS-1: The food product and menu elaboration management system shall take into account the interfaces between:

1. FPPS product storage (40% DW crew needs), capacity for minimum 1 batch harvest.
2. Resupply food storage (60% DW crew needs) (external to FPPS).
3. FPPS processing and menu-elaboration infrastructure (TBD, 2 sub-systems).
4. Mission food galley (kitchen annex dining room with basic equipment for warming up meals etc.).

8.4 Data management

SYS-IF-DATA-1: Data management for crop growth, harvest and food processing and menu elaboration shall be integrated into the mission scenario data management system (see also 3.6).

8.5 Communication architecture

SYS-IF-COM-1: Mission-provided interfaces shall be used for all data transfer, including the ground station control system.

SYS-IF-COM-2: The FPPS scheduling system shall be integrated into the mission scenario with regards to maintenance.

SYS-IF-COM-3: Follow-up of food production shall be possible from a ground-based control centre, in order to adjust planning or growth conditions to guarantee the production of the needed food products.

SYS-IF-COM-4: The ground-station shall use an earth-validated predictive plant-growth model to assist in adjusting planning or growth conditions.

SYS-IF-COM-5: The one-way communication delay (3-20 min in case of Mars) shall be taken into account for all communication and control transmissions and especially for emergency situations.

9 Product assurance requirements

9.1 Reliability ALISSE criterion

SYS-RAMS-REL-1:	Reliability shall be provided by guaranteeing a minimum lifetime of the components to be employed during the duration of the surface stay-tentatively based on statistics of functioning under earth-based conditions.
SYS-RAMS-REL-2:	Critical components shall be provided with a manual operation mode (e.g. indispensable food processing equipment) to allow basic usage in emergency situations.
SYS-RAMS-REL-3:	The system shall be designed to degrade gracefully, that is, failures may affect the performance of the system but not stop its life critical functions.
SYS-RAMS-REL-4:	Expected time of spares resupply can vary from weeks to months (Moon), therefore maintenance of the system components shall be programmed accordingly.

A detailed maintenance protocol remains TBD (see 11.4).

9.1.1 Redundancy

Depending on the level of miniaturization attainable for the processing equipment, it might not be possible to provide all equipment in duplicate, given the mission scenario mass and volume constraints.

SYS-RAMS-REL-5:	Redundancy of the FPPS outputs oxygen and water shall be provided by the mission primary LSS (physicochemical system).

If possible the storage facilities of the primary LSS will be used for FPPS products. Thus there will be no redundancy on the storage volume. Storage requirements (conditions and volumes) are TBD. Possibly additional storage facilities will be required to provide the correct conditions for all FPPS products.

9.2 Risk to crew ALISSE criterion

9.2.1 *Microbial safety*

SYS-RAMS-RISK-1: The FPPS shall be equipped with a system (CIP) to avoid microbial proliferation in the processing subsystems of the FPU and in the PPU, and thus to exclude contamination of the crew food.

SYS-RAMS-RISK-2: A strategy for periodical cleaning of critical (TBD) FPPS elements shall be envisaged (protocol TBD).

SYS-RAMS-RISK-3: Microbial strains shall be sampled, identified and quantified in critical (TBD) FPPS subsystems at regular (TBD) time intervals to highlight any contamination with human pathogenic organisms or organisms with negative influence on the system.

SYS-RAMS-RISK-4: The food end product shall comply with TBD microbiological safety requirements.

9.2.2 *Handling safety*

SYS-RAMS-RISK-5: Equipment shall comply with maximum and minimum surface temperature (touch temperature) and the associated maximum exposure duration (TBD).

SYS-RAMS-RISK-6: Equipment/structure design shall comply with TBD ergonomic regulations at mission level.

SYS-RAMS-RISK-7: The equipment design shall prevent any ill-being, poisoning, wounding at any level of severity.

9.2.3 *Maintenance safety*

SYS-RAMS-RISK-8: Safety and ease of equipment disassembly shall be taken into account within this study.

SYS-RAMS-RISK-9: Radiation level in all compartments shall be compliant with TBD standard during crew presence.

SYS-RAMS-RISK-10: Requirements concerning handling safety (SYS-RAMS-RISK-5 and SYS-RAMS-RISK-6) shall be respected also for maintenance issues at all times.

10 Human factor requirements

10.1 Crew time allocation ALISSE criterion

For this study only physiological maintenance related activities (muscle atrophy avoidance) are considered. Several FPPS tasks will need crew time for efficient completion, these tasks shall be planned within the overall mission scenario planning (number of hours per day or per week TBD).

- Plant seeding and propagation
- Plant maintenance (e.g. containment of senescing foliage)
- Control of the plant growth system
- Harvest and coarse processing
- Storage
- Processing
- Storage of (semi-finished) products
- Menu elaboration
- Storage of dishes

10.1.1 Workload

SYS-HUM-TIME-1: The overall time schedule shall be based on the current ISS schedule 8h work, 8h sleep, 8h leisure activity.

In general the crew time required for maintenance and operation of the FPPS shall be kept as low as possible. Detailed requirements must be elaborated based on trade-off cost assessment of the equipment automation vs. crew time requirements. A good starting point for further analysis is provided by Ref 7 chapter 3.3.2 Crew Time Estimates.

10.1.2 Cognitive / leisure activity

A combination of maintenance operations with leisure activity might be considered on a voluntary basis. Planning will however need to guarantee that enough working hours will be available for the needed tasks.

10.1.3 Physical activity

Timing of physical activity is TBD in accordance with needs implied by mission scenario duration.

Energetic expenditure will depend on:

1. Planned activities, number of surface-EVAs TBD
2. Individual crew member physiology (weight etc. TBD)
3. Scenario chosen (Mars versus Moon)

The implementation of energy expenditure data into the menu cycle remains TBD. In Fig. 1 this interface is represented as crew physiological data input into the MELiSSA information system.

10.2 Human Machine Interface

A user friendly Human Machine Interface (HMI) will be needed to display the necessary control system parameters and system status (e.g. temperature graphs, growth cycle information, alarms etc.) and to be able to interact with the system (e.g. change control system values, activate operation modes etc.). The HMI itself does not perform any control operations but rather allows a user to interact with the underlying control layers and to give feedback to a user on the systems status.

SYS-HUM-HMI-1:	A HMI shall be provided for nutritional status supervision per crewmember.
SYS-HUM-HMI-2:	A HMI shall be provided for plant growth supervision.
SYS-HUM-HMI-3:	A HMI shall be provided for crop processing steps.
SYS-HUM-HMI-4:	A HMI shall be provided for menu elaboration functionalities.
SYS-HUM-HMI-5:	A decentralized local interface per-equipment shall be provided to allow adjustments during processing.
SYS-HUM-HMI-6:	Operational settings and performance of each utility shall be logged to a central data management system to keep track of overall performance and efficiency.
SYS-HUM-HMI-7:	A link with ground-station experts (and expert system) shall be provided.

11 Logistic requirements

The overall strategy for the first deployment on Moon/Mars surface is described in chapter 7.1 and Ref 1. For the Moon a human-assisted assembly missions can be considered. The exact scenario and assembly strategy is TBD. At this point only general limitations in view on the launcher capability are given.

11.1 Launcher

As a first approach, the (hypothetic) capabilities of an ARES V launcher are used. ARES V has a payload capacity of 45 metric tons to the moon’s surface. The lunar lander module ALTAIR can be equipped with a cargo module instead of a crew vehicle. In this configuration the descent stage can carry 14 tons to the moon’s surface. Despite the mass capabilities, the FPPS will most likely not be launched preassembled in one go since the HPC will probably be composed of several modules (e.g. 4 Destiny ISS like modules).
The module approximately has a 4.5 meter diameter and a length of 7.5 meter.

11.2 Lunar transit

The logistic scenario for the lunar transit is TBD.

11.3 Resupply missions

SYS-LOG-RES-1: For the moon one resupply mission every 6 months is envisaged. A spare part plan shall be defined in order to identify the FPPS items that will need repair or replacement within the next six month (see Ref 1).

No intermediate resupply is envisaged for a Mars scenario see 7.1.2. Emergency resupply possibilities are TBD. Resupply is possible with crew cycling.

11.4 Maintenance

A detailed maintenance plan remains TBD.

For maintenance operation modes see chapter 7.4.4.

12 Verification & Validation

Possible strategies for verification and validation need to be determined at a later stage (conceptual design/demonstrator design available to determine test and inspection needs) TBD.

12.1 Requirements validation

TBD

12.2 System tests validation

TBD
Validation phase, redundancy to primary LSS

Annex 1

Nutritional requirements for humans for exploration mission on Moon or Mars

This annex document elaborates on the estimation of the nutritional requirements for longer-term space exploration, based on the limited specific info available today, as compared with the well established human nutritional needs on earth: see Annex12 of this annex document, which provides the currently estimated needs for each essential nutritional component.

For space exploration, provision of proteins, vitamins and minerals are seen as crucial, with emphasis on bio-availability (determining efficiency of absorption by the consumer).
The preferred high levels of protein, vitamin (and mineral) availabilities as also stated in (Ref 2 and Ref 3) have to be assessed on the individual component basis (see 4.1). Therefore nutritional reports based on menus need to be assessed, according to the example added to the annex. This preliminary document indicates for which minerals and vitamins a high degree of coverage of the nutritional requirements will likely be achieved based on the current MELiSSA crop selection.

FC1 - nutrient requirement evaluation 4 FC crops from menu 31 days - IPL.xls

Proteins have to comply with an optimal composition of the essential amino-acids (AA). To illustrate this, the AA-composition of the protein of each MELiSSA crop was added to a calculation sheet (added to this annex). In order to allow assessing the nutritional quality of the protein contained in the to be produced 40% DW plant derived food for the proposed mission scenario (see 4.1), the overall protein quality of menus will need to be calculated to ascertain provision of the required amounts of essential AA.

FC1 - amino acids of Melissa crops - 2009.04.20.xls

The Annex 1 last annex table summarizes the estimated needs for energy, macronutrients, essential AA and lipids, minerals and vitamins, and indicates the identified risks for deficiency.

MELiSSA

UNIVERSITEIT GENT

FACULTEIT WETENSCHAPPEN

Memorandum of Understanding 19071/05/NL/CP

MELiSSA FOOD CHARACTERIZATION: PHASE 1

TECHNICAL NOTE: 1.1

ANNEX

NUTRITIONAL REQUIREMENTS FOR HUMANS FOR EXPLORATION MISSION ON MOON OR MARS

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List of Abbreviations

Abbreviations	Definition	Abbreviations	Definition
AA	Arachidonic acid c20:4	MELiSSA	Micro-ecological life support system alternative
ACP	Acyl Carrier Protein	mg	Milligram
ARS	Agricultural research service	ml	Milliliter
ATP	Adenosine triphosphate	NAD	Nicotinamide adenine dinucleotide
BM	Basal metabolism	NADP	Nicotinamide adenine dinucleotide phosphate
BMR	Basal metabolic rate	NASA	National aeronautics and space administration
Ca/P	Calcium/phosphorus ratio	NE	Niacin equivalent
CHO	Carbohydrates	NEAT	Non-exercise activity thermogenesis
CLA	Conjugated linoleic acid	oz	Ounce
CoA	Coenzyme a	PAL	Physical activity level
DEXA	Dual energy x-ray absorptiometry	PDCAAS	Protein digestibility corrected amino acid score
DFE	Dietary folate equivalent	PTH	Para-thyroid hormone
DHA	Docosahexaenoic acid c22: 6	RAE	Retinol activity equivalent
DHF	Dihydrofolic acid	RDA	Recommended dietary allowances
DIT	Diet-induced thermogenesis	RE	Retinol equivalents
DNA	Deoxyribonucleic acid	RMR	Resting metabolic rate
DRI	Dietary reference intakes	SLS	Spacelab life sciences
DW	Dry weight	SOD	Superoxide dismutase
EFSA	European food safety authority	SR USDA	National nutrient database for standard reference
EPA	Eicosapentaenoic acid c20: 5	TEE	Total energy expenditure
ESA	European space agency	TEF	Thermic effect of food
EVA	Extra vehicular activity	TEI	Total energy intake
FAD	Flavin adenine dinucleotide	THF	Tetrahydrofolate
FAO/WHO/UNU	Food and agriculture organization/ world health organization/united nations universities	TSH	Thyroid-stimulating hormone or thyrotropin
FNDDS USDA	Food and nutrient database for dietary studies	Vit.	Vitamin
g	Gram	µg	Microgram
GI	Glycemic index		
INFOODS	International network of food data systems		
ISS	International space station		
IU	International unit		
Kcal	Kilocalorie		
Kg	Kilogram		
kJ	KiloJoule		
LA	Linoleic acid c18:2		
LDL	Low density lipoprotein		
LNA	α-linolenic acid c18: 3		

1 Introduction

Food provides the nutrients that human need to stay healthy. Consuming enough energy, vitamins and minerals is a necessity for the astronaut as well as for people living on earth. The elaboration of menus for space missions is complex, since one must be sure that the selected food will cover all nutritional requirements.

The adaptation of the human body to microgravity requires (and hence induces) many physiological changes. Many of these changes affect food consumption; on the other hand specific aspects of malnutrition can further accentuate some of the phenomena linked to space-adaptation. Many studies demonstrate that in microgravity humans are confronted with loss of bone density, muscle atrophy, heart problems, changes in blood circulation, ...

Consumption of sufficient amounts of nutrients cannot avoid these changes, but having a diet too low in nutrients and micronutrients may have additional deleterious effects on health.

Before considering a space mission, it is of prime importance that the astronaut is in perfect health, that he remains as much as possible in a status of optimal health throughout the trip, and that upon return on earth his adjustment to gravity will take place quickly (adjustment to lower level of gravity on planetary surface to be considered likewise).

Therefore, with this aim, the nutritional status of the crew of the ISS (as a current example), is monitored before, during and after the flight. Before and after a trip to space, blood and urine of the crew are analyzed, the status of bones is assessed (with the X-ray DEXA-method), the concentration of vitamins and minerals is analyzed. In addition, the astronauts must complete a "food book", during the trip, in which they report what they consumed. This food frequency questionnaire is then sent to earth where experts analyze the data and can try to improve the diet of astronauts of the ongoing mission.

Historically, nutrition has always had an important role in exploration, referring to long distance exploration over the sea, and including the more recent spatial level.

The importance of optimal nutrition increases with the extension of the duration of space travel. Indeed, from a few weeks on board of the shuttle, we went to several months on the ISS, and it will take a journey of several years to reach other planets.

The aim of this technical note is to determine the nutritional requirements for astronauts on longer-time missions (Moon or Mars). In annex 1 the functions of all nutrients are summarised, as well as the consequences of deficiencies and excesses. All requirements are based on nutritional requirements for healthy people (annex 2, 3), dietary assessment in adults of European countries (annex 4-10), nutritional intakes of astronauts (annex 11). All specific requirements estimates for a Moon or Mars mission are summarized in annex 12, and the most likely risks for deficiencies are indicated.

2 Energy

2.1 Energy expenditure

The energy requirement of an individual is the level of energy intake from food that

1. will balance his or her energy expenditure (determined by body size and composition and level of physical activity),
2. is consistent with long-term good health; and
3. Will allow for the maintenance of economically necessary and socially desirable physical activity.

(FAO/WHO/UNU 1985).

To preserve a good health, total energy expenditure must equal energy consumed. Energy is derived from the oxidation of macronutrients (carbohydrate - CHO, fat, protein, alcohol …). Normally, metabolisable energy is about 90-95% of energy intake. (Jequier, 1999).
If a subject is trying to increase body mass, then energy intake must exceed energy expended. On the other hand, if a subject is trying to reduce body mass, energy expended must exceed energy intake. But this equality solely based on energy needs linked to body weight and composition is not sufficient nor universally applicable; many other factors like physiological, environmental, behavioral and genetic aspects can influence the balance of this equation. (Jequier, 1999).
In conclusion, determining energy expenditure will be essential to maintain good health and an appropriate level of physical activity in the framework of space exploration...

2.2 Basal energy expenditure or basal metabolic rate

Basal metabolic rate (BMR) is the energy required at rest to both maintain (the systems of) the body functions, and to regulate body temperature. The measurement of the BMR subject must be carried out

1. in the post-prandial state
2. at complete rest in the morning
3. in a thermo-neutral environment and
4. free from stress, medication or any other stimulation.

.

In this case BMR approximately equals energy expenditure during sleeping.
In addition, there are many studies which measure resting metabolic rate (RMR). The difference between BMR and RMR is less than 10% .
In a sedentary adult BMR represents 60-80% of total daily energy expenditure. Factors influencing BMR are age, sex, body size, level of lean mass (determined by DEXA). Muscles represent 18% of whole metabolic rate.

2.3 Thermic effect of food

Thermic effect of food (TEF) also called diet-induced thermogenesis (DIT). This is the energy expenditure above RMR which result from the energy cost of food digestion, absorption, transport, metabolism and storage in the body. This represents approximately 6-10% of total daily energy expenditure.

However, many studies evaluate the thermic effect of a meal (TEM). This represents the increase in metabolic rate above the RMR (see above) after eating a meal, TEM values of each meal per day to be added to obtain a value comparable to TEF.

2.4 Adaptive thermogenesis

Adaptive thermogenesis (AT) includes the influence of factors that can slightly increase BMR such as cold, heat, fear, stress, drugs (tobacco, caffeine, theobromine, alcohol), medications but also stress associated to special events or higher altitude.

2.5 Physical activity

This is the most variable component of Total Energy Expenditure (TEE). This represents the energy above RMR and TEF. Physical activities include daily life activities (also called non-exercise activity thermogenesis; NEAT) and exercise or sport.

Astronauts consume, on average, 80% of their recommended energy intake; during a mission their energy expenditure remains unchanged or even increases. However, such energy deficit during space flights of short duration is not a major problem. On long term missions on the other hand, a chronic negative energy balance will result in decreased physical performance, decreased immune system activity, ... The specific reasons for the inability of astronauts to maintain energy balance during spaceflight are not yet well understood. This phenomenon could be due to

1. a higher energy expenditure,
2. alteration of the functioning of the gastrointestinal tract
3. metabolic changes affecting appetite.

…

During experiments under microgravity on rats, no changes in energy balance were recorded, in contrast with the findings in humans. The comparison with rats shows that the low energy uptake observed in humans during spaceflight is not due to microgravity. Moreover, it was observed that the inability of astronauts to adjust their diet to their needs was not an individual problem. Indeed, food consumption varies according to the missions types, and not between individuals, which would mean that the astronauts "synchronize" their energy consumption within a crew .

According to some comments, it appears that food consumption is inversely related to the amount of exercise performed during the flight. This inverse relationship is thought to be due to the accumulation of metabolic products produced during the mission: heat and CO_2. Physical activity increases the amounts of CO_2 and heat released, which should subsequently be evacuated. However, the thermoregulatory mechanisms are less effective in space (higher ambient and CO_2 concentration, lower convective heat loss), and this phenomenon persists in the days following the return to earth. Low consumption of food would therefore be due to the accumulation of waste products that are not removed as quickly as needed. The loss of body mass would thus be linked to the environment, air movement and purification.

During the Skylab missions, the space shuttle missions and in the Mir space station, there was an increase in energy expenditure of 10% to 30% compared to the Gemini, Vostok, Apollo and Salyut missions. This increase can be explained by the fact that the design of the more recent spacecraft allows more physical activity. For example, the astronauts of the space shuttle move freely in a relatively large space (of approx. m^3) (H. Lane, 2002).

Actually, when energy consumption is too low, the body draws the energy it needs from its reserves, resulting in a decrease of body weight, loss of muscle mass, and reduced physical abilities. The nutrients and micronutrients an astronaut needs are the same as on earth, but their absolute and/or relative quantity is different. It was shown that the energy needs of the individual astronauts were about the same as their requirements when on earth. The energy can be supplied by a normal diet because, in microgravity, the absorption of energy substrates in the intestines did not undergo changes, the peristalsis of the digestive tract being still functional albeit reduced.

Astronauts eat three major meals a day: breakfast, lunch and dinner. Nutritionists and dieticians need to ensure that the proposed food provides a balanced intake of vitamins and minerals. There is a limited amount of data available on nutrition, specific for women. Energy needs are calculated assuming that there are no differences between men and women concerning the physiological changes that occur in microgravity. According to some observations, the energy expenditure for women is on average lower than for men, because women tend to have a lower body mass, however the difference in energy expenditure is not significant. (Lane H. 2002)

During the space age, energy consumption fluctuated according to the different mission types. One can observe that the astronauts on the Skylab 4 mission all ingested approximately the same amount of energy (between 40 and 45 $kcal.kg^{-1}.day^{-1}$). In contrast, those participating in the mission ½ SLS (Spacelab Life Sciences 1 & 2 / STS Space Shuttle missions) ingested significantly less energy (between 25 and 33 $kcal.kg^{-1}.day^{-1}$).

It was found that energy expenditure under microgravity did not differ from that on earth. In contrast, the energy cost of physical activity decreases because there is no need to ‘fight’ against gravity. Indeed, the energy needed for conducting experiments on the lunar surface is approximately 40% lower compared to the expenditure for the same activity on earth, because the gravity of the Moon is weaker than on Earth (gravity on the Moon = 1/6 Earth gravity). This same activity on Mars would require more energy than on the Moon, but less than on Earth because gravity on the red planet is 1/3 of Earth's gravity.

Despite the reduction in energy cost of various physical activities, total energy expenditure under microgravity is not significantly different from the needed value on earth. Because:

1. The energy expenditure at rest is higher, and
2. The astronauts will spend more energy for common movements in microgravity.

For example, fixing a screw in space leads to a higher energy expenditure as compared to Earth conditions, because the astronaut needs to exert some extra force to immobilize himself in a stable position, otherwise he would turn instead of the screw (action and reaction is dependent on gravity for the efficient transmittance of forces). As mentioned above, the effort required for an astronaut to move his body around is significantly reduced. To calculate the energy needs of the astronauts, the same formulas as on earth can be used (Lane H., 2002)
Energy needs: TEE = PAL x BM (kcal / day)
• TEE x = 1.7 BM (*) For all adults, the value of 1.7 represents the ideal PAL. This value is proposed by WHO and indicates a medium level of activity, which was found to also apply to the astronauts' needs.

Tab. 1 The World Health Organization equations for calculating energy requirements

	Male	Woman
18 to 29 years	BM = 679 + 15.3 W	BM = 496 + 14.7 W
30 to 59 years	BM = 879 + 11.6 W	BM = 829 + 8.7 W

(*) Basal metabolism (BM) is based on age, weight and sex.
BM: W: weight in kilograms. To convert kcal/day to kJ/day, multiply by 4.186

Taking as an example a 74 kg astronaut, being less than 30 years old. What are his/her energy needs?
TEE = PAL x BM = 1.7 x BM
The metabolic basis for an adult male is:
BM = 15.3 x 74 + 679 = 1811 kcal
TEE = 1.7 x 1811 = 3079 kcal
The astronaut should thus consume 3079 kcal per day.
Astronauts consume on average 80% of their recommended energy intake; for this astronaut intake is in fact only 2450 kcal, which is clearly insufficient.

These formulas are valid for physical exercise of moderate intensity. Thus, the estimated energy expenditure seems correct except in cases of intensive exercise, used as a measure against loss of muscle mass ... During more recent space missions, there was a decrease in crew appetite and increased energy needs. This could likely pose a problem during long flights, but research to identify and characterize the involved factors remains to be carried out.
These formulas do not apply to extra-vehicular exits and EVA (Extra Vehicular Activity). Energy expenditure during these trips depends on the duration of the activity. Moreover, the energy cost of these activities varies from one individual to another depending on the training done before the flight. This take into account the increased agility/dexterity and gain of time associated with training. Data on energy expenditure during the EVA is always available, since the suit that astronauts don at these 'sorties, space-walks' is equipped with a system supplying O_2 and including a device that records the consumption of O_2. This consumption determines and is directly correlated with energy expenditure during extra-vehicular trips. The data ranges

from 570 kJ / hour to 1.1 MJ / hr (136 kcal to 263 kcal / h), this probably reflects the intensity of activities. There was a decrease in energy expenditure during the EVA over time. Indeed, it was 1 MJ / h during the Apollo and Skylab missions, and 820 kJ / h for the missions of space shuttles (STS). This decrease was attributed to improved space suits that allowed greater mobility, better design of tools used during the EVA and an increase in the training of astronauts. (H. Lane, L. Feeback 2002) In practice, we must add 0.4 MJ/hour (95 kcal/h) per day of activity. If regular EVA are scheduled, such as for building the international space station, the TEE equation needs to be multiplied by 0.06 for each hour EVA.

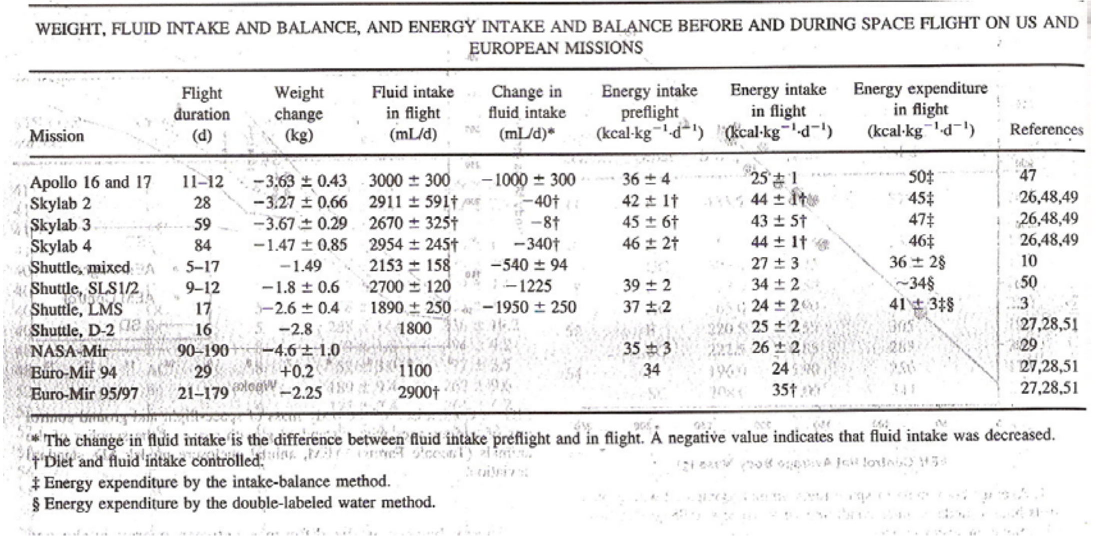
Consider the example of our astronaut. If he/she would be part of a team responsible for building the ISS, extra-vehicular trips would be fairly important. How much extra energy has to be foreseen: 1.7 x 0.06 x BM x 1 hour = 3079 x 0.06 = 185 kcal / hour. It should be 185 kcal per hour EVA, in addition to the previously calculated TEE. If he works 5 hours per day it would have to be: 5 x 185 = + 925 kcal. Thus 3079 kcal + 925 kcal equaling approximately 4000 kcal / day.

In contrast, if his extra-vehicular trips are not so regular, 95 kcal/h would need to be added. If he or she works 5 hours during such an EVA, 95 x 5 = + 475 kcal will be needed. In total: 3079 kcal +475kcal = 3550 kcal.

The fluid transport and distribution changes that occur in the body under microgravity, and the changes in fat content do not affect energy needs, unlike the loss of muscle mass. In fact, each kilo of muscle loss reduces the basic metabolism by 90 kJ. One goal of long-duration space flight is to prevent muscular atrophy. (Lane, 2000)

In general, people consume less food and water during spaceflight and lose weight. In missions where food consumption was controlled, weight loss was less significant. Two astronauts even gained weight during long-duration flights, one on Skylab and another one on Mir, as shown in the following table. Remarkably a third NASA astronaut performing a mission on Mir had maintained satisfactory food consumption, but still had lost weight. However, he did not suffer from a decrease in protein turnover as important as the other astronauts who had reduced their food. In general, when food consumption schedule is not predetermined, energy consumption is lower. In most cases, this reflects a negative energy balance. (C. Wade, 2002)

Tab. 2 Weight, fluid, energy on US/European missions



WEIGHT, FLUID INTAKE AND BALANCE, AND ENERGY INTAKE AND BALANCE BEFORE AND DURING SPACE FLIGHT ON US AND EUROPEAN MISSIONS

Mission	Flight duration (d)	Weight change (kg)	Fluid intake in flight (mL/d)	Change in fluid intake (mL/d)*	Energy intake preflight (kcal·kg^{-1}·d^{-1})	Energy intake in flight (kcal·kg^{-1}·d^{-1})	Energy expenditure in flight (kcal·kg^{-1}·d^{-1})	References
Apollo 16 and 17	11–12	−3.63 ± 0.43	3000 ± 300	−1000 ± 300	36 ± 4	25 ± 1	50‡	47
Skylab 2	28	−3.27 ± 0.66	2911 ± 591†	−40†	42 ± 1†	44 ± 1†	45‡	26,48,49
Skylab 3	59	−3.67 ± 0.29	2670 ± 325†	−8†	45 ± 6†	43 ± 5†	47‡	26,48,49
Skylab 4	84	−1.47 ± 0.85	2954 ± 245†	−340†	46 ± 2†	44 ± 1†	46‡	26,48,49
Shuttle, mixed	5–17	−1.49	2153 ± 158	−540 ± 94		27 ± 3	36 ± 2§	10
Shuttle, SLS1/2	9–12	−1.8 ± 0.6	2700 ± 120	−1225	39 ± 2	34 ± 2	~34§	50
Shuttle, LMS	17	−2.6 ± 0.4	1890 ± 250	−1950 ± 250	37 ± 2	24 ± 2	41 ± 3‡§	3
Shuttle, D-2	16	−2.8	1800			25 ± 2		27,28,51
NASA-Mir	90–190	−4.6 ± 1.0			35 ± 3	26 ± 2		29
Euro-Mir 94	29	+0.2	1100		34	24		27,28,51
Euro-Mir 95/97	21–179	−2.25	2900†			35†		27,28,51

* The change in fluid intake is the difference between fluid intake preflight and in flight. A negative value indicates that fluid intake was decreased.
† Diet and fluid intake controlled.
‡ Energy expenditure by the intake-balance method.
§ Energy expenditure by the double-labeled water method.

There is growing concern over the lack of nutrient and energy absorption, especially as a low caloric intake is often related to a lack of vitamins and minerals. (Smith SM, 2005)

2.6 Moon and Mars requirements:

Expect the exact energy need for astronauts for a trip like this is crucial. Indeed, an overestimation of 10% will have an impact on the weight of astronauts, but also a very significant increase of food and packaging to carry. Unlike an underestimation of 10% will increase a state of malnutrition. With an energy intake below 1800 kcal for men and 1500 kcal for women it is impossible to maintain a healthy life.

The energy requirements of astronaut candidates in different situations should be fully evaluated.

However, many studies on the astronauts say they do not consume the entirety of their needs. Now it is indispensable that the inputs match the needs. As such it must Melissa menus are particularly healthy, balanced and tasty.

The dietary recommendation for a mission to the Moon or Mars is estimated on the first 2 months after landing at least at 40-45 kcal.kg^{-1}.d^{-1} during the first 2 months or WHO equation with a coefficient of high physical activity level. The goal is to provide enough energy to reconstruct muscle mass required for a stay under gravity.

During EVA more energy is needed (2.5 kcal.kg^{-1}.h^{-1}). On the Moon physical activity required less energy due to less gravity. On Mars we can expect also a reduction of energy expenditure but more than on the moon.

3 Macronutrients needs

3.1 Protein

Proteins are polymers of amino acids. The specific property of a protein depends on amino acid composition. An amino acid may be essential or nonessential. The former cannot be synthesized by the body and must be given daily through the diet. Essential amino acids are phenylalanine, histidine, isoleucine, leucine, lysine, methionine, threonine, tryptophan and valine. The non-essential amino acids are alanine, arginine, acid asparagine, cysteine, cystine, glutamine, glutamic acid, glycine, hydroxyproline, proline, serine and tyrosine.

The quality of a protein depends on the digestibility and the presence of essential amino acids. The Protein Digestibility-Corrected Amino Acid Score (PDCAAS) can be used to measure protein quality. The PDCAAS represents the content of essential limiting amino acid in the protein, expressed in mg per gram of protein, divided by the need for this amino acid in children under 4 years, also expressed as mg per gram of protein, multiplied by digestibility of the protein.

In general, the PDCAAS of animal origin is higher than plant sources. Soybeans and derivatives are an exception. Most other plant products have an amino acid limiting specific. Examples methionine for legumes and lysine for corn and wheat. By combining and varying food plant, it is possible to meet the recommendation for all essential amino acids.

Lysine is the limiting amino acid to the lacto-ovo-vegetarians and especially vegans, as part of a diet lacto-ovo-vegetarian (dairy/wheat as sources of protein), the PDCAAS would amount to 84 % within a vegan diet (wheat/soybeans as protein sources) the PDCAAS would amount to 77% (Nederlandse Voedingsnormen, 2001). It follows therefore that the protein needs of lacto-ovo-vegetarians are 1.2 times higher than those with mixed feeding and 1.3 times higher in the case of vegans.

A protein intake too high could have a negative impact on health caused by increased acidity of the body. Except in specific patient groups, these negative effects have never been demonstrated. No harmful effect on health has been found in cases of protein intake to 25% of energy. This value could then be used as a safe upper limit (Conseil supérieur de la santé 2009)

3.1.1 In microgravity or simulation:

During space travel there is a decrease in overall nitrogen balance caused by different adaptations to microgravity and associated changes in the body energy balance.

During the first day of flight, food consumption and nitrogen balance generally decrease due to space motion sickness.

On the third day, the astronauts regain appetite and subsequent food consumption remained fairly stable during the rest of the mission, but was still below the recommendations. Nitrogen balance also readjusted quickly on the sixth day of flight. One possible explanation is that muscle immediately adapts to microgravity by losing nitrogen, and that a negative energy balance further increases this loss. When the energy balance is readjusted, the nitrogen balance increases, indicating that the tissues like liver compensate the energy deficit.

If the gain of muscle tissue does not equal the loss of muscles (anabolism = catabolism), then these effects indicate an increase in nitrogen retention.

On the ninth day, the first visceral protein losses were offset, the loss of muscle proteins decreases, the nitrogen balance improves. The data suggest that the ninth day, the loss of protein slows down due to the reduction of the natural size of the muscles in response to the reduction of tension in microgravity. (Lane 1999)

The loss of protein in muscle is due to:

- muscle atrophy caused by the decrease in support to microgravity. Bed rest studies showed a reduction of protein synthesis by about 15%. (Stein TP, 1999)
- protein-energy deficit due to a decrease in food consumption or increased physical exercise. (Lane 1999) It can be observed that when astronauts absorb insufficient energy, the nitrogen balance decreases and vice versa. It is therefore necessary that astronauts consume enough food to avoid a negative nitrogen balance.
- metabolic stress. Indeed, the human body may levy a microgravity stress and respond accordingly. The response includes the activation of the hypothalamic system, increases rates of entire metabolism that increases the protein turnover in the entire body. Other responses also increase: gluconeogenesis, the activity of proinflammatory cytokines, basic metabolism and loss of protein. These reactions can reduce stress and protect the rest of the body by mobilizing defense mechanisms. This process called "metabolic stress response” is regulated by the central nervous system, neuroendocrine system and immune system. Spaceflight causes changes that disrupt the endocrine metabolism. This alteration in metabolism affects body composition and nutritional needs of astronauts.

Transcription and translation are involved in regulating protein synthesis, and degradation of myofibrils. This regulation is responsible for maintaining the efficiency of muscle contractions. But the intracellular signal responsible for the loss of muscle mass is not yet fully understood. (Bajotto G, 2006)

A consistent loss of protein has been observed during space flights, mainly in muscle. It was concluded to occur partly in response to the reduced efforts required of the muscles in microgravity. Indeed, when the muscles should no longer bear the body by fighting against gravity, muscular activity is reduced.

The excessive muscle activity is mitigated by a change of prostaglandins affecting the tension on the muscles. (Stein TP, 1999) The inactivity associated with stress leads to increased protein catabolism, decreased muscle function and nitrogen balance. The body is not able to maintain an adequate protein synthesis. The drop in activity, resulting in an imbalance between synthesis and protein catabolism, leads to a loss of body weight. These losses may lead to functional decline in performance and decrease the health of crew members during flights of long duration. (Paddon-Jones D.2006)

If we associate to this muscle volume reduction phenomenon a low calorie diet, impaired synthesis and catabolism of hormone pathway, the problem is further magnified. (Ferrando AA, 2002)

- pathological changes in muscle occurring during excessive exercise while the muscle is weak.

Defining optimal nutrient requirements is a critical step to ensure good health for astronauts during long flights. Unfortunately, data on dietary recommendations are limited. But according to data collected on Skylab, the U.S. space shuttle, the Soviet and Russian flights, it appears that the protein needs are similar to those on earth.

The recommended protein intake is 12% to 15% of TEE and considering an animal protein / vegetable proteins ratio of 60/40. We must combine a variety of sources, or vary over time, or both with which frequency vary the protein sources to ensure an adequate intake of essential amino acids with a high PDCAAS (Protein digestibility corrected amino acid score) value.

A diet too rich in proteins should be avoided since it is associated with hypercalciuria and consumption too high in sodium; this would contribute to acid/base metabolism imbalance and the occurrence of kidney stones.

After the flight, the synthesis of proteins in tissues other than muscle is not optimal because there is competition for amino acids between the muscles and other tissues that also need protein. Protein synthesis is at a low level during the return to earth and amino acids are the limiting factors. (Stein TP, 2006) Only two weeks after landing, energy consumption and protein synthesis returned to normal or to levels comparable to the value recorded before the flight. (Stein TP, 1999)

The combination of measures including exercise, diet, and sometimes drugs has been necessary to maintain muscle health during long flights. (Lane HW, 1998) It has been shown that the practice of resistance exercises preserves protein synthesis in muscle. In addition, the supplementation of essential amino acids and carbohydrates could counteract the loss of weight and muscle strength. Indeed, supplementation of essential amino acids stimulates protein synthesis.

Ongoing research on the link between inactivity and the alteration of protein metabolism during space flight will also be useful on earth. Indeed, the decrease in activity occurring with aging poses problems for the society as a whole. (Paddon-Jones D.2006)

3.1.2 Moon and Mars requirements:

Usually the protein intake is well above the recommended requirements. Although to date it is not fully demonstrated that an excess may have deleterious effects, it seems that the increased risk of decalcification and kidney stone formation is higher. On the other hand, inadequate intakes may exacerbate malnutrition.

When the astronauts will arrive on Mars after a long trip in weightlessness, they will have significant muscle losses. It will be important in the early days of Mars landing to enrich the diet in protein and energy associated with physical activity training sufficient and appropriate to promote muscle anabolism and prevent a negative nitrogen balance.

It seems interesting to add protein with high biological value and carbohydrates with a high glycemic index just after the weight training sessions or EVA for long durations. Indeed, hyperinsulinemia produced by carbohydrates with a high glycemic index and an increase of glucose transporters (GLUT 4), means that more glucose can enter the muscle cells. Insulin is also an anabolic hormone, amino acids can also enter cells.

The principle of menus MELiSSA is to provide by 40% of DW per plant. But protein quality is not perfect. However, by mixing of sources, it is possible to obtain a better quality protein. Additional proteins will be achieved by providing ISS space food.

The dietary recommendation for a mission to the Moon or Mars is on the first 2 months after landing will be estimated at 1.5 to 1.7 $g.kg^{-1}.d^{-1}$ and provide enough energy 150-200 kcal/ g N. After 1.2 $g.kg^{-1}.d^{-1}$ may correspond to requirement. This will represent 10 to 15 % of TEI. With Needs for women are lower about 15 %. An intake of 2.4 $g.kg^{-1}.d^{-1}$ or 25% of TEI maximum is proposed.

3.2 Lipids

Fats are important components of the diet because they provide energy (9 kcal/g), essential fatty acids (omega-3, -6, -9) and fat-soluble vitamins (A,D,E). In Europe, lipids are consumed in abundance and composition of dietary fatty acids may play a role in both the pathophysiology of diseases (obesity, cardiovascular disease ...) and the prevention of certain diseases. According to the recommendation, fat intake is expected to reach no more than 30-35% of total energy intake.

In addition to the total intake of fat the ingestion of certain subgroups of the lipid family should also be considered since the human body cannot synthesize them.

Some saturated fatty acids increase serum total cholesterol and the proportion of LDL cholesterol (LDL: Low Density Lipoprotein). It is recommended to keep the consumption of saturated fatty acids as low as possible and in any case not to exceed 10% of TEI.

At the level of unsaturated fatty acids, there are three major chemical families. In the group of omega-3, synthesis startsfromthe precursor α-linolenic acid (C18:3) (LNA) leading to the long chain derivatives C20:5 acid eicosapentaenoic (EPA) and C22:6, docosahexaenoic acid (DHA). In the omega 6 group, the precursor is linoleic acid (C18:2) (LA) whose elongation leads to arachidonic acid C20:4 (AA). Finally, there is still omega-9 with oleic acid (C18:1) that can be converted into C20:3. Unsaturated fatty acids, and especially the monounsaturated and polyunsaturated lineage of omega-3 positively influence the overall risk of ischemic heart disease. In addition, linoleic acid and alpha-linolenic acid are essential nutrients as they play an essential role in the integrity of certain physiological functions. Their affinity for the competitive enzymes decreases in the sequence of omega-3 and omega-6 and finally omega-9. The rate of biotransformation and synthesis of these compounds depends on content and relative composition of fatty acids in the diet.

Among the polyunsaturated fatty acids and their derivatives containing many double bonds, peroxidation may occur. Therefore, the presence of antioxidants (e.g. vitamin E) is essential.

Trans fatty acids are produced as byproducts in some chemical processes in the food industry. These fatty acids have a deleterious effect comparable to that of saturated fatty acids and thus also increase the risk of cardiovascular disease. Given this property, it is best to seek an intake as low as possible.

However, trans fatty acids formed during biohydrogenation process may have different physiological effects in humans. The most representative in our diet is the CLA - conjugated linoleic acid. According to information available, some of these CLA isomers could have potentially favorable effects on health.

3.2.1 In microgravity or simulation:

In response to the decline in the use of skeletal muscle, there is an increased use of carbohydrates rather than fat as an energy source. Moreover, after the flight, muscles have a reduced capacity to oxidize palmitate. Studies have shown that the mRNA expression of enzymes involved in beta-oxidation is reduced in the muscles of rats, after exposure to microgravity. In contrast, the expression of the mRNA of enzymes involved in glycolysis is increased. (Stein TP, 2002)

Microgravity leads to changes in the body composition including a decrease in muscle mass and an increased fat mass. There is also a change in the oxidation (stress-related) of fats. These variations are related to a decrease in fat free mass, a positive lipid balance and an increase in fat mass. (Ritz P, 1998)

It seems that the damage due to oxidation and also including radiation damage would decrease during the flight, but would increase upon return to Earth. (Stein TP, 1999)

The recommended intake of fat during spaceflight is the same as on earth: 30% to 35% of total energy and is provided mainly in the form of triglycerides. We must also ensure a good relationship between omega 3 and omega 6 fatty acids. (Lane 1999)

3.2.2 Moon and Mars requirements:

A relatively high dietary fat input is needed to maintain certain acceptable meal palatability, and provide energy.

A diet rich in Omega 3 (e.g. EPA and DHA) could protect astronauts against cosmic radiation, because these fatty acids are prone to peroxidation. Too few data were collected to determine the optimum omega 3 level, which may reduce the risk of radiation exposure of astronauts, people living on earth or people undergoing treatment with radiation. Further research must be done to determine requirements. (Turner ND, 2002)

The dietary recommendation for a mission to the Moon or Mars is for total fat 30-35% of TEI, with up to 10% saturated fat, less than 1 g of Trans fatty acids. 10% TEI for mono-unsaturated fatty acids, 5-10% TEI for polyunsaturated fatty acids, omega-3 1.3 to 2.0% TEI, LNA> 1, EPA-DHA> 0.3, omega-6 4-8% TEI, LA> 2% TEI, cholesterol <300 mg per day

3.3 Carbohydrates

The carbohydrates found in foods are divided into:

Mono or disaccharides consisting of one or two sugars units. They usually have a sweet taste. These include glucose, fructose contained in fruit, sucrose, table sugar or lactose, milk sugar.

Complex carbohydrates consisting of chains (polymers) of simple sugars units; this group also contains starch. Digestion, if possible, leads to the formation of mono-saccharides, usable by the body to produce energy. Also found in this group is the dietary fiber. Generally of plant origin, such as cellulose or pectin, they are neither digested nor absorbed (see point Fibers).

The fact that carbohydrates are simple or complex does not reflect how they are digested and utilized by our body but only the way they are constructed. Thus, simple carbohydrates alike complex carbohydrates can be digested completely or, conversely, entirely escape any digestion.

The important contribution of fructose-induced hypertriglyceridemia due to increased hepatic production of VLDL, insulin resistance and increased body weight. The hyperglycaemic effect of different foods containing carbohydrates is quantified in terms of their glycemic index (GI). GI expresses the relationship between the elevation of blood glucose level as induced by ingestion of a particular food (representing 50g available carbohydrate), and the hyperglycaemic effect of the same amount of carbohydrate contained in 50 g of glucose (the reference food with GI=100; alternatively white bread is used as a reference food). The glycemic index of foods is influenced by their content of fiber (especially soluble), proteins and lipids, as well as the cooking method. Indeed, prolonged cooking of starch increases significantly its hyperglycaemic power.

Glycogen is stored in the carbohydrate reserves of the body. These reserves are distributed in the liver and mostly in skeletal muscles. The liver glycogen is used to keep glycemia stable, while the muscular stores are used in situ for muscle contraction.

According to the dietary recommendations of most European countries, the overall carbohydrate intake should cover at least 50-55% of TEI. These recommendations also indicate that carbohydrate intake should be made primarily in the form of complex carbohydrates, so mostly under the form of starch. There is not really a recommendation for simple carbohydrates. However, it seems reasonable not to exceed 10% of TEI in the form of added simple sugars.

3.3.1 In microgravity or simulation:

Different studies have shown that microgravity causes impaired insulin sensitivity, glucose tolerance and insulin secretion. Insulin has an essential role in preserving muscle mass. It allows the entry of glucose into cells, thus promoting the formation of glycogen (muscle, also liver), and thus build-up of an energy reserve to allow for proper muscle function. Microgravity is associated with events similar to those of diabetes. (Tobin BW, 2002) It seems that the pancreas is no longer able to overcome insulin resistance and poor regulation of amino acid uptake during spaceflight. There would be an increase in insulin secretion, indicating a decrease in sensitivity of tissues to the hormone, especially the muscles seem inactive. (H. Lane, 2002) To put in place effective measures against the loss of muscle mass, insulin secretion and action during spaceflight should be measured. Hence much research remains to be done. (Tobin BW, 2002) The recommended dietary intake of carbohydrates for astronauts does not differ from those on Earth. Half of their energy must be provided in the form of carbohydrate to obtain 50% to 55% of TEE. (Smith 2003) Carbohydrates should be provided preferably in complex and digestible form (>30% of TEE), such as starch from grain products. Simple sugars such as sucrose must represent not more than 10% of total energy. (Lane 1999)

3.3.2 Moon and Mars requirements:

Nutritional requirement for a Moon or Mars mission will be 50 to 55% TEI with at least 4 – 6 $g.kg^{-1}.d^{-1}$, mainly as starch products. A tolerable intake of added simple sugars can be granted on the order of 10% TEI.
Before an EVA, a carbohydrate intake of approximately 1-4 g.kg-1.d-1, 1-4 h before must be provided. And during EVA, at least 37g CHO/hour or 1 g CHO.kg-1.h-1 to avoid hypoglycemia.

3.4 Fibers

Dietary fiber is a class of nutrients including compounds that are chemically very different. However, they are resistant – at least partially- to digestive enzymes. Some fibers, such as soluble fiber (pectins, gums ...), oligosaccharides and resistant starch - can be fermented by bacteria of the intestinal flora, thereby generating effects that can participate in improving and / or maintaining intestinal function (decreased intestinal pH, the balance of intestinal flora, intestinal motility ...). Insoluble fibers such as cellulose and lignin, are not fermented, but their ability to hydrate is a phenomenon likely to contribute to the regulation of intestinal transit. The total dietary fiber for an adult should be equal to or greater than 30 g per day, to be associated with improved gut function and to reduce the risk of cardiovascular disease, obesity, certain cancers, as well as infections and inflammatory conditions.

3.4.1 In microgravity or simulation:

The recommended dietary fiber uptake is set at 10 to 25g per day of total dietary fiber, with an appropriate balance between soluble and insoluble fiber to help maintain gastrointestinal function and reduce the risk of constipation. (Lane 1999) Despite these recommendations space meals are often low in fiber and astronauts may suffer from constipation.

3.4.2 Moon and Mars requirements:

The major risk of inadequate consumption of dietary fiber, combined with inadequate fluid intake and insufficient physical activity is initially constipation. However, many studies also suggest beneficial effects of fiber and prebiotics and probiotics on human health. It is therefore essential to study the effects of pre-and probiotics on intestinal microbiota in astronauts.
Nutritional requirement for a Moon or Mars mission will be at least 30 g of total dietary fibers per day, with a balanced repartition between soluble and insoluble fibers.

3.5 Water

Water is crucial to enable the development of life. This is the most important element after oxygen, the third element is energy.

Water is the main component of the body (55 - 65% of body mass). The fluid intake must ensure the needs required by the BMR, the skin and respiratory losses, production of urine and sweat in case of physical activity.

To maintain fluid balance, adults need, under normal conditions, a water intake of 2.5 liters per day (including water from food). During physical activity losses may be around 600 to 1000 ml per hour.

The needs are covered by consumption of drinking water (1.5 l), water from food (800 ml) and metabolic water (300 ml).

3.5.1 In microgravity or simulation:

The study of the fluid needs was started after the return of astronauts subsequently diagnosed as suffering from orthostatic intolerance, and therefore would have difficulty maintaining upright position. This effect (causing temporary loss of consciousness and posture) is commonly found as a consequence of dehydration. Specific studies on fluids and electrolytes during space flight are difficult to achieve, because weight loss is due a well to low consumption of energy and liquid, as to the loss of muscle mass and bone due to lack of load level musculoskeletal conditions in microgravity. Weight as a monitoring parameter is hence not usable.

Simulations allow ground control to monitor food consumption and other health-determining parameters. Through the years, many models have been used to simulate changes in fluids and electrolytes that occur during spaceflight. The most used is the "head-down tilt bed-rest" in which the level of activity and consumption of energy, water, sodium and potassium can be rigorously controlled. Bed-rest studies have shown a negative water balance as observed in astronauts.

The consumption of liquid must be sufficient to prevent dehydration and reduce the risk of kidney stones. These appear due to a decrease in urine volume, itself due to a reduction of thirst among astronauts.

The fluid intake depends upon various factors including microgravity, stress, change in body composition, nutrition, physical activity, cycle of sleep, temperature and humidity. (Lane 1998)

During space flight there is a loss of total body water. This reduction could be attributed to the loss of body mass. There was a weight loss of 1 to 3kg during short time spaceflight and 8 to 10 kg during long flights. Astronauts usually recover the weight lost after return to earth. The decrease in body fluids may in part be caused by a slight reduction in physical exercise. Transpiration during the flight may be lower than normal because of the reduction in the intensity of physical activity. In addition there is a 11% reduction of evaporation losses in microgravity. However physical activity is used as a measure against the lower evaporation loss, to increase transpiration and water needs. (H. Lane, 2002)

The loss of fluid varies from one individual to another and can range from 1% to 10%, depending on the amount of energy ingested, the fluid balance and changes in body composition. The amount of liquid consumed varies from individual to individual; on average 1600ml per day and for most of the astronauts less than 2000ml/jour. (H. Lane, 2002) or 1 to 1.5ml/kcal. It is therefore better to promote a diet rich in water. (Lane HW, 2002)

Tab. 3 shows in parallel the fluid ingestion on earth and in microgravity. We can observe that indeed the astronauts drink less during spaceflight, it has an impact on (this is one of the causes of) their decreasing urinary excretion. One can also observe that fluid loss changes little in microgravity; astronauts should consume as much liquid as on earth.

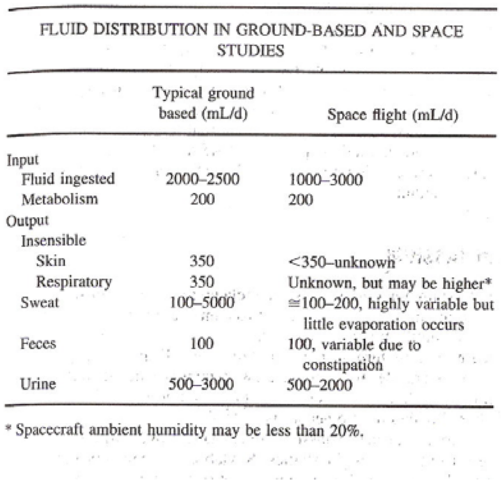
But there has been a report mentioning that space shuttle astronauts with adequate energy and fluid, and having a minimal weight loss still had a decrease in body water of up to 2%.

Thirst is an important signal because the body continually loses water through evaporation, transpiration and excretion of urine. However, in space, astronauts do not feel thirsty, as a consequence intake does not sufficiently compensate for the loss of fluid to maintain plasma volume.

In summary, the fluid changes are related to body mass loss caused by inadequate consumption of energy, reduced burden on the musculoskeletal system, lack of resistance exercise to maintain bone mass.

During ISS missions the recommendation of total water intake is 1.0 to 1.5 ml/kcal, with a minimum of 2 liters per day, provided by food and drinks.

Tab. 3 Fluid distribution in ground-based and space studies



FLUID DISTRIBUTION IN GROUND-BASED AND SPACE STUDIES

	Typical ground based (mL/d)	Space flight (mL/d)
Input		
Fluid ingested	2000–2500	1000–3000
Metabolism	200	200
Output		
Insensible		
Skin	350	<350–unknown
Respiratory	350	Unknown, but may be higher*
Sweat	100–5000	≅100–200, highly variable but little evaporation occurs
Feces	100	100, variable due to constipation
Urine	500–3000	500–2000

* Spacecraft ambient humidity may be less than 20%.

3.5.2 *Moon and Mars requirements:*

The importance of water is well demonstrated. During a mission, all must be implemented to promote an adequate supply of water to astronauts. The organoleptic quality of water must be perfect, as well as its microbiological quality. Water is also a vector of minerals, they are going to cover some of the recommended nutritional requirements. However, these elements can also have an impact on taste. It is necessary to define all the required qualities of a drinking water program for MELiSSA. Acute dehydration can be fatal. Chronic dehydration has implications for risk on the formation of kidney stones, orthostatic hypotension ... Inadequate intakes have a significant impact on physical and mental performance.

Conversely excessive consumption of water, even if rare, or of very low mineral content water, can lead to water intoxication which also is deadly.

In the Melissa program, the amount of consumer-grade water must be larger than required from a nutritional viewpoint, because it must also meet the requirements necessary for food preparation and processing.

Nutritional requirement for a Moon or Mars mission will be obtained with 1.0 to 1.5 ml per kcal intake. This represents 2.1 to 3.1 liters per day for women and 3.0 to 4.5 liters per day for men, with a minimum of 2/3 by drinks and the rest through food.

During a physical activity or EVA, an additional water intake of about 600 to 1000 ml per hour is necessary.

4 Micronutrient needs

4.1 Calcium

Calcium is essential for the formation of bone tissue, thus forming an essential component of the skeleton. Almost 99% of body calcium is deposited in the bone in the form of amorphous calcium phosphate and crystalline hydroxyapatite, which provide the strength and rigidity of the skeleton, and the hardness of teeth. Calcium is also involved in various metabolic functions: blood coagulation, neuromuscular excitability, nerve impulse conduction, muscle contraction, membrane permeability and release of hormones. Calcium needs are influenced by various factors. Phosphates decrease urinary calcium excretion (inhibit bone resorption), whereas urinary excretion of sodium and protein lead to calcium excretion. Vitamin D increases the intestinal absorption of calcium. Fiber, phytate and oxalate have an opposite effect.

4.1.1 In microgravity or simulation:

The length of stay in space is increasing steadily. The major problem of these long flights is bone demineralization. An adequate intake of calcium is required to minimize this loss. Microgravity causes a calcium deficiency, increased urinary excretion leading to negative calcium balance, a decrease of absorption at the intestinal level, an elevation of blood calcium, decreased parathyroid hormone secretion and calcitriol formation. In general, PTH (parathyroid hormone) acts on the kidneys, it stimulates the formation of a hormone, calcitriol, which is the active form of vitamin D. Parathyroid hormone (PTH) is secreted by the parathyroid glands. This is the main hormone involved in regulating the exchange of calcium between bone and blood. It increases osteoclast (cell involved in bone degradation) activity resulting in release of calcium from bones, raising the calcium level in blood. Skylab data on calcium balance showed a loss of calcium from 200 to 300mg/day. (S. Smith, 2002)

In microgravity, bone resorption is increased in contrast to the synthesis of bone. This phenomenon is accentuated by a low-calorie diet, low calcium consumption which is common among astronauts, a decrease in the plasma levels of vitamin D or calcitriol, and a diet rich in salt. These factors contribute to the development of osteoporosis in astronauts.

Calcium and vitamin D, magnesium and phosphorus are the micronutrients that are necessary to be provided in adequate quantity, in order to preserve bone quantity and quality. (Lane 1999)
Various studies have demonstrated that a high consumption of calcium during space flight does not affect bone metabolism, but helps prevent a rise in blood calcium. (Iwamoto J, 2005)

Calcium needs are difficult to determine especially for flights of long duration. It seems that the optimal intake is 900mg per day. (Heer, 2002) These are the same recommendations as for an adult on earth.
Beyond this level of intake, there is no improvement in mitigating the loss of calcium. Calcium overload however increases the risk of kidney stones. (Smith, 1997)
It was demonstrated that a human in microgravity had a high risk of developing kidney stones. The increase in bone resorption resulting in hypercalciuria contributes to the saturation of urine with calcium salts (calcium oxalate and calcium phosphate) but also in sodium urate and uric acid. Also other dietary factors affect the composition of urine, including reduced urinary volume, pH ... It is therefore important that astronauts follow dietary recommendations. (Zerwekh JE, 2002) This does not mean that calcium intake should be low. Adequate consumption is necessary to form calcium oxalate (in the digestive tract) in order to minimize the absorption of oxalate. If there is too little calcium in the digestive tract, the complex with oxalic acid is no longer formed, oxalic acid is then absorbed, which may form oxalic acid kidney stones.
It was reported that consumption of calcium was very low in astronauts. One solution is to enrich some foods with calcium lactate to provide a daily consumption of 900mg and have a Ca / P = 1 to 2. (Smith 2003)
Adjusted food intake alone cannot remedy bone demineralization, but the consumption of adequate amounts of calcium, vitamin D and other nutrients in combination with various countermeasures can largely preserve bone mass during space travel.
The recommended intake of potassium for astronauts is at least 1000 to 1200 mg per day. (Lane H., 1999)

4.1.2 Moon and Mars requirements:

After a long travel, the impact on bone densitometry is important. Even if the gravity on Moon or Mars is higher than in the ISS, it will not be sufficient to restore and to prevent risk fracture. Moreover the return trip to earth will aggravate the situation.
The impact of other nutrients like sodium, protein, phosphorus, potassium, omega-3 fatty acid, vitamin D and vitamin K are also important on bone health.

It will be very crucial to provide good sources of calcium. The amount proposed is 1200 mg without gender differences. With a Ca/P ratio of 1.5. More studies are needed to determine the impact of nutritional countermeasure on bone losses in space. In the same way the amount of calcium as supplement and type of calcium salt will be defined. But never be higher than 2 - 2.5 g per day.

4.2 Phosphorus

Phosphorus is involved in bone metabolism. Approximately 85% of body phosphorus is contained in the bones where it has a structural role. In an adult with healthy kidneys, there is a balance between the urinary excretion and absorption of phosphorus. When the plasma levels of phosphorus increases, the absorption of vitamin D is stimulated and decreases bone resorption. A lack of phosphorus is termed hypophosphatemia, which is manifested by anorexia, anemia, muscle weakness, bone pain and osteomalacia (softening of bones)

In general the recommendation is to have an intake of Ca/P >1, because an excess of phosphorus stimulates bone resorption, which may promote osteoporosis especially if calcium intake is insufficient. (Smith, 2003). In addition, an excessive intake of phosphorus relative to calcium can alter the absorption of the latter. Excess dietary phosphorus is frequent and requires mechanisms of renal elimination which represents an additional charge. The long-term health effects of excess P intake are however not yet known. (Lane 1999)

In microgravity or simulation:

According to data collected on Skylab and space shuttle and ISS missions, the consumption of phosphorus is high among astronauts, with a low Ca/P ratio.

Taking into account the recommendations of calcium during spaceflight, the recommended intake of phosphorus is a maximum of 1000-1200mg per day, which corresponds to the recommended dietary intakes on earth for older people. (Lane, 1999)

4.2.1 Moon and Mars requirements:

Proposition to limit phosphorus in the space food menu, with a high Calcium/Phosphorus ratio of 1.5.

As for calcium many studies are needed.

4.3 Sodium

Sodium, chlorine and potassium are essential to maintain homeostasis, i.e. the physiological balance of intra-and extracellular fluids to replace the obligatory losses (breathing, sweat, urine and fecal losses). Sodium is the main extracellular cation. The kidney is the major site to regulate the excretion of excess water and sodium.

4.3.1 In microgravity or simulation:

Microgravity affects the metabolism of sodium: excretion decreases resulting in a positive sodium balance. (Heer M, 2002) Endocrine systems retaining sodium such as the reninangiotensin-aldosterone and cathecholamines see their activity increased. Recall that aldosterone acts on the renal tubules to retain sodium and leads to increased urinary excretion of potassium. Microgravity rate remains normal aldosterone decreased. (Lane, 1999) The natriuretic peptide inhibits the reabsorption of sodium and water by the kidneys, increasing the excretion of water and sodium. (Drummer C, 2001)

A diet too rich in sodium during spaceflight is problematic because sodium increases bone loss, hence the loss of calcium and a more concentrated urine, increasing the formation of calcium oxalate and thus kidney stones. It is therefore recommended not to exceed consumption of 1500mg to 3500 mg of sodium per day, with a maximum of 9g NaCl (H. Lane, 2002). The ingestion of sodium by astronauts often exceeds this limit, the salt being used to increase the taste of the preparations. Apollo missions are the exception: the astronauts consumed less sodium than the RDA. It was noted that in the space shuttle missions, the consumption of sodium was very low during the first days of flight. One possible explanation is that the crew then consumes only 64% of their recommended energy intake. (Lane 1999). A low-sodium diet decreases urinary excretion but a high rate of sodium uptake is associated with an increased urine volume. NASA and the Russian Space Agency are trying to develop dishes with a pleasant taste but with low sodium content.

The potassium requirement for ISS mission up to 360 days is at maximum 3500 mg (≈9g NaCl) per day (Lane 1999)

4.3.2 Moon and Mars requirements:

Because of the risk of increased bone loss, renal stones formation and cardiovascular failure, sodium use must be limited. But on the other hand, too little sodium intake has an impact on taste perception and will induce anorexia, aggravate denutrition, orthostatic hypotension and other cardiovascular problems.

Nutritional requirement for a Moon or Mars mission will be obtained with 2000 to 2500 mg per day. This represents 4.5 to 6 g of NaCl per day. The upper limit intake for sodium is difficult to determine for an astronaut. The relation between sodium intake and bone loss has to be more studied. Maybe a maximum of 6 g NaCl per day will be the upper limit intake.

4.4 Chloride

Chloride is provided in our diet, mainly in the form of NaCl. It is an anion localized mainly in the extracellular space, and is involved in maintaining sodium, osmolality and blood volume. In addition, chloride is involved in regulating the acid-base balance and production of gastric hydrochloric acid. Its urinary excretion is similar as dietary intakes. Sweat losses are slightly higher than the sweat sodium loss. The recommended dietary intake of chlorine is the recommended salt intake, which limited to 6 g per day, providing around 3.6 g of chlorine.

4.4.1 Moon and Mars requirements:

Since chlorine is associated with sodium, there is really no specific recommendation for chlorine.

4.5 Potassium

Potassium is the main intracellular cation. Potassium is an essential micronutrient for many biochemical functions, hence the rate of body potassium is closely monitored. Potassium is reabsorbed by the kidneys. An increase in aldosterone secretion is linked to an increase in potassium excretion. The rate of urinary potassium secretion reflects the concentration of potassium in the body, which depends on food consumption and metabolic activity such as muscle catabolism.

4.5.1 In microgravity or simulation:

In microgravity, the metabolism of potassium is related to muscle loss. Indeed, the decrease in muscle mass leads to increased urinary excretion of potassium. According to comments made on the space shuttle missions, stress causes a release of cortisol enhancing protein catabolism. The secretion rate of cortisol is high among all the astronauts involved in the studies. This indicates that there may be a link between stress, increased catabolism of proteins and alteration of potassium homeostasis. (H. Lane, 2002)

An increase in blood potassium level has been observed in astronauts, this would likely be caused by the hemolysis of red blood cells.

During the Skylab missions, the consumption of potassium was higher than the dietary recommendations. However the potassium balance became gradually less positive, which suggests a loss of potassium from the body. But in general, consumption of potassium is lower than the recommendations. (Lane, 1999)

It is not yet known whether countermeasures to reduce the loss of muscle mass are effective in maintaining the recommended level of potassium. A menu for ISS provided about 4000 mg per day but their actual consumption was lower (3200 mg) because of poor appetite.

The potassium requirement for ISS mission up to 360 days is at least 3500 mg per day (Lane, 2000)

4.5.2 Moon and Mars requirements:

Due to muscle loss, risk of depletion of potassium and cardiac alteration is high.

MELiSSA menus will be rich in potassium thanks to ubiquity of this element.

Nutritional requirement for a Moon or Mars mission will be obtained with 3000 to 4000 mg per day. There is no really an upper limit intake for potassium.

4.6 Manganese

Manganese enters in the constitution of several enzymes such as manganese superoxide dismutase (MnSOD), arginase, glutamine synthetase or pyruvate carboxylase. Besides this constitutive role, manganese is also a non-specific activator of various other enzymes such as adenylyl cyclase, phosphoenolpyruvate kinase, prolidase, the galactosyl transferase, fructose 1,6-bisphosphatase or glucosyltransferase. It is often in competition with calcium, magnesium, iron or cobalt and one even considers that part of its biological properties could be related to its antagonism with these minerals. Manganese is involved more or less specifically in certain metabolic pathways and participates in several biological functions related to the formation of bone and cartilage, fat metabolism, regulation of blood glucose or in brain and nerve activity . Its antioxidant role (MnSOD) seems particularly important in the mitochondria, highly exposed to oxidative metabolism. Manganese deficiency was mainly observed in animals and results in growth defects, impaired reproductive function, skeletal abnormalities, glucose intolerance and other aberrations in carbohydrate and lipid metabolism. The different effects are sometimes contradictory. However, its essential character for humans was demonstrated when pronounced deficiencies in children or subjects in total parenteral nutrition, which are accompanied by events such as bone demineralization, growth retardation and various carbohydrate and lipid disorders, were reversed by adequate supplementation. The need for manganese and its metabolism are imperfectly known. Intestinal absorption is low (3-8%). It is influenced by many factors such as iron, calcium, phosphorus and phytate which inhibit its bioavailability. The antagonism with iron seems especially significant to the point that an excess in one or another element may induce a deficiency in the antagonist element. As reported by the experts, the exact figures are still unreliable. They are derived from extrapolations from the values recommended for adults who, themselves, are nothing but a reflection of the usual food intake through healthy subjects. Contributions are highest (up to 10 mg / day) in high consumers of products of plant origin (including tea) and lowest among those consuming food of animal origin. The risks associated with a high intake of manganese has been recently reviewed by the EFSA (European Food Safety Authority, 2006), who has finally decided to take no position and set no maximum intake recommended that it is expressed as No Observed Adverse Effect Level (NOAEL:) or Tolerable Upper intake level (UL). Excess manganese may be neurotoxic food. (Conseil supérieur de la santé, 2009)

4.6.1 In microgravity or simulation:

There is only sparse information on manganese status during and after space flight.
An intake of 2-5 mg of manganese per day seems to be sufficient for the astronauts. (Lane 1999)

4.6.2 Moon and Mars requirements:

As anti-oxidant, manganese is crucial to reduce oxidative stress.
Contributions are highest (up to 10 mg/day) in high consumers of products of plant origin (including tea) as MELiSSA food menu and lowest among those consuming food of animal origin.
Nutritional requirement for a Moon or Mars mission will be obtained with 2.0 mg per day. There is no upper limit intake of manganese, but due to the interaction with other minerals, it seems that a maximum of 10 mg is permitted.

4.7 Magnesium

Magnesium is found in the human body in the form of magnesium salt. Approximately 60% is in bone, ¼ in skeletal muscle, the rest is mostly distributed in the nervous system. Magnesium helps maintain strong bones by destabilizing hydroxyapatite crystals. Without such intervention these crystals grow too large and become fragile. Mg interacts with ATP to stabilize the complex amorphous calcium phosphates. An appropriate rate of plasma magnesium is necessary to prevent hypocalcemia, resistance to vitamin D and PTH (para-thyroid hormone) resistance. Magnesium is also used as a cofactor by many enzymes which are involved in energy production and transfer of phosphate in all cells, including bone cells. Phosphorus deficiency leads to arrest of bone growth, reduced the activity of osteoclasts and osteoblasts. Create an osteopenia, and increases bone fragility. It should be noted that magnesium is essential for muscle contraction.

4.7.1 In microgravity or simulation:

In microgravity there is a decrease in urinary excretion of magnesium, it is probably due to low dietary intake of this micronutrient. According to data from the crews of Skylab and space shuttles, food consumption of magnesium is lower than the dietary recommendations. (Lane, 2000)

Various studies have shown a deficiency in magnesium and an elevation of cytokines (interleukin-6), mechanisms promoting vascular inflammation. (Rowe WJ.2004)

An intake of 350mg of magnesium per day seems to be sufficient for the astronauts. (Lane 1999)

4.7.2 Moon and Mars requirements:

This decrease in the levels of magnesium could be a problem during long flights because it regulates the formation of calcium oxalate, thus preventing the formation of kidney stones. (Smith SM., 2005).

High intake of food and water magnesium will be interesting to preserve bone health and muscles performances.

Nutritional requirement for a Moon or Mars mission will be 320 mg per day for women and 420 mg per day for men. A tolerable upper limit intake of 350 mg per day is proposed.

The upper limit for magnesium represents intake from a pharmacological agent only and does not include intake from food and water.

4.8 Iron

Iron is a constituent of hemoglobin and myoglobin involved in the transport of oxygen. Iron is also present in the cytochromes that are essential in cellular respiration. It plays an important role in many enzymes of oxidation. The reserves of iron in the body in the form of ferritin occur in the liver, spleen, bone marrow, and in skeletal muscle. Iron deficiency leads to anemia which can reduce the level of attainable physical effort, and impacts on the ability of resistance to infection.

4.8.1 In microgravity or simulation:

The anemia that occurs in astronauts during spaceflight is a known phenomenon. This effect appears to be a normal physiological adaptation to microgravity.

The theory of neocytolysis formulates that the body adapts to microgravity by a selective destruction of new red blood cells produced. Two-thirds of iron in the body is contained in the circulating red blood cells. Neocytolysis therefore impacts on iron metabolism. Indeed, there was an increase of ferritin, a reduction in hemoglobin concentration, decreased transferrin concentration (and hence) a decrease in plasma iron concentration. (Smith SM., 2005)

Recall that transferrin is a plasma protein, transporting iron in the bloodstream. The decrease in hemoglobin suggests that the mass of red blood cells decreased. There is also evidence that the rate of iron is high. Increasing the availability of oxygen, from the increase in air pressure (cabin air 1 atmosphere, but higher O2 content /partial air pressure of O2), helps reduce the need for red blood cells. The iron is no longer available for hemoglobin is stored as ferritin. This process is induced by neocytolyse. (Smith SM., 2005) Iron and available reserves are thus increasing during long flights. The consequences of these changes are not yet well understood. (Smith SM, 2002) This increase in content of ferritin and other iron compounds in the body increase the risk of oxidation of the tissues. The oxidation is linked to exposure to cosmic radiation. (Lane, 2000) It appears that microgravity causes a decrease in iron absorption. During long flights iron deficiency would be due to the increase in ferritin. However, this is only a hypothesis at present. (Lane, 2000)

It was observed that the astronauts ate larger quantities of iron that was recommended (about 20 to 22mg/jour). Moreover, when consumption is low in fiber, iron absorption is slowed down.

According to data collected on board the ISS, an RDA 10mg of iron per day was determined. This contribution is the same as for an adult male on earth. (Lane, 2000)

It is now established that malnutrition (low-calorie diet, hypoprotein, ...) or an excess of certain nutrients including iron, vitamin C, ... increases the oxidation of biomolecules and subsequent cellular damage. (Fang YZ, 2002)

Dietary iron excess may lead to overload, thus causing oxidation and hence tissue damage. Therefore, the needed dietary amount of iron for women is set to the same value as for men. (Lane, 2000)

4.8.2 Moon and Mars requirements:

A typical rich diet could cause an iron overload leading to oxidative damage in body tissues. Determining the iron requirements during spaceflight is important for the development of food strategies in the future exploration of planets and to ensure good health for the crew throughout the mission.

The consequences of excess iron during long flights are not yet known, and until now little research has been done on iron metabolism and pro-oxidative effects, cancer promotion, cardiovascular diseases, etc.
Nutritional requirement for a Moon or Mars mission will be 10 mg per day, without gender differences.
In terms of absorption, two types of dietary iron are considered: the heme iron and non-heme iron. The first is of animal origin (meat, poultry, fish) and second of plant origin (vegetables, legumes, cereals, fruits). The absorption of heme iron varies from 10 to 40% depending on the status of reservations, saturated or depleted, respectively. We consider that with a normal diet bioavailability of iron is 15%.
A tolerable upper limit intake of 45 mg per day is proposed.

4.9 Zinc

Zinc is a cofactor of many enzymes and is involved in various metabolic processes: the synthesis of proteins and nucleic acids, the synthesis of hormones and the control of gene expression. The bioavailability of zinc in food depends on the nature and composition of foods, because of interactions with protein, fiber, phytates and other minerals. 60% of zinc is found in muscle and 30% in the bones. The negative balance of zinc observed in bed rest studies is probably due to the loss of muscle mass and bone. A zinc deficiency can cause skin damage, immunological abnormalities, anorexia, dysgeusia, and diarrhea.
An excessive intake is toxic to various immune functions and is accompanied by a decline in copper and serum HDL (high density lipoprotein)-cholesterol.

4.9.1 In microgravity or simulation:

Microgravity affects the immune system and causes a decrease in the number of T-lymphocytes and a drop of their duties. A zinc deficiency is associated with similar changes related to the T-lymphocytes. The loss of zinc is associated with decreased muscle and bone mass in microgravity, but supplementation is not effective in preventing this loss. Physical activity and other measures against weight and bone loss are necessary. (Lane, 2000)
The zinc consumption by astronauts in flight is less than the recommendations, this may be associated with dysfunction of smell and taste (less contact between food and taste-sensors) during spaceflight and thus affect food intake. RDA for zinc for astronauts is 15 mg per day.

4.9.2 Moon and Mars requirements:

The major risk of space flight is, at present, exposure to cosmic radiation. This radiation produces reactive oxygen molecules that attack biomolecules (lipids, proteins, amino acid, DNA). Zinc is an antioxidant, it works in concert with other compounds to eliminate free radicals: it is a "radioprotector”. (Fang YZ, 2002).
Many nutrients (fibers, phytates, oxalates, polyphenols, …) can affect zinc absorption.

Upon return to earth, having a balanced diet provided to the astronauts with the recommended intakes of zinc and other nutrients, is important to ensure the restoration of bone and muscle. Nutritional requirement for a Moon or Mars mission will be 8 mg per day for women and 11 for men. A tolerable upper limit intake of 100 mg per day is proposed.

4.10 Copper

Copper is also an antioxidant. Copper is a cofactor in many enzymes of oxidation, including erythrocyte superoxide dismutase that protects cell membranes against free radicals and ceruloplasmin which is essential for the use of iron in hematopoiesis. The copper deficiency causes anemia due to lack of mobilization of endogenous iron. Excess copper is toxic and can cause acute hemolytic anemia.

4.10.1 In microgravity or simulation:

There is little data on the optimum to provide the astronauts. Microgravity probably leads to changes in the metabolism of the "trace elements" but scientists have not found any evidence showing nutritional intake to be different from that on Earth. The recommended intake for copper is 1.5 to 3mg per day. (Lane, 2000)

4.10.2 Moon and Mars requirements:

As anti-oxidant, as immune system co-factor and as co-factor of red blood cells metabolism, copper is important.
Nutritional requirement for a Moon or Mars mission will be comprised between 1.5 and 3.0 mg. A tolerable upper limit intake of 5.0 mg per day is proposed.

4.11 Selenium

Selenium is a cofactor of the enzyme glutathione peroxidase, active in the supply chain to reduce peroxides. It is part of systems for protecting cell membranes against oxidative degradation. Selenium is an antioxidant.
Some studies have shown that radiation damage to many cells can finally lead to the appearance of tumour cells (statistically – in some cells repair mechanisms do not succeed in overcoming damage or destroying the cell when damage is beyond repair). Selenium protects cells against peroxides and is a preventive agent against tumours, especially skin cancer.

4.11.1 In microgravity or simulation:

A decrease of 10% of serum selenium concentration was demonstrated in astronauts. Reasons are unknown.
The recommended nutrient intake of selenium is 70µg per day. (Lane, 2000)

4.11.2 Moon and Mars requirements:

Selenium as anti-oxidant is crucial to counter the effects of radiation. Risk of deficiency is common due to the typically low Se concentrations in food. On the other hand the toxicity (potential cancerogenicity) of selenium as supplement has been identified as a real problem.
Nutritional requirement for a Moon or Mars mission will be 60 µg per day for women and 70 µg per day for men. A tolerable upper limit intake of 400 µg per day is proposed.

4.12 Iodine

The only known role of iodine in the body is as an essential element in the structure of thyroid hormones: T4 (tetraiodothyronine) and T3 (triiodothyronine). These hormones exert a regulatory action on metabolism. Iodine deficiency induces a thyroid hormone deficiency which will result in a slowing of all metabolic activities in tissues. A profound deficiency of iodine is responsible for the formation of goiter swelling of the thyroid gland but also mental retardation and reduced fertility.

4.12.1 In microgravity or simulation:

During space flights, NASA adds iodine to drinking water (1-4mg/l) to prevent bacterial growth. It was suggested that this dose of iodine consumed by astronauts decreased the activity of the thyroid gland, it is seen by a high TSH level but these data have not been statistically proven. (McMonigal KA, 2000)
In microgravity, according to research done on Skylab, the plasma T3 concentration decreases while the T4 and TSH increased. The consequences of these changes are not yet known. Now during ISS mission iodine (the excess used for disinfecting) is removed from drinking water.
The recommended intake of iodine for astronauts is up to 150µg per day. (Lane, 2000)

4.12.2 Moon and Mars requirements:

The problem of contamination of water by micro-organisms during space missions has to be resolved.
Due to this unknown aspect of contamination of iodine in water, recommendation for food concentration will be adapted. There are some risks of Iodine deficiency if astronauts don't consume fish and seafood products. The possibility exists to use iodized salt. However during missions, the usual problem is the need to reduce salt consumption; in addition also the stability of iodine during the travel is to be taken into account (conversion to iodine gas).
Nutritional requirement for a Moon or Mars mission will be 150 µg per day, without gender differences. A tolerable upper limit intake of 1100 µg per day is proposed.

4.13 Fluoride

Fluorine is found mainly in teeth and bones. Could the loss of bone mass that occurs in microgravity be linked to a fluoride deficiency?

4.13.1 In microgravity or simulation:

According to bed-rest studies, fluoride supplements do not prevent the loss of calcium. Indeed, the loss of bone mass is caused by an increase in resorption compared to the synthesis of bone. Fluorine may act on osteoblasts, but it does not prevent bone loss. An intake of 4mg per day of fluoride is recommended. (Lane, 2000)

4.13.2 Moon and Mars requirements:

Nutritional requirement for a Moon or Mars mission will be comprised between 31.7 and 2.0. A tolerable upper limit intake of 100 mg per day is proposed. The possible contribution of fluoride supplement should reflect the concentration of fluoride in the water and food consumed as well as hygiene products (toothpaste in particular) used. (Conseil supérieur de la santé, 2009)

When diet is varied and balanced, there are few risks of fluorine deficiency. On the other hand, any excess, even moderate, is harmful and leads to potential toxic effects (fluorosis).

4.14 Chromium

Trivalent chromium is an essential trace element. It plays a role in glucose metabolism, potentiates insulin: it would increase the number of insulin receptors, modulate the biological response to insulin and increase the internalization of insulin, would decrease HDL-cholesterol and hypertriglyceridemia. However, chromium supplementation does not lead to significant effects on lipid metabolism. Chromium deficiency is characterized by decreased glucose tolerance, which translates to: hyperinsulinemia, fasting hyperglycemia and increased triglyceride and cholesterol plasma. Neurological signs are observed in cases of severe deficiency (which remains anecdotal) such as peripheral neuropathy and metabolic encephalopathy. Disorders related to a less pronounced deficiency were observed in diabetics, the elderly or the malnourished child while severe impairments have been reported in patients with prolonged total parenteral nutrition.

The chrome needs are imperfectly known. Chromium in various inorganic and organic forms has a very low efficiency of absorption (less than 3%) which is modulated according to the usual intake. The elimination of chromium is mainly urinary.

4.14.1 In microgravity or simulation:

There is no information about impact of chromium on the insulin resistance observed during space flight.

An intake of 100 to 200 µg per day was recommended. (Lane, 2000), but values have been lowered (see below)

4.14.2 *Moon and Mars requirements:*

Recent studies suggest that chromium exerts many pharmacological activities in subjects with diabetes type 2, but at doses of very high intake of about 1000 mg / day. But this is of clinical applications that do not fall within the field of nutrition and dietary recommendations. (Conseil supérieur de la santé, 2009)

Nutritional requirement for a Moon or Mars mission will be 25µg for women and 35 µg for men. A tolerable upper limit intake of 100 mg per day is proposed.

WHO estimates that chromium supplementation should not exceed 250 µg / day (trivalent chromium).

5 Vitamins

5.1 Vitamin A

Humans can get vitamin A or its equivalent only in two ways: by consuming provitamin A carotenoids of plant origin or by using preformed vitamin A (retinol) from animal food sources. The main provitamin A carotenoid is beta-carotene, it also has antioxidant activity involved in protecting tissues against free radicals. Vitamin A has different functions in the body: it intervenes in the synthesis of visual pigments (rhodopsine), in the regulation and differentiation of epithelial tissues including the cornea, and it has anti-infectious properties. The absorption and utilization of vitamin A is favoured by the presence of lipids, proteins and vitamin E in food. It is hampered by fat peroxydation and by the presence of other oxidizing agents. A lack of iron, zinc, vitamin E or protein counteracts the transport, storage and use of vitamin A. Vitamin A deficiency results in loss of twilight vision. Severe deficiency is reflected by the appearance of dry mucous membranes and conjunctiva with corneal lesions possibly leading to blindness. Excess vitamin A is toxic.

5.1.1 In microgravity or simulation:

Vitamin A is necessary in microgravity. Its antioxidant properties help defend the body against free radicals. (Fang YZ, 2002) Several studies have demonstrated that pretreatment with antioxidants such as vitamin A, but also vitamin C and E and beta-carotene could prevent to a certain extent damage caused by radiation.

The recommended intake for vitamin A for astronauts is up to 1000µg retinol equivalent (RE).

Remember that:

- 1 RE = 1µg retinol
- 1 RE = 6µg beta-carotene
- 1 RE = 12µg of activity to other dietary provitamin A carotenoids

RAE is equivalent for retinol, but specifies a double amount for the 2 other classes.

- 1 RE = 3.3 IU (International Unit).

The RDA is higher for astronaut than the RDA on earth which is 700µg. (Lane, 2000)

5.1.2 Moon and Mars requirements:

Due to an increase of oxidative stress for a mission to the Moon or Mars, vitamin A has a crucial role with other antioxidant to protect body against radiation. On the other side, the excess of vitamin A can be dangerous with teratogenesis properties or effects on bone resorption and risk of bone fracture.

Nutritional requirement for a Moon or Mars mission will be under 1000 µg as retinol equivalent per day. A tolerable upper limit intake of 3000 µg per day is proposed.

5.2 Vitamin D

Vitamin D exists in two chemical forms: vitamin D3 or cholecalciferol present exclusively in animals and vitamin D2 or ergocalciferol, the vegetable or microbial form. Vitamin D3 provided to the human body can come from two sources: also a share can be obtained through endogenous synthesis in the skin, through the action of ultraviolet rays on cholesterol. This source represents the endogenous key inputs on earth. Vitamin D3 is also taken up from food (the abovementioned animal source). This vitamin has yet to undergo two successive hydroxylations: in the liver to 25-hydroxy-vitamin D and in the kidney to 1,25-dihydroxy vitamin D, in order to get active. Vitamin D has a role in bone formation through its action on the metabolism of calcium and phosphorus. A deficiency in vitamin D causes demineralization of the skeleton or osteomalacia in adults. The secondary hyperparathyroidism (see 9. calcium) also increases bone resorption. On the other hand, an excess of vitamin D is toxic associated with polyuria, polydipsia, calcification of other tissues and depression. This can cause problems in microgravity where bone resorption and hypercalcemia are major problems.

5.2.1 In microgravity or simulation:

In microgravity, the concentration of parathyroid hormone (PTH) and 25 (OH) D3 tend to decrease. This is important to consider, especially during long flights where there is no exposure to UV rays. (Smith, 2004)

It was found that astronauts during long stays in space had a lower rate of 25 (OH) D3 production in spite of daily supplements of vitamin D. This decrease does not appear during the flights of short duration. (Smith SM., 2005) It was concluded that the reduction in the synthesis of 25 (OH) cholecalciferol was due to the lack of ultraviolet radiation. (Heer M, 2002)

During space flights, where exposure to UV radiation is absent and therefore also the endogenous synthesis of vitamin D is reduced, the recommended nutrient intake is up to 10µg per day. A supplement of vitamin D, which has anabolic and anti-resorptive capacities, is used to stabilize the balance of calcium, bone metabolism and prevent loss of bone mass in astronauts during spaceflight. (Iwamoto J, 2005) This supplement provides 650 IU (16.2µg) of vitamin D per day, but taking this supplement is not enough to counter osteoporosis. The consumption of vitamin D by the astronauts has not been studied extensively, because of the lack of UV exposure but we know that the menus include only few foods containing vitamin D (fish, butter, egg yolk, ...). The problem in assessment is linked to the fact that the supplement is not always taken by the astronauts because of the difficulties in management of pills in microgravity. (Lane, 2000)

5.2.2 Moon and Mars requirements:

Vitamin D has a crucial role in bone and calcium metabolism. Even on other planet, the exposition to UV will be strictly limited due to radiation. The poor amount of vitamin D in space food and the stability of it will be another problem. The amount with the MELiSSA

products will be also low. The major risk of vitamin D deficiency is osteomalacia, osteoporosis. Moreover new researches tend to demonstrate interest of vitamin D in prevention of cancer, cardiovascular diseases and infections.
The toxicity of vitamin D supplementation can lead to hypercalcemia with nephrocalcinosis, arteriosclerosis, renal stones, calcification of soft tissues and death.
Nutritional requirement for a Moon or Mars mission will be 10 µg as Vitamin D per day. A tolerable upper limit intake of 50µg per day is proposed.

5.3 Vitamin E

Vitamin E consists of two categories of compounds. The most important are the tocopherols. The second group consists of tocotrienols which have an accessory role. In each series there are 4 compounds: alpha, beta, gamma and delta which differ by the position and number of methyl group on the chromanol cycle. The most active form of vitamin E is alpha-tocopherol. Tocopherols are physiologically proven natural antioxidants. Vitamin E is involved in stabilizing cell membranes and platelet aggregation (involved in blood clotting), it also acts as an enzymatic cofactor. A vitamin E deficiency causes hemolytic anemia and neurological disorders with ocular motor and cerebellar ataxia.

Vitamin E is important in microgravity because of its antioxidant effects. (Fang YZ, 2002) Indeed, alpha-tocopherol protects the body against (re)active oxygen species (ROS). One molecule of alpha-tocopherol can disable 120 molecules of O_2. Alpha-tocopherol is especially effective against oxidation of lipids, because it is lipophilic and consequently found mostly in lipid environments. A molecule of vitamin E may protect 220 molecules of polyunsaturated fatty acids from oxidation. It was shown that a diet rich in vitamin E reduces genotoxic alterations induced by radiation on cells of the skin by restoring the incorporation of thymidine into DNA. The recommended intake of vitamin E is 20mg of tocopherol equivalent. (Lane, 2000) remember that:
- 1 IU (International Unit) = 1 mg alpha tocopherol
- 1 equivalent of alpha-tocopherol = 1 mg alpha-tocopherol = 1.49 IU.

5.3.1 Moon and Mars requirements:

As major antioxidant, it is essential to find enough of this vitamin in space food. But the stability is to be determined during long travel is space.
There are no specific toxic effects of vitamin E even with high doses. But the impact of an excess of anti-oxidant can be deleterious.
Nutritional requirement for a Moon or Mars mission will be 10 to 20 mg α-tocopherol per day. A tolerable upper limit intake of 300 mg per day is proposed.

5.4 Vitamin K

Vitamin K exists in three forms: vitamin K1 or phylloquinone with a vegetable origin, vitamin K2 or menaquinone produced by bacteria, and the water soluble vitamin K3 menadione as obtained by synthesis. K1 is the most important food source. Vitamin K is essential for blood clotting. Indeed, it functions as a cofactor of gamma-carboxylase, which acts on the glutamic residue of certain proteins, such as prothrombin and others involved in hemostasis. Vitamin K is also involved in the synthesis and carboxylation of osteocalcin involved in the metabolism of bone. The different forms of vitamin K have a similar biological activity. Deficiencies are rare since this vitamin has a high bioavailability.

A vitamin K deficiency increases the rate of circulating osteocalcin, thus contributing to the development of osteoporosis and the risk of fractures.

The role of osteocalcin in bone mineralization is not yet fully understood, it probably regulates the growth of hydroxyapatite crystals. Vitamin K2 inhibits the factors responsible for the differentiation of osteoclasts.

Various studies suggest that vitamin K2 stimulates the formation and decreases bone resorption. It would therefore be effective in the fight against osteoporosis. (Iwamoto J, 2004) In studies with rats it was observed that there was a preventive effect on bone loss by biophosphonates, testosterone and vitamin K2. Research remains to be done on this topic. (Iwamoto J, 2005)

5.4.1 In microgravity or simulation:

The dietary recommendations of vitamin K are 80µg per day. (Lane, 2000).

5.4.2 Moon and Mars requirements:

A deficiency of this vitamin is rare. But the impact of space flight on microbiota has to be studied, and the production of vitamin K.

Nutritional requirement for a Moon or Mars mission will be 10 to 20 mg α-tocopherol per day. There is no tolerable upper limit intake for vitamin K.

5.5 Vitamin C

Vitamin C exists in two chemical forms: the L-ascorbic acid and dehydro-L-ascorbic. Humans are unable to synthesize vitamin C, the only source is food. Vitamin C is involved in collagen synthesis (hydroxylation of proline), in iron metabolism; in carbohydrates, lipids and protein metabolism in muscle and brain, and in the control of osteogenesis and hormonogenesis. It is also involved in defense mechanisms humoral immune type. Most of its roles result from its antioxidant properties. It also protects other vitamins from oxidation, and tissues against the harmful effects of free radicals. A deficiency of vitamin C causes scurvy. Excess vitamin C is rapidly excreted in the urine, this vitamin seems to have no toxic effects, but at very high doses there seems to be a risk of kidney stone formation or hypertension.

5.5.1 In microgravity or simulation:

Vitamin C is effective in protecting the nucleated cells of bone marrow against low doses of radiation but not against lethal doses. This vitamin can act as an antioxidant but can also become a pro-oxidative compound, when consumed in excess. Indeed, vitamin C increases the bioavailability of iron. Vitamin C is also involved in the regeneration of alpha-tocopherol during lipid oxidation.

The recommended intake of vitamin C for astronauts is higher than on earth, in order to take maximum advantage of its antioxidant properties. But we should not exaggerate in increasing doses to prevent it acting as a pro-oxidative agent. That is why the NRA has been fixed 100mg per day. (RDA land = 60mg). (Lane 1999)

5.5.2 Moon and Mars requirements:

Due to higher free radical formation in radiation environment, vitamin C as anti-oxidant will act as buffer and will minimize oxidative and DNA damages.

Ascorbic acid can act as anti-oxidant, but in some case, high dose and presence of high amount of iron or copper, vitamin C can act as pro-oxidant.

Stability of vitamin C in MELiSSA space food has to be determined.

A nutritional requirement of 75 –to 100 mg per day of vitamin C is proposed. More research are needed to determine the real impact on space radiation on the anti-oxidant status. Due to the possibility of pro-oxidant capacity of vitamin C, it is not indicate to give supplement.

5.6 The B group vitamins

Microgravity generally causes changes in metabolism. However, there is no evidence that the status of vitamins of group B is altered in microgravity. Nevertheless, it is better to assess vitamin B carefully, since it has some influence on physical performance, on mood and on cognitive functions. It is important to consider this aspect especially for people in a confined space, like shuttles or other spacecraft.

5.6.1 Thiamine or Vitamin B1

Thiamine is a coenzyme of several enzymes. It plays a key role in energy metabolism, especially carbohydrate metabolism: it participates in the oxidative decarboxylation of pyruvate and alpha-ketoglutarate in the Krebs cycle. Vitamin B1 also plays a role in the transfer of nerve impulses. Thiamine is highly bioavailable, except in elderly people, whose capacity for utilization decreases. Some factors such as alcohol consumption or certain medications may reduce its absorption. A thiamine deficiency causes beriberi, characterized by anorexia, digestive and neurological abnormalities. A deficit is responsible for malaise, irritability, confusion and lack of sleep. Excess Vitamin B1 is excreted in the urine. There are no known toxic effects for this vitamin.

5.6.1.1 In microgravity or simulation:

There are no demonstrating abnormalities during spaceflights.
It was demonstrated that thiamine is the B vitamin group most likely to be destroyed by radiation. The contribution during long flights should be higher than the NRA. The recommended intake is 1.5mg per day for the astronauts without gender differences. (Lane, 2000) (RDA = 1.1mg/day on earth).

5.6.1.2 Moon and Mars requirements:

A minimum of 1.1 to 1.5 mg per day is proposed. Stability of thiamine in MELiSSA space food has to be determined. There is no documented risk of excess.

5.6.2 Riboflavin or vitamin B2

Riboflavin is the precursor of coenzymes with FAD (flavin adenine dinucleotide) which is involved in enzyme systems playing a key role in metabolic processing of various food substrates. Vitamin B2 is involved in metabolism of proteins, amino acids, fatty acids and carbohydrates. A deficiency in vitamin B2 deficiency can induce a secondary defect in iron intestinal absorption and mobilization of endogenous reserves. Moreover, the transformation of vitamin B6 in its active ingredient is delayed by riboflavin deficiency.

5.6.2.1 In microgravity or simulation:

The recommended intake is 2mg per day. (Lane, 2000) (RDA = 1.6 on Earth).

5.6.2.2 Moon and Mars requirements:

There is no evidence that riboflavin status is altered during long mission spaceflight. Only that the incidence of cataract is higher in astronaut. And some animal studies seem to demonstrate that cataract is more describe with riboflavin deficiency
Riboflavin seems to be stable in space food with radiation exposure but more sensible with light. A vegetarian diet can be poor in riboflavin.
A minimum of 1.1 mg per day for women and 1.3 mg per day for men is recommended. No toxic effects are associated to high doses.

5.6.3 Niacin or Vitamin B3

The niacin designation includes nicotinic acid and nicotinamide. Humans synthesise niacin from tryptophan, an essential amino acid. Nicotinamide is the precursor of two coenzymes: NAD (nicotinamide adenine dinucleotide) and NADP (nicotinamide adenine dinucleotide phosphate). NAD and NADP are involved in many enzymatic redox reactions that are essential to cellular metabolism. Remember that:

- 1 NE (niacin equivalent) = 1 mg nicotinic acid
- 1 EN = 1 mg of nicotinamide
- 1 NE = 60mg tryptophan food.

It is advised not to ingest more than 500mg of preformed niacin per day to avoid liver problems. A deficiency of niacin causes pellagra, characterized by asthenia, stomatitis, diarrhea, anemia, anorexia with dermatoses.

5.6.3.1 In microgravity or simulation:

It was found that exposure to cosmic radiation alters DNA (causes DNA damage), an adequate concentration of niacin is therefore very important, since it is involved in DNA repair. The rate of niacin synthesis is influenced by vitamin B6, riboflavin, zinc (for interaction with steroid hormone receptors) and iron (for the synthesis of heme). It was also observed that the rate of NAD synthesis varies during space flight while the NADP remains stable. The RDA is 20 mg. (Lane 1999) RDA on earth is 18mg.

5.6.3.2 Moon and Mars requirements:

There is few documented information on Niacin metabolism. A requirement of 16 to 20 mg Niacin equivalents is proposed with an upper limit of 35 mg per day. Stability of niacin in MELiSSA space food has to be determined.

5.6.4 Pantothenic acid

This vitamin is included in the group B vitamins, and plays a major role in using energy from carbohydrates, lipids and several amino acids, pantothenic acid as part of the structure of coenzyme A (CoA) and the Acyl Carrier Protein (ACP).

These two molecules (CoA and ACP) are also involved in the synthesis of fatty acids.

Pantothenic acid is heat stable in neutral solution, but this water-soluble vitamin is rapidly hydrolyzed, then inactivated in an acidic or alkaline environment. To ensure greater stability, pantothenic acid is used in food supplements in the form of sodium salts and especially calcium.

Adult intake documented in several European countries and deemed appropriate range from 5 to 12 mg / day. The intestinal absorption is a saturable active transport, and 50% of the pantothenic acid made in the diet is actually absorbed.

Elimination is mainly via urine, and is proportional to the dietary intake of this vitamin. Nutritional deficiencies in pantothenic acid are quite exceptional and can manifest as fatigue, headache, insomnia and paraesthesia of hands and feet. No toxicity of pantothenic acid has been demonstrated, even when administering this important vitamin in doses exceeding 1.0 to 1.5 g per day.

5.6.4.1 In microgravity or simulation:

No specific data on pantothenic metabolism in space.

The recommended intake is 5mg per day for the astronauts without gender differences. (Lane, 2000) (RDA = 5mg/day on earth).

5.6.4.2 Moon and Mars requirements:

There is no indication to enhance the earth requirement (5 mg/day). Even if there is no upper limit demonstrated.

Stability of pantothenic acid in MELiSSA space food will be determined.

5.6.5 Vitamin B6

This term designates three natural chemical forms: pyridoxine, pyridoxal and the pyridoxamine. All three eventually become active as pyridoxal phosphate. It acts as a cofactor of enzymes involved in metabolism of carbohydrates, lipids and especially proteins. Pyridoxal phosphate contributes to the synthesis and degradation of amino acids (transaminases cofactor), the synthesis of glucose from amino acids, the synthesis of neurotransmitters, and phosphorylation of liver and muscle glycogen. It is also involved in the metabolism of polyunsaturated fatty acids and phospholipids formation. It is advised not to consume more than 50mg or 100 mg of vitamin B6 per day to avoid the risk of irreversible neuropathy of the extremities described in some adults.

5.6.5.1 In microgravity or simulation:

Approximately 70% of vitamin B6 is found in the muscles and is associated with glycogen phosphorylase. The changes induced by microgravity in muscle could influence the metabolism of vitamin B6. In addition, there is a decrease in protein synthesis during spaceflight. This vitamin plays a key role in the metabolism of amino acids, a supplement of B6 could thus be effective in stimulating protein synthesis. The loss of bone mass is one of the main problems of spaceflight. Vitamin B6 influences the formation of the cartilage matrix of bone. We have also seen that microgravity alters fluid balance, mineral metabolism and urinary pH, leading to an increased risk of calcium oxalate kidney stone formation. Or a deficiency of vitamin B6 is associated with increased urinary excretion of oxalate, thereby increasing the risk of kidney stones. A lack of vitamin B6 also raises the concentration of agents of oxidative stress. We must be careful to have an adequate intake of vitamin B6. RDA for astronauts was set at 2mg (RDA on earth is 1.7mg). (Lane, 2000)

5.6.5.2 Moon and Mars requirements:

Due to the loss of muscle mass, it will be interesting to little increase the requirement of vitamin B6. Moreover deficiency of vitamin B6 will induce a decrease of serotonin and cathecolamines, associated with depression.

Stability of vitamin B6 in MELiSSA space food will be determined.

Nutritional requirement for a Moon or Mars mission will be comprise between 1.7 and 2.0. A tolerable upper limit intake of 100 mg per day is proposed.

5.6.6 Biotin or vitamin B8

Biotin, also known as vitamin H or B8 is a coenzyme of several carboxylases involved in gluconeogenesis, the synthesis of fatty acids and the metabolism of several amino acids. This vitamin is water soluble, but only in solutions at neutral or alkaline pH, heat stable but was destroyed by UV.

The wealth of different dietary sources of biotin explains the scarcity of nutritional deficiency in this vitamin. This consumption is satisfactory in the absence of specific nutritional recommendations.

A small amount of biotin is synthesized by intestinal bacteria, but the status of biotin in the body depends largely on food intake. Its elimination is mainly renal. Biotin deficiency may occur either after several weeks (or months) of parenteral nutrition supplemented.

Biotin has a very high affinity for a glycoprotein of egg white called avidin, which inhibits the uptake and biological activity of biotin to the point that regular consumption of raw eggs may cause signs of biotin deficiency.

This deficiency results in mucocutaneous a keratoconjunctivitis, candidiasis, as well as neuropsychiatric disorders (depression, paresthesia, muscle pain, drowsiness) and gastrointestinal (nausea, vomiting, hepatic steatosis). There is no known state overload associated with an overdose of biotin, although this vitamin is administered in doses 100 times the input usual food.

5.6.6.1 In microgravity or simulation:

There are no specific data on biotin metabolism during spaceflight. The requirement for ISS is the same as the RDA.

5.6.6.2 Moon and Mars requirements:

Because of the gut microbiota synthesize a part of biotin needed. And the lack of information on the impact on space travel and/or space food on this microbiota, it will be difficult to extrapolate the exact amount of biotin needed during a long mission.

Nutritional requirement for a Moon or Mars mission will provide at least 30µg per day. No tolerable upper limit intake is proposed.

5.6.7 Vitamin B9

Vitamin B9 includes all natural food folate compounds and synthetic folic acid. Folic acid is 1.7 times more bioavailable than natural folates, hence DFE is multiplied by 1.7 for this compound (Bekaert 2008). Food folate exists for 90% out of polyglutamates. These must be transformed into monocomponent (monoglutamate) folates to be absorbed. Folic acid has to be reduced to dihydrofolic acid (DHF) and tetrahydrofolate (THF), the active compound. The liver captures folate (absorbed from food) and stores it under the form of polyglutamates. It puts into circulation THF bound to serum proteins, including albumin. In tissues and erythrocytes, folate is found mainly in the form of polyglutamates. The liver also removes a proportion of folate in bile, but folates can be reabsorbed by the enterohepatic circulation. Folate is a coenzyme involved in the synthesis of certain amino acids and purines. Folate intervenes in the metabolism of histidine, glycine, methionine, and in the synthesis of proteins, purine and pyrimidine bases essential for the synthesis of DNA and RNA. These enzymatic activities are linked with functions of vitamin B12 and B6. In the case of folic acid deficiency, the synthesis of DNA and RNA decreases. All systems needing rapid cell renewal are affected. This results in a macrocytic anemia, neurological abnormalities and a higher risk of cardio-vascular disease, stroke, neurodegenerative disorder, cancer... There is no known toxicity associated with a high intake of natural folates, as the excess is eliminated via urine. For the artificial form of the vitamin, folic acid, used in food fortification and in pills, this might however not be the case. More and more studies indicate that synthetic forms or excess of minerals or vitamins can enhance risks for people. This is currently also under debate for folic acid. A high intake (>1 mg/day) of folic acid but not natural folates can mask symptoms of B12 deficiency.

5.6.7.1 In microgravity or simulation:

There are interactions between vitamin B6, folate and vitamin B12 in relation to the metabolism of homocysteine, which is a risk factor for cardiovascular disease. Folate seems to have much influence on the plasma levels of homocysteine. The recommended folate intake is higher than on earth because of its role in the synthesis of purine and pyrimidine bases and DNA repair. This contribution could minimize the damage caused by radiation. The RDA is 400µg of folic acid per day, the RDA on earth is currently also 400µg. (Lane, 2000).

5.6.7.2 Moon and Mars requirements:

As anti-oxidant factor associated with other nutrients (carotenoïds, vit E, Cit C, Vit Se, Cu, Zn) and due to exposure to space radiation, a target of 400µg per day is proposed. Blood folate monitoring will be necessary with the length of the travel and maybe more for a Mars mission. Stability of folate in MELiSSA space food will be determined. But there is no additional benefit to supplement in folate. A tolerable upper limit level of 1000 µg per day is proposed.

5.6.8 Vitamin B12

Vitamin B12 exists in several chemical forms: the cobalamines, all characterized by the presence of a tetrapyrrole nucleus encompassing cobalt. In humans, two forms are particularly active in metabolism: methylcobalamine and adenosylcobalamine which are each the cofactor of only one enzyme activity. The methylcobalamine is involved in the remethylation reaction of homocysteine to methionine. In blood, cobalamin is always linked to protein carriers: the transcobalamines. Vitamin B12 is stored in the liver.

There may be malabsorption of vitamin B12 in the absence of intrinsic factor secretion by gastric parietal cells what are these factors doing. This lack of assimilation leads to macrocytic anemia or pernicious anemia. Vitamin B12 excess does not appear to have toxic effects.

5.6.8.1 In microgravity or simulation:

No nutritional data are documented about vitamin B12 metabolism during a space mission.
RDA for astronauts is up to 2µg per day, the RDA on earth is 2.4µg/jour. (Lane, 2000)

5.6.8.2 Moon and Mars requirements:

Deficiency of vitamin B12 is rare except in strict vegetarians, because the only sources of cobalamines are of animal origin. It will therefore be necessary to pay particular attention to the contribution of this vitamin in future long-duration flights. Indeed, unable to carry enough food for a trip as a mission to Mars, it is possible that astronauts will eat primarily plants they have grown; this could be the case with the MELiSSA program.

Stability of cobalamins in MELiSSA space food will need to be determined.

Nutritional requirement for a Moon or Mars mission will be set to provide 2.4µg per day. There is no upper limit proposed.

5.7 Antioxydants

In general, antioxidants may provide some protection to astronauts against cosmic radiation damage when they leave the Earth's magnetic field (and when they get into the radiation belts). Antioxidants, including arginine, taurine, creatine, selenium, zinc, vitamin E, vitamin C, vitamin A and polyphenols associated with antioxidant enzymes: superoxide dismutase, catalase, glutathione reductase and glutathione peroxidase; exert a simultaneous action against free radicals. (Fang YZ, 2002)

6 Conclusion

Physical activity, resistance exercise, and pharmacological countermeasures are proposed to reduce the deleterious effects of spaceflight, and to maintain the health of the crew during long term missions. These measures are necessary to prevent cardiovascular, muscle and bone diseases. Diet plays an important part in maintaining the health of astronauts. A low energy consumption affects muscle protein synthesis, essential for physical activity. Low liquid and potassium intake can cause cardiovascular problems. Pharmacological countermeasures, such as biophosphonates, are alone not sufficient to avoid the loss of bone mass. Well equilibrated food is essential to enable such countermeasures to be effective.

The previous space flights have shown a change in circadian rhythm, an increased level of hormones related to stress, an altered rate of growth hormone production, and an alteration in cytokines and insulin sensitivity. Physical exercise can be practiced against these effects as it may affect all these factors. These changes may be mimicked with terrestrial models (e.g. bedrest, ...) to better understand their mechanisms in order to treat them more efficiently. The role of macronutrients in these metabolic changes is particularly important for the turnover of muscle proteins and the interactions of lipids and carbohydrates with the endocrine system during spaceflight. Understanding these interactions may be useful for devising effective countermeasures.

Still, new methods must be developed to simplify the research in space models. Blood and urine are difficult to collect and store during spaceflight as laboratory equipment is minimal, the freezers are small and the crew has limited time for individual studies. New miniaturised measuring techniques would be useful for future research.

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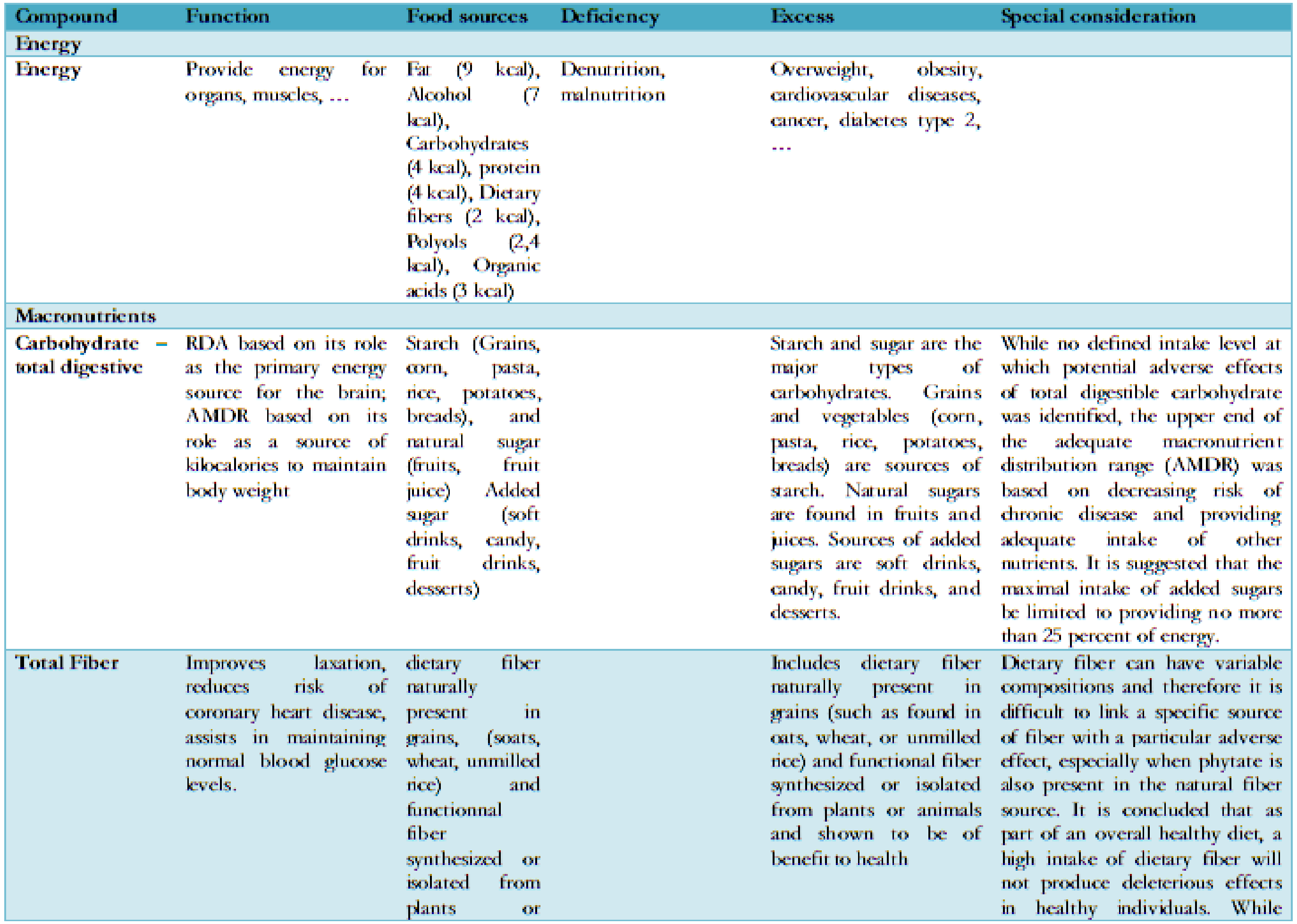
8 Annex

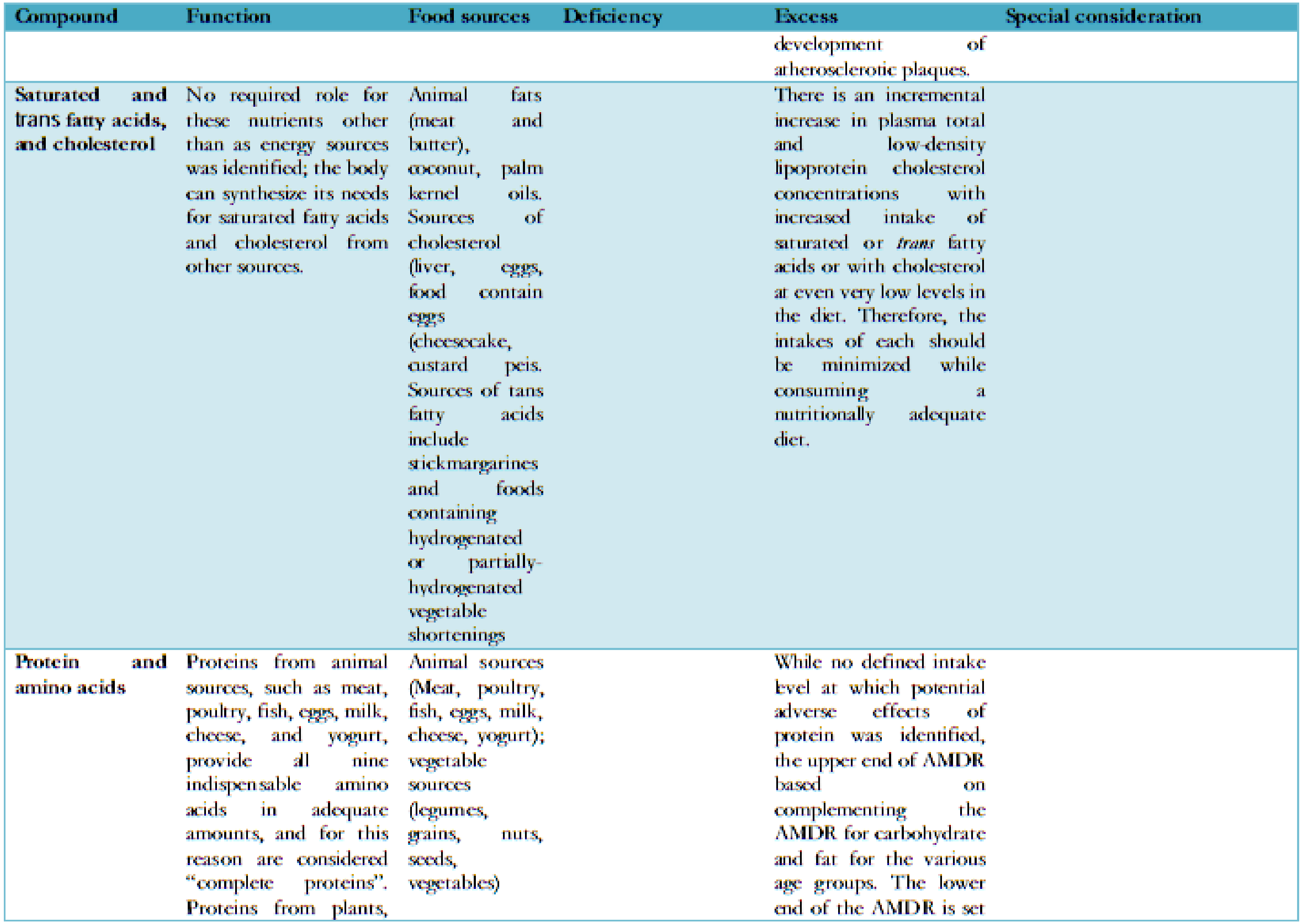
8.1 Annex 1: Table of nutrient functions, deficiencies and excesses



Compound	Function	Food sources	Deficiency	Excess	Special consideration
Energy					
Energy	Provide energy for organs, muscles, …	Fat (9 kcal), Alcohol (7 kcal), Carbohydrates (4 kcal), protein (4 kcal), Dietary fibers (2 kcal), Polyols (2,4 kcal), Organic acids (3 kcal)	Denutrition, malnutrition	Overweight, obesity, cardiovascular diseases, cancer, diabetes type 2, …	
Macronutrients					
Carbohydrate – total digestive	RDA based on its role as the primary energy source for the brain; AMDR based on its role as a source of kilocalories to maintain body weight	Starch (Grains, corn, pasta, rice, potatoes, breads), and natural sugar (fruits, fruit juice) Added sugar (soft drinks, candy, fruit drinks, desserts)		Starch and sugar are the major types of carbohydrates. Grains and vegetables (corn, pasta, rice, potatoes, breads) are sources of starch. Natural sugars are found in fruits and juices. Sources of added sugars are soft drinks, candy, fruit drinks, and desserts.	While no defined intake level at which potential adverse effects of total digestible carbohydrate was identified, the upper end of the adequate macronutrient distribution range (AMDR) was based on decreasing risk of chronic disease and providing adequate intake of other nutrients. It is suggested that the maximal intake of added sugars be limited to providing no more than 25 percent of energy.
Total Fiber	Improves laxation, reduces risk of coronary heart disease, assists in maintaining normal blood glucose levels.	dietary fiber naturally present in grains, (soats, wheat, unmilled rice) and functionnal fiber synthesized or isolated from plants or		Includes dietary fiber naturally present in grains (such as found in oats, wheat, or unmilled rice) and functional fiber synthesized or isolated from plants or animals and shown to be of benefit to health	Dietary fiber can have variable compositions and therefore it is difficult to link a specific source of fiber with a particular adverse effect, especially when phytate is also present in the natural fiber source. It is concluded that as part of an overall healthy diet, a high intake of dietary fiber will not produce deleterious effects in healthy individuals. While

Compound	Function	Food sources	Deficiency	Excess	Special consideration
		animals and shown to be of benefit to health			occasional adverse gastrointestinal symptoms are observed when consuming some isolated or synthetic fibers, serious chronic adverse effects have not been observed. Due to the bulky nature of fibers, excess consumption is likely to be self-limiting. Therefore, a UL was not set for individual functional fibers.
Total Fat	Energy source and when found in foods, is a source of *n*-6 and *n*-3 polyunsaturated fatty acids. Its presence in the diet increases absorption of fat soluble vitamins and precursors such as vitamin A and pro-vitamin A carotenoids.	Butter, margarine, vegetable oils, whole milk, visible faton meat and poultry products, invisible fat in fish, shellfish, some plant products (seeds, nuts), bakery products		While no defined intake level at which potential adverse effects of total fat was identified, the upper end of AMDR is based on decreasing risk of chronic disease and providing adequate intake of other nutrients. The lower end of the AMDR is based on concerns related to the increase in plasma triacylglycerol concentrations and decreased HDL cheolesterol concentrations seen with very low fat (and thus high carbohydrate) diets.	
n-6 polyunsaturated fatty acids (linoleic acid)	Essential component of structural membrane lipids, involved with cell signaling, and precursor of	Nuts, seeds, vegetables oils (soybean, sunflower, corn)		While no defined intake level at which potential adverse effects of *n*-6 polyunsaturated fatty acids was identified, the	

Compound	Function	Food sources	Deficiency	Excess	Special consideration
	eicosanoids. Required for normal skin function.			upper end of the AMDR is based the lack of evidence that demonstrates long-term safety and human in vitro studies which show increased free-radical formation and lipid peroxidation with higher amounts of n-6 fatty acids. Lipid peroxidation is thought to be a component of in the development of atherosclerotic plaques.	
n-3 **polyunsaturated fatty acids (α-linolenic acid)**	Involved with neurological development and growth. Precursor of eicosanoids.	Vegetable oils (soybean, canola, flax seed oil) fish oils, fatty fish and smaller amount in meats and eggs		While no defined intake level at which potential adverse effects of *n*-3 polyunsaturated fatty acids was identified, the upper end of AMDR is based on maintaining the appropriate balance with n-6 fatty acids and on the lack of evidence that demonstrates long-term safety, along with human in vitro studies which show increased free-radical formation and lipid peroxidation with higher amounts of polyunsaturated fatty acids. Lipid peroxidation is thought to be a component of in the	



Compound	Function	Food sources	Deficiency	Excess	Special consideration
				development of atherosclerotic plaques.	
Saturated and trans fatty acids, and cholesterol	No required role for these nutrients other than as energy sources was identified; the body can synthesize its needs for saturated fatty acids and cholesterol from other sources.	Animal fats (meat and butter), coconut, palm kernel oils. Sources of cholesterol (liver, eggs, food contain eggs (cheesecake, custard peis. Sources of tans fatty acids include stickmargarines and foods containing hydrogenated or partially-hydrogenated vegetable shortenings		There is an incremental increase in plasma total and low-density lipoprotein cholesterol concentrations with increased intake of saturated or *trans* fatty acids or with cholesterol at even very low levels in the diet. Therefore, the intakes of each should be minimized while consuming a nutritionally adequate diet.	
Protein and amino acids	Proteins from animal sources, such as meat, poultry, fish, eggs, milk, cheese, and yogurt, provide all nine indispensable amino acids in adequate amounts, and for this reason are considered "complete proteins". Proteins from plants,	Animal sources (Meat, poultry, fish, eggs, milk, cheese, yogurt); vegetable sources (legumes, grains, nuts, seeds, vegetables)		While no defined intake level at which potential adverse effects of protein was identified, the upper end of AMDR based on complementing the AMDR for carbohydrate and fat for the various age groups. The lower end of the AMDR is set	

Compound	Function	Food sources	Deficiency	Excess	Special consideration
	legumes, grains, nuts, seeds, and vegetables tend to be deficient in one or more of the indispensable amino acids and are called 'incomplete proteins'. Vegan diets adequate in total protein content can be "complete" by combining sources of incomplete proteins which lack different indispensable amino acids.			at approximately the RDA..	
Indispensable amino acids: Histidine, Isoleucine, Leucine, Lysine, Methionine & Cysteine, Phenylalanine & Tyrosine, Threonine, Tryptophan, Valine	The building blocks of all proteins in the body and some hormones. These nine amino acids must be provided in the diet and thus are termed indispensable amino acids. The body can make the other amino acids needed to synthesize specific structures from other amino acids and carbohydrate precursors.			Since there is no evidence that amino acids found in usual or even high intakes of protein from food present any risk, attention was focused on intakes of the L-form of these and other amino acid found in dietary protein and amino acid supplements. Even from well-studied amino acids, adequate dose-response data from human or animal studies on which to base a UL were not available. While no defined intake level at which potential adverse effects of protein was	

Compound	Function	Food sources	Deficiency	Excess	Special consideration
				identified for any amino acid, this does not mean that there is no potential for adverse effects resulting from high intakes of amino acids from dietary supplements. Since data on the adverse effects of high levels of amino acid intakes from dietary supplements are limited, caution may be warranted.	
Water and electrolytes					
Sodium	Maintains fluid volume outside of cells and thus normal cell function.	Salt (40% sodium by weight), Processed foodsto wich sodium chloride, benzoate, phosphate have been added; salted meats, nuts, cold cuts; margarine, salted butter		Hypertension; increased risk of cardiovascular disease and stroke.	The AI is set based on being able to obtain a nutritionally adequate diet for other nutrients and to meet the needs for sweat losses for individuals engaged in recommended levels of physical activity. Individuals engaged in activity at higher levels or in humid climates resulting in excessive sweat may need more than the AI. The UL applies to apparently healthy individuals without hypertension; it thus may be too high for individuals who already have hypertension or who are under the care of a health care professional.
Chloride	With sodium, maintains fluid volume outside of cells and thus normal cell function.	Same as sodium, 60% by weight of salt		In concert with sodium, results in hypertension.	Chloride is lost usually with sodium in sweat, as well as in vomiting and diarrhea. The AI and UL are equi-molar in

Compound	Function	Food sources	Deficiency	Excess	Special consideration
					amount to sodium since most of sodium in diet comes as sodium chloride (salt).
Potassium	Maintains fluid volume inside/outside of cells and thus normal cell function; acts to blunt the rise of blood pressure in response to excess sodium intake, and decrease markers of bone turnover and recurrence of kidney stones.	Fruits, vegetables, dried peas, dairy products, meats, nuts	The nutritional deficiency of potassium is rare, because potassium is contained in most foods.	None documented from food alone; however, potassium from supplements or salt substitutes can result in hyperkalemia and possibly sudden death if excess is consumed by individuals with chronic renal insufficiency (kidney disease) or diabetes.	Individuals taking drugs for cardiovascular disease such as ACE inhibitors, ARBs (Angiontensin Receptor Blockers), or potassium sparing diuretics should be careful to not consume supplements containing potassium and may need to consume less than the AI for potassium.
Water	Maintains homeostasis in the body and allows for transport of nutrients to cells and removal and excretion of waste products of metabolism.	Water, all beverages, moisture in foods		No UL because normally functioning kidneys can handle more than 0.7 L (24 oz) of fluid per hour; symptoms of water intoxication include hyponatremia which can result in heart failure and rhabdomyolosis (skeletal muscle tissue injury) which can lead to kidney failure.	Recommended intakes for water are based on median intakes of generally healthy individuals who are adequately hydrated; individuals can be adequately hydrated at levels below as well as above the AIs provided. The AIs provided are for total water in temperate climates. All sources can contribute to total water needs: beverages (including tea, coffee, juices, sodas, and drinking water) and moisture found in foods. Moisture in food accounts for about 20% of total water intake. Thirst and consumption of beverages at meals are adequate to maintain hydration.
Inorganic Sulfate	Required for biosynthesis of 3'-	Dried fruits, soy flour, fruit		Osmotic diarrhea was observed in areas where	

Compound	Function	Food sources	Deficiency	Excess	Special consideration
	phosphoadenosine- 5'-phosphate (PAPS), which provides sulfate when sulfurcontaining compounds are needed such as chondroitin sulfate and cerebroside sulfate.	juices, coconut milk, red and white wine, bread, meat, sulfated water		water supply had high levels; odor and off taste usually limit intake, and thus no UL was set.	
Minerals and elements					
Arsenic	No biological function in humans although animal data indicate a requirement	Dairy products, meat, poultry, fish, grains, cereal		No data on the possible adverse effects of organic arsenic compounds in food were found. Inorganic arsenic is a known toxic substance. Although the UL was not determined for arsenic, there is no justification for adding arsenic to food or supplements.	
Boron	No clear biological function in humans although animal data indicate a functional role	Fruit-based beverages and products, potatoes, legumes, milk, avocado, peanut butter, peanuts		Reproductive and developmental effects as observed in animal studies.	
Calcium	Essential role in blood clotting, muscle contraction, nerve transmission, and bone and tooth formation	Milk, cheese, yogurt, cron tortillas, calcium-set tofu, chinese cabbage, kale, broccoli	chronic deficit can lead to a reduction in the density of bone mass and fracture risk more frequent	Kidney stones, hypercalcemia, milk alkali syndrome, and renal insufficiency	There is no consistent data to support that a high protein intake increases calcium requirement.

Compound	Function	Food sources	Deficiency	Excess	Special consideration
Chromium	Helps to maintain normal blood glucose levels	Some cereals, meats, poultry, fish, beer	Chromium deficiency is characterized by decreased glucose tolerance, which translates to: hyperinsulinemia, fasting hyperglycemia and increased triglyceride and cholesterol plasma. Neurological signs are observed in cases of severe deficiency (which remains anecdotal) such as peripheral neuropathy and metabolic encephalopathy. Disorders related to a less pronounced deficiency were observed in diabetics, the elderly or the malnourished child while severe impairments have been reported in patients with prolonged total parenteral nutrition.	Chronic renal failure	
Copper	Component of enzymes in iron metabolism	Organ meats, seafood, nuts, seeds, wheat bran cereals, whole grain, products, cocoa		Gastrointestinal distress, liver damage	Idiopathic copper toxicosis may be at adverse effects from excess intake

Compound	**Function**	**Food sources**	**Deficiency**	**Excess**	**Special consideration**
		products			
Fluoride	Inhibits the initiation and progression of dental caries and stimulates new bone formation	Fluoridated water, teas, marine fish, fluoridated dental products		Enamel and skeletal fluorosis	
Iodine	Component of the thyroid hormones; and prevents goiter and cretinism	Marine origin, processed foods, iodized salt	Neonatal mortality, psychomotor development, goiter and cretinism	Elevated thyroid stimulating hormone (TSH) concentration	Individuals with autoimmune thyroid disease, previous iodine deficiency, or nodular goiter are distinctly susceptible to the adverse effect of excess iodine intake. Therefore, individuals with these conditions may not be protected by the UL for iodine intake for the general population.
Iron	Component of hemoglobin and numerous enzymes; prevents microcytic hypochromic anemia	Meats and poultry (heme iron sources); fruits, vegetables and fortified bread and grain products such as cereal (non-heme iron sources)	Effects of iron deficiency are known as incidence on the level of physical activity, on brain development and intellectual. Decreased attention, ability to concentrate and impaired memory. Lack of iron also affects the immune system and body's defences against infection.	Gastrointestinal distress	Non-heme iron absorption is lower for those consuming vegetarian diets than for those eating nonvegetarian diets. Therefore, it has been suggested that the iron requirement for those consuming a vegetarian diet is approximately 2- fold greater than for those consuming a nonvegetarian diet. Recommended intake assumes 75% of iron is from heme iron sources.
Magnesium	Cofactor for enzyme systems	Green leafy, vegetables, unpolished grains, nuts, meat, starches, milk		There is no evidence of adverse effects from the consumption of naturally occurring magnesium in foods. Adverse effects from	

Compound	Function	Food sources	Deficiency	Excess	Special consideration
				magnesium containing supplements may include osmotic diarrhea. The UL for magnesium represents intake from a pharmacological agent only and does not include intake from food and water.	
Manganese	Involved in the formation of bone, as well as in enzymes involved in amino acid, cholesterol, and carbohydrate metabolism	Nuts, legumes, tea, whole grains	Manganese deficiency was mainly observed in animals and results in growth defects, impaired reproductive function, skeletal abnormalities, glucose intolerance and other violations of carbohydrate and lipid metabolism. The different effects are sometimes contradictory and do not always relate to the human. However, its essential character for man was demonstrated when pronounced deficiencies in children or subjects in total parenteral nutrition who are accompanied by events such as bone	Elevated blood concentration and neurotoxicity	Because manganese in drinking water and supplements may be more bioavailable than manganese from food, caution should be taken when using manganese supplements especially among those persons already consuming large amounts of manganese from diets high in plant products. In addition, individuals with liver disease may be distinctly susceptible to the adverse effects of excess manganese intake.

Compound	Function	Food sources	Deficiency	Excess	Special consideration
			demineralization, growth retardation and various carbohydrate and lipid disorders, reversed by adequate supplementation. The antagonism with iron seems especially significant to the point that an excess in one or another element may precipitate a deficiency in his element antagonist.		
Molybdenum	Cofactor for enzymes involved in catabolism of sulfur amino acids, purines and pyridines.	legumes, grain products, nuts	Molybdenum deficiency is extremely rare in men. But has been reported in varying degrees in younger patients or in patients with Total Parenteral Nutrition not adequately supplemented. It is accompanied by cardiac rhythm disorders (tachycardia) of tachypnea, neurological disorders (loss of night vision, encephalopathy and coma) as well as various biochemical alterations	Reproductive effects as observed in animal studies.	Individuals who are deficient in dietary copper intake or have some dysfunction in copper metabolism that makes them copper-deficient could be at increased risk of molybdenum toxicity.

Compound	Function	Food sources	Deficiency	Excess	Special consideration
			(Hypermethioninemia, hypouricemia, hyperxanthinurie, hypersulfiturie, hyposulfaturie and hypo -uricosuric).		
Nickel	No clear biological function in humans has been identified. May serve as a cofactor of metalloenzymes and facilitate iron absorption or metabolism in microorganisms.	Nuts, legumes, cereals, sweeteners, chocolates milk powder, chocolate candy		Decreased body weight gain Note: As observed in animal studies	Individuals with preexisting nickel hypersensitivity (from previous dermal exposure) and kidney dysfunction are distinctly susceptible to the adverse effects of excess nickel intake
Phosphorus	Maintenance of pH, storage and transfer of energy and nucleotide synthesis	Milk, yogurt, ice cream, cheese, peas, meat, eggs, some cereals and breads	The phosphorus deficiency is rare. A drop of phosphate can lead to osteomalacia	Metastatic calcification, skeletal porosity, interference with calcium absorption	Athletes and others with high energy expenditure frequently consume amounts from food greater than the UL without apparent effect.
Selenium	Defense against oxidative stress and regulation of thyroid hormone action, and the reduction and oxidation status of vitamin C and other molecules	organ meats, seafood, plants (dependind on soil selenium content)	The lack of intake of selenium is accompanied by various biochemical and clinical disturbances of varying intensity depending on the degree of impairment. Decreased resistance to oxidative stress, increased susceptibility to infections (including viral infections),	Hair and nail brittleness and loss	

Compound	Function	Food sources	Deficiency	Excess	Special consideration
			increased incidence of cancer or cardiovascular disease, impaired fertility, etc.. We currently attaches special attention to the anticancer properties of selenium, particularly with the prostate cancer		
Silicon	No biological function in humans has been identified. Involved in bone function in animal studies.	Plant-based foods		There is no evidence that silicon that occurs naturally in food and water produces adverse health effects.	
Vanadium	No biological function in humans has been identified.	Mushrooms, shellfish, black pepper, parsley, and dill seed		Renal lesions as observed in animal studies.	
Zinc	Component of multiple enzymes and proteins; involved in the regulation of gene expression.	Fortified cereals, red meats, certain seafood		Reduced copper status	Zinc absorption is lower for those consuming vegetarian diets than for those eating nonvegetarian diets. Therefore, it has been suggested that the zinc requirement for those consuming a vegetarian diet is approximately 2- fold greater than for those consuming a nonvegetarian diet.
Vitamins					
Vitamin A	Required for normal vision, gene expression, reproduction, embryonic development and immune function	Liver, dairy products, fish, darkly colored fruits and leafy vegetables	blindness, xerophthalmia. In industrialized countries, vitamin A deficiency is rare. Important quantity in	Teratological effects, Iver toxicity Note: From preformed Vitamin A only.	Individuals with high alcohol intake, preexisting liver disease, hyperlipidemia or severe protein malnutrition may be distinctly susceptible to the adverse effects of excess preformed vitamin A

Compound	Function	Food sources	Deficiency	Excess	Special consideration
			the liver.		intake. !-carotene supplements are advised only to serve as a provitamin A source for individuals at risk of vitamin A deficiency.
Vitamin D	Maintain serum calcium and phosphorus concentrations.	Fish liver oils, flesh or fatty fish, liver and fat from seals and polar bears, eggs from hens that have been fed vitamin D, fortified milk products and fortified cereals	rickets but also osteoporosis and osteomalacia, incidence in cancer development	Elevated plasma 25 (OH) D concentration causing hypercalcemia	
Vitamin E	A metabolic function has not yet been identified. Vitamin E's major function appears to be as a nonspecific chainbreaking antioxidant.	vegetable oils, unprocessed cereals grain, nuts, fruits, vegetables, meats	The deficiency in vitamin E are rare in adults and are often associated with food (very) rich in PUFA. Deficiencies can cause a clinical picture of hemolytic anemia and/or neurological disorders (Dupuytren disease), including motor combined and ocular cerebellar ataxia. The peripheral damage leads to chronic denervation and myopathy with degeneration lipopigmentaire, infertility. If these	There is no evidence of adverse effects from the consumption of vitamin E naturally occurring in foods. Adverse effects from vitamin E containing supplements may include hemorrhagic toxicity. The UL for vitamin E applies to any form of "-tocopherol obtained from supplements, fortified foods, or a combination of the two.	

Compound	Function	Food sources	Deficiency	Excess	Special consideration
			neurological grow very slowly in adults, they seem to be irreversible.		
Vitamin K	Coenzyme during the synthesis of many proteins involved in blood clotting and bone metabolism	synthesized by the bacterial flora of the colon. Green vegetables (collard, spinach, salad greens, broccoli), brussel sprouts, cabbage, plant oils and margarine	In industrialized countries, clinical deficiency in adults are rare because of high bioavailability of vitamin K, whether from food or synthesized by the bacterial flora of the colon. Deficiency requiring supplement vitamin K can however occur in the context of severe liver disease during prolonged antibiotic therapy combined with a lack of dietary vitamin K, in malabsorption due to food intolerance (celiac disease) or as a complication of bariatric surgery (biliopancreatic diversion) dedicated to the treatment of obesity.	No adverse effects associated with vitamin K consumption from food or supplements have been reported in humans or animals. This does not mean that there is no potential for adverse effects resulting from high intakes. Because data on the adverse effects of vitamin K are limited, caution may be warranted	
Biotin	Coenzyme in synthesis of fat, glycogen, and amino acids	liver, fruits, meats	This deficiency results in mucocutaneous a keratoconjunctivitis,	No adverse effects of biotin in humans or animals were found. This does not mean that	

Compound	Function	Food sources	Deficiency	Excess	Special consideration
			candidiasis, as well as neuropsychiatric disorders (depression, paresthesia, muscle pain, drowsiness) and gastrointestinal (nausea, vomiting, hepatic steatosis).	there is no potential for adverse effects resulting from high intakes. Because data on the adverse effects of biotin are limited, caution may be warranted.	
Choline	Precursor for acetylcholine, phospholipids and betaine	milk, liver, eggs, peanut		Fishy body odor, sweating, salivation, hypotension, hepatotoxicity	Individuals with trimethylaminuria, renal disease, liver disease, depression and Parkinson's disease, may be at risk of adverse effects with choline intakes at the UL. Although AIs have been set for choline, there are few data to assess whether a dietary supply of choline is needed at all stages of the life cycle, and it may be that the choline requirement can be met by endogenous synthesis at some of these stages.
Folate	Coenzyme in the metabolism of nucleic and amino acids; prevents megaloblastic anemia	cereals grains, dark leafy vegetables, enriched and whole-grain breads and bread products, fortified ready-to-eat cereals	lack of red blood cells and platelets in the blood	Masks neurological complication in people with vitamin B12 deficiency. No adverse effects associated with folate from food or supplements have been reported. This does not mean that there is no potential for adverse effects resulting from high intakes. Because data on the adverse	

Compound	Function	Food sources	Deficiency	Excess	Special consideration
				effects of folate are limited, caution may be warranted. The UL for folate applies to synthetic forms obtained from supplements and/or fortified foods.	
Niacin	Coenzyme or cosubstrate in many biological reduction and oxidation reactions—thus required for energy metabolism	meat, fish, poultry, enriched and whole grain breads and bread products, fortified ready-to eat cereals	Pellagra, solar intolerance, gastrointestinal mucositis. This deficiency exists in the countries where the diet contains little animal protein.	There is no evidence of adverse effects from the consumption of naturally occurring niacin in foods. Adverse effects from niacin containing supplements may include flushing and gastrointestinal distress. The UL for niacin applies to synthetic forms obtained from supplements, fortified foods, or a combination of the two.	
Pantothenic Acid	Coenzyme in fatty acid metabolism	chicken, bef, potatoes, oats, cereals, tomato products, liver, kidney, yeast, egg yolk, broccoli, whole grains	Fatigue, headache, insomnia and paraesthesia of hands and feet.	No adverse effects associated with pantothenic acid from food or supplements have been reported. This does not mean that there is no potential for adverse effects resulting from high intakes. Because data on the adverse effects of pantothenic acid are limited, caution may be warranted.	

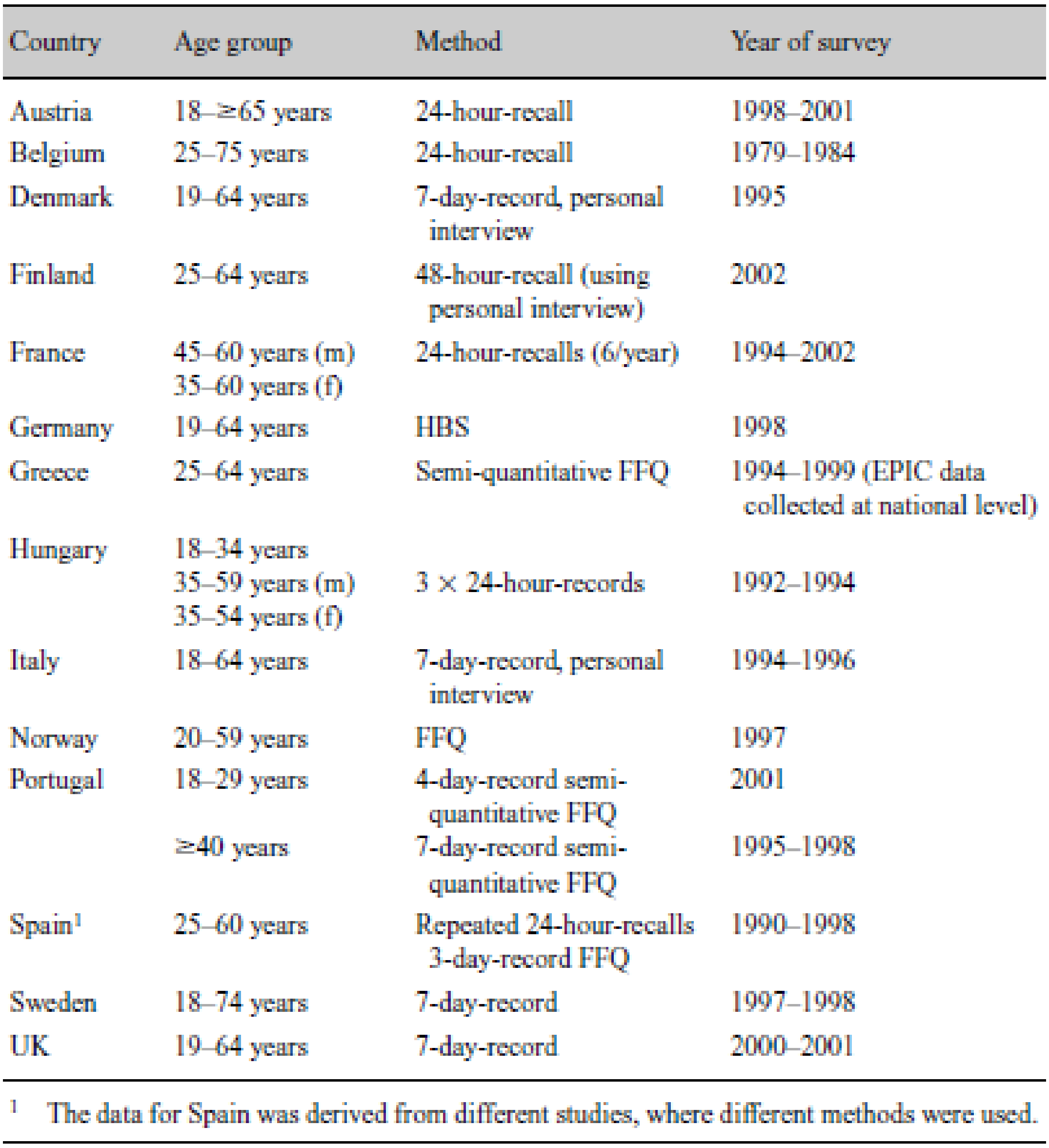
Compound	Function	Food sources	Deficiency	Excess	Special consideration
Riboflavin	Coenzyme in numerous redox reactions	organ meats, milk, bread products, fortified cereals	Its deficiency, although rare, can cause mucosal and cutaneous infection (lip, mouth, tongue ...)	No adverse effects associated with riboflavin consumption from food or supplements have been reported. This does not mean that there is no potential for adverse effects resulting from high intakes. Because data on the adverse effects of riboflavin are limited, caution may be warranted.	
Thiamin	Coenzyme in the metabolism of carbohydrates and branched chain amino acids	enriched, fortified or whole-grain, products, bread and bread products, mixed foods whose main ingredient is grain, and ready-to-eat cereals	clinical consequences can be serious: the Beri-Beri, alcoholic encephalopathy	No adverse effects associated with thiamin from food or supplements have been reported. This does not mean that there is no potential for adverse effects resulting from high intakes. Because data on the adverse effects of thiamin are limited, caution may be warranted.	
Vitamin K	Coenzyme during the synthesis of many proteins involved in blood clotting and bone metabolism	synthesized by the bacterial flora of the colon. Green vegetables (collard, spinach, salad greens, broccoli),	In industrialized countries, clinical deficiency in adults are rare because of high bioavailability of vitamin K, whether from food or synthesized by the bacterial flora of the	No adverse effects associated with vitamin K consumption from food or supplements have been reported in humans or animals. This does not mean that there is no potential for adverse effects resulting	

Compound	Function	Food sources	Deficiency	Excess	Special consideration
		brussel sprouts, cabbage, plant oils and margarine	colon. Deficiency requiring supplement vitamin K can however occur in the context of severe liver disease during prolonged antibiotic therapy combined with a lack of dietary vitamin K, in malabsorption due to food intolerance (celiac disease) or as a complication of bariatric surgery (biliopancreatic diversion) dedicated to the treatment of obesity.	from high intakes. Because data on the adverse effects of vitamin K are limited, caution may be warranted	
Vitamin B6	Coenzyme in the metabolism of amino acids, glycogen and sphingoid bases	fortified cereals, organ meats, fortified soy-based meat substitutes	Vitamin B6 deficiency generally result of several factors involved. The clinical implications are then: stunted growth, nervous disorders, arteriosclerosis, decreased immunity	No adverse effects associated with Vitamin B6 from food have been reported. This does not mean that there is no potential for adverse effects resulting from high intakes. Because data on the adverse effects of Vitamin B6 are limited, caution may be warranted. Sensory neuropathy has occurred from high intakes of supplemental forms.	
Vitamin B12	Coenzyme in nucleic acid metabolism;	fortified cereals, meat,	pernicious anaemia	No adverse effects have been associated with the	

Compound	Function	Food sources	Deficiency	Excess	Special consideration
	prevents megaloblastic anaemia	fish, poultry		consumption of the amounts of vitamin B12 normally found in foods or supplements. This does not mean that there is no potential for adverse effects resulting from high intakes. Because data on the adverse effects of vitamin B12 are limited, caution may be warranted.	
Vitamin C	Cofactor for reactions requiring reduced copper or iron metalloenzyme and as a protective antioxidant	citrus fruits, tomatoes, tomato juice, potatoes, brussel sprouts, cauliflower, broccoli, strawberries, cabbage and spinach	Scurvy, anaemia,	Gastrointestinal disturbances, kidney stones, excess iron absorption	

(Adapted from DRI, Conseil Supérieur de la Santé)

8.2 Annex 2: Method and period of dietary assessment in adults of European countries

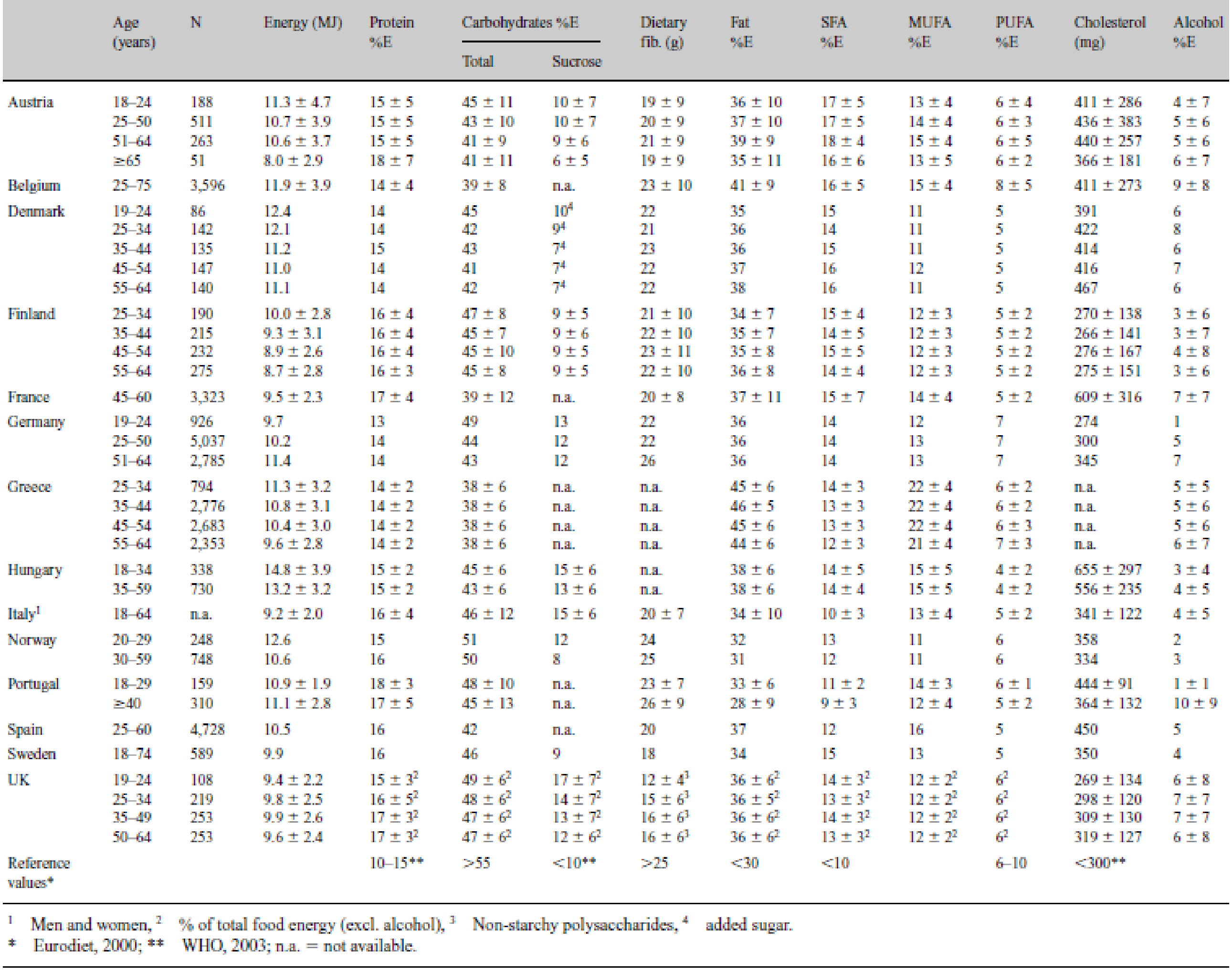


Country	Age group	Method	Year of survey
Austria	18–≥65 years	24-hour-recall	1998–2001
Belgium	25–75 years	24-hour-recall	1979–1984
Denmark	19–64 years	7-day-record, personal interview	1995
Finland	25–64 years	48-hour-recall (using personal interview)	2002
France	45–60 years (m) 35–60 years (f)	24-hour-recalls (6/year)	1994–2002
Germany	19–64 years	HBS	1998
Greece	25–64 years	Semi-quantitative FFQ	1994–1999 (EPIC data collected at national level)
Hungary	18–34 years 35–59 years (m) 35–54 years (f)	3 × 24-hour-records	1992–1994
Italy	18–64 years	7-day-record, personal interview	1994–1996
Norway	20–59 years	FFQ	1997
Portugal	18–29 years	4-day-record semi-quantitative FFQ	2001
	≥40 years	7-day-record semi-quantitative FFQ	1995–1998
Spain[1]	25–60 years	Repeated 24-hour-recalls 3-day-record FFQ	1990–1998
Sweden	18–74 years	7-day-record	1997–1998
UK	19–64 years	7-day-record	2000–2001

[1] The data for Spain was derived from different studies, where different methods were used.

(European Nutrition and Health Report, 2004)

8.3 Annex 3: Intake of energy and macronutrients (mean + SD) in adults of European countries (men)

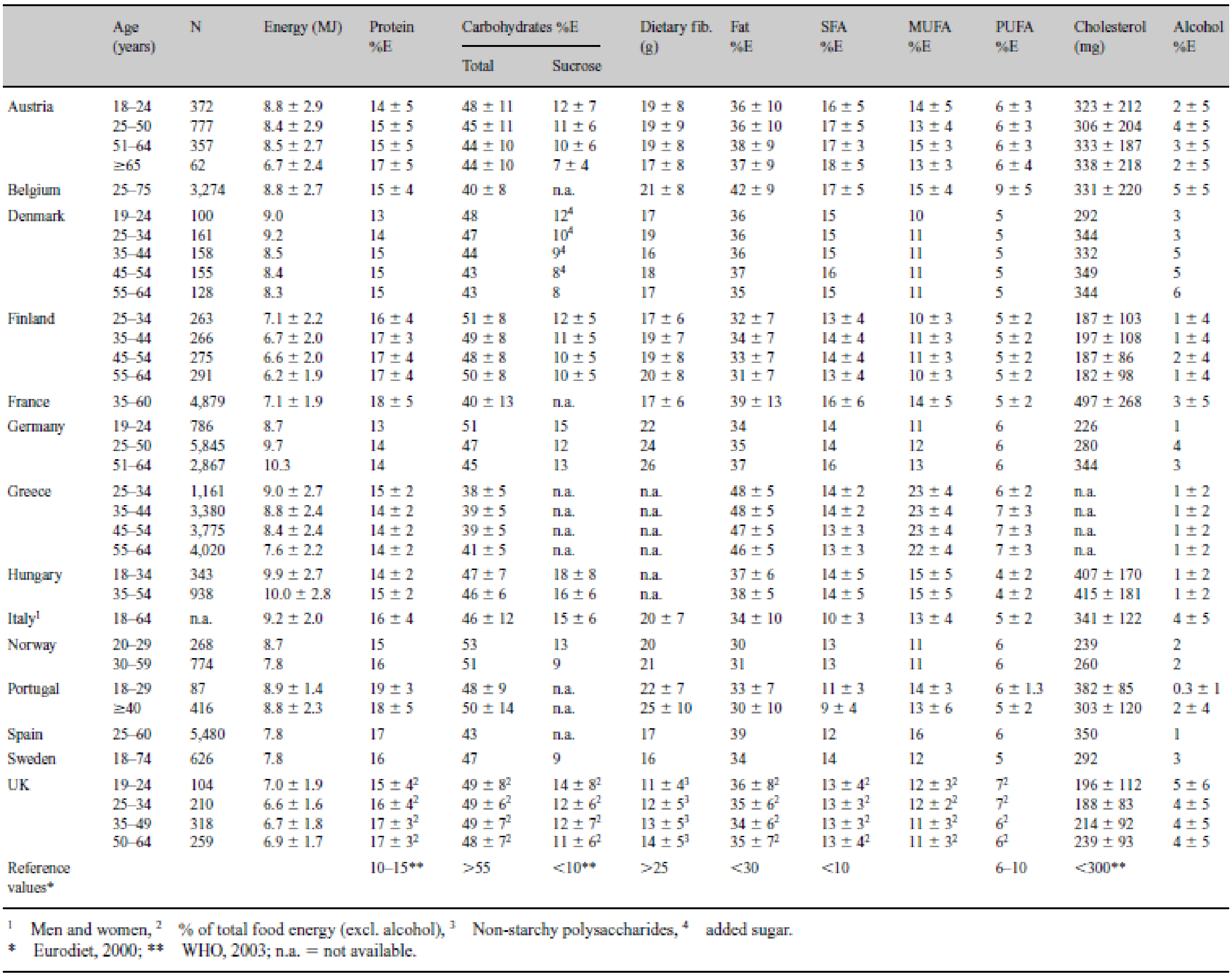


	Age (years)	N	Energy (MJ)	Protein %E	Carbohydrates %E		Dietary fib. (g)	Fat %E	SFA %E	MUFA %E	PUFA %E	Cholesterol (mg)	Alcohol %E
					Total	Sucrose							
Austria	18–24	188	11.3 ± 4.7	15 ± 5	45 ± 11	10 ± 7	19 ± 9	36 ± 10	17 ± 5	13 ± 4	6 ± 4	411 ± 286	4 ± 7
	25–50	511	10.7 ± 3.9	15 ± 5	43 ± 10	10 ± 7	20 ± 9	37 ± 10	17 ± 5	14 ± 4	6 ± 3	436 ± 383	5 ± 6
	51–64	263	10.6 ± 3.7	15 ± 5	41 ± 9	9 ± 6	21 ± 9	39 ± 9	18 ± 4	15 ± 4	6 ± 5	440 ± 257	5 ± 6
	≥65	51	8.0 ± 2.9	18 ± 7	41 ± 11	6 ± 5	19 ± 9	35 ± 11	16 ± 6	13 ± 5	6 ± 2	366 ± 181	6 ± 7
Belgium	25–75	3,596	11.9 ± 3.9	14 ± 4	39 ± 8	n.a.	23 ± 10	41 ± 9	16 ± 5	15 ± 4	8 ± 5	411 ± 273	9 ± 8
Denmark	19–24	86	12.4	14	45	10[4]	22	35	15	11	5	391	6
	25–34	142	12.1	14	42	9[4]	21	36	14	11	5	422	8
	35–44	135	11.2	15	43	7[4]	23	36	15	11	5	414	6
	45–54	147	11.0	14	41	7[4]	22	37	16	12	5	416	7
	55–64	140	11.1	14	42	7[4]	22	38	16	11	5	467	6
Finland	25–34	190	10.0 ± 2.8	16 ± 4	47 ± 8	9 ± 5	21 ± 10	34 ± 7	15 ± 4	12 ± 3	5 ± 2	270 ± 138	3 ± 6
	35–44	215	9.3 ± 3.1	16 ± 4	45 ± 7	9 ± 6	22 ± 10	35 ± 7	14 ± 5	12 ± 3	5 ± 2	266 ± 141	3 ± 7
	45–54	232	8.9 ± 2.6	16 ± 4	45 ± 10	9 ± 5	23 ± 11	35 ± 8	15 ± 5	12 ± 3	5 ± 2	276 ± 167	4 ± 8
	55–64	275	8.7 ± 2.8	16 ± 3	45 ± 8	9 ± 5	22 ± 10	36 ± 8	14 ± 4	12 ± 3	5 ± 2	275 ± 151	3 ± 6
France	45–60	3,323	9.5 ± 2.3	17 ± 4	39 ± 12	n.a.	20 ± 8	37 ± 11	15 ± 7	14 ± 4	5 ± 2	609 ± 316	7 ± 7
Germany	19–24	926	9.7	13	49	13	22	36	14	12	7	274	1
	25–50	5,037	10.2	14	44	12	22	36	14	13	7	300	5
	51–64	2,785	11.4	14	43	12	26	36	14	13	7	345	7
Greece	25–34	794	11.3 ± 3.2	14 ± 2	38 ± 6	n.a.	n.a.	45 ± 6	14 ± 3	22 ± 4	6 ± 2	n.a.	5 ± 5
	35–44	2,776	10.8 ± 3.1	14 ± 2	38 ± 6	n.a.	n.a.	46 ± 5	13 ± 3	22 ± 4	6 ± 2	n.a.	5 ± 6
	45–54	2,683	10.4 ± 3.0	14 ± 2	38 ± 6	n.a.	n.a.	45 ± 6	13 ± 3	22 ± 4	6 ± 3	n.a.	5 ± 6
	55–64	2,353	9.6 ± 2.8	14 ± 2	38 ± 6	n.a.	n.a.	44 ± 6	12 ± 3	21 ± 4	7 ± 3	n.a.	6 ± 7
Hungary	18–34	338	14.8 ± 3.9	15 ± 2	45 ± 6	15 ± 6	n.a.	38 ± 6	14 ± 5	15 ± 5	4 ± 2	655 ± 297	3 ± 4
	35–59	730	13.2 ± 3.2	15 ± 2	43 ± 6	13 ± 6	n.a.	38 ± 6	14 ± 4	15 ± 5	4 ± 2	556 ± 235	4 ± 5
Italy[1]	18–64	n.a.	9.2 ± 2.0	16 ± 4	46 ± 12	15 ± 6	20 ± 7	34 ± 10	10 ± 3	13 ± 4	5 ± 2	341 ± 122	4 ± 5
Norway	20–29	248	12.6	15	51	12	24	32	13	11	6	358	2
	30–59	748	10.6	16	50	8	25	31	12	11	6	334	3
Portugal	18–29	159	10.9 ± 1.9	18 ± 3	48 ± 10	n.a.	23 ± 7	33 ± 6	11 ± 2	14 ± 3	6 ± 1	444 ± 91	1 ± 1
	≥40	310	11.1 ± 2.8	17 ± 5	45 ± 13	n.a.	26 ± 9	28 ± 9	9 ± 3	12 ± 4	5 ± 2	364 ± 132	10 ± 9
Spain	25–60	4,728	10.5	16	42	n.a.	20	37	12	16	5	450	5
Sweden	18–74	589	9.9	16	46	9	18	34	15	13	5	350	4
UK	19–24	108	9.4 ± 2.2	15 ± 3[2]	49 ± 6[2]	17 ± 7[2]	12 ± 4[3]	36 ± 6[2]	14 ± 3[2]	12 ± 2[2]	6[2]	269 ± 134	6 ± 8
	25–34	219	9.8 ± 2.5	16 ± 5[2]	48 ± 6[2]	14 ± 7[2]	15 ± 6[3]	36 ± 5[2]	13 ± 3[2]	12 ± 2[2]	6[2]	298 ± 120	7 ± 7
	35–49	253	9.9 ± 2.6	17 ± 3[2]	47 ± 6[2]	13 ± 7[2]	16 ± 6[3]	36 ± 6[2]	14 ± 3[2]	12 ± 2[2]	6[2]	309 ± 130	7 ± 7
	50–64	253	9.6 ± 2.4	17 ± 3[2]	47 ± 6[2]	12 ± 6[2]	16 ± 6[3]	36 ± 6[2]	13 ± 3[2]	12 ± 2[2]	6[2]	319 ± 127	6 ± 8
Reference values*				10–15**	>55	<10**	>25	<30	<10		6–10	<300**	

[1] Men and women, [2] % of total food energy (excl. alcohol), [3] Non-starchy polysaccharides, [4] added sugar.
* Eurodiet, 2000; ** WHO, 2003; n.a. = not available.

(European Nutrition and Health Report, 2004)

8.4 Annex 4: Intake of energy and macronutrients (mean + SD) in adults of European countries (women)

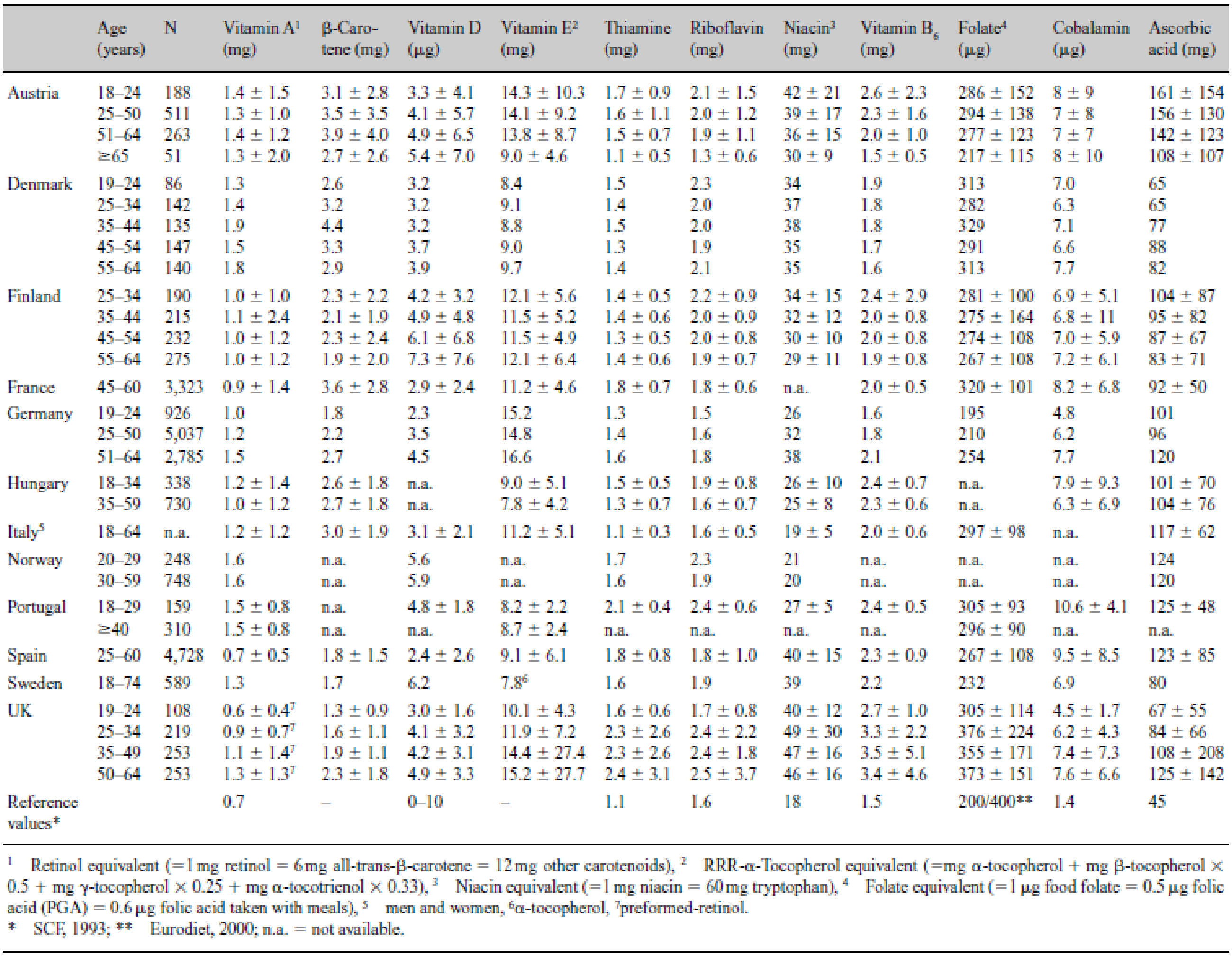


	Age (years)	N	Energy (MJ)	Protein %E	Carbohydrates %E		Dietary fib. (g)	Fat %E	SFA %E	MUFA %E	PUFA %E	Cholesterol (mg)	Alcohol %E
					Total	Sucrose							
Austria	18–24	372	8.8 ± 2.9	14 ± 5	48 ± 11	12 ± 7	19 ± 8	36 ± 10	16 ± 5	14 ± 5	6 ± 3	323 ± 212	2 ± 5
	25–50	777	8.4 ± 2.9	15 ± 5	45 ± 11	11 ± 6	19 ± 9	36 ± 10	17 ± 5	13 ± 4	6 ± 3	306 ± 204	4 ± 5
	51–64	357	8.5 ± 2.7	15 ± 5	44 ± 10	10 ± 6	19 ± 8	38 ± 9	17 ± 3	15 ± 3	6 ± 3	333 ± 187	3 ± 5
	≥65	62	6.7 ± 2.4	17 ± 5	44 ± 10	7 ± 4	17 ± 8	37 ± 9	18 ± 5	13 ± 3	6 ± 4	338 ± 218	2 ± 5
Belgium	25–75	3,274	8.8 ± 2.7	15 ± 4	40 ± 8	n.a.	21 ± 8	42 ± 9	17 ± 5	15 ± 4	9 ± 5	331 ± 220	5 ± 5
Denmark	19–24	100	9.0	13	48	12[4]	17	36	15	10	5	292	3
	25–34	161	9.2	14	47	10[4]	19	36	15	11	5	344	3
	35–44	158	8.5	15	44	9[4]	16	36	15	11	5	332	5
	45–54	155	8.4	15	43	8[4]	18	37	16	11	5	349	5
	55–64	128	8.3	15	43	8	17	35	15	11	5	344	6
Finland	25–34	263	7.1 ± 2.2	16 ± 4	51 ± 8	12 ± 5	17 ± 6	32 ± 7	13 ± 4	10 ± 3	5 ± 2	187 ± 103	1 ± 4
	35–44	266	6.7 ± 2.0	17 ± 3	49 ± 8	11 ± 5	19 ± 7	34 ± 7	14 ± 4	11 ± 3	5 ± 2	197 ± 108	1 ± 4
	45–54	275	6.6 ± 2.0	17 ± 4	48 ± 8	10 ± 5	19 ± 8	33 ± 7	14 ± 4	11 ± 3	5 ± 2	187 ± 86	2 ± 4
	55–64	291	6.2 ± 1.9	17 ± 4	50 ± 8	10 ± 5	20 ± 8	31 ± 7	13 ± 4	10 ± 3	5 ± 2	182 ± 98	1 ± 4
France	35–60	4,879	7.1 ± 1.9	18 ± 5	40 ± 13	n.a.	17 ± 6	39 ± 13	16 ± 6	14 ± 5	5 ± 2	497 ± 268	3 ± 5
Germany	19–24	786	8.7	13	51	15	22	34	14	11	6	226	1
	25–50	5,845	9.7	14	47	12	24	35	14	12	6	280	4
	51–64	2,867	10.3	14	45	13	26	37	16	13	6	344	3
Greece	25–34	1,161	9.0 ± 2.7	15 ± 2	38 ± 5	n.a.	n.a.	48 ± 5	14 ± 2	23 ± 4	6 ± 2	n.a.	1 ± 2
	35–44	3,380	8.8 ± 2.4	14 ± 2	39 ± 5	n.a.	n.a.	48 ± 5	14 ± 2	23 ± 4	7 ± 3	n.a.	1 ± 2
	45–54	3,775	8.4 ± 2.4	14 ± 2	39 ± 5	n.a.	n.a.	47 ± 5	13 ± 3	23 ± 4	7 ± 3	n.a.	1 ± 2
	55–64	4,020	7.6 ± 2.2	14 ± 2	41 ± 5	n.a.	n.a.	46 ± 5	13 ± 3	22 ± 4	7 ± 3	n.a.	1 ± 2
Hungary	18–34	343	9.9 ± 2.7	14 ± 2	47 ± 7	18 ± 8	n.a.	37 ± 6	14 ± 5	15 ± 5	4 ± 2	407 ± 170	1 ± 2
	35–54	938	10.0 ± 2.8	15 ± 2	46 ± 6	16 ± 6	n.a.	38 ± 5	14 ± 5	15 ± 5	4 ± 2	415 ± 181	1 ± 2
Italy[1]	18–64	n.a.	9.2 ± 2.0	16 ± 4	46 ± 12	15 ± 6	20 ± 7	34 ± 10	10 ± 3	13 ± 4	5 ± 2	341 ± 122	4 ± 5
Norway	20–29	268	8.7	15	53	13	20	30	13	11	6	239	2
	30–59	774	7.8	16	51	9	21	31	13	11	6	260	2
Portugal	18–29	87	8.9 ± 1.4	19 ± 3	48 ± 9	n.a.	22 ± 7	33 ± 7	11 ± 3	14 ± 3	6 ± 1.3	382 ± 85	0.3 ± 1
	≥40	416	8.8 ± 2.3	18 ± 5	50 ± 14	n.a.	25 ± 10	30 ± 10	9 ± 4	13 ± 6	5 ± 2	303 ± 120	2 ± 4
Spain	25–60	5,480	7.8	17	43	n.a.	17	39	12	16	6	350	1
Sweden	18–74	626	7.8	16	47	9	16	34	14	12	5	292	3
UK	19–24	104	7.0 ± 1.9	15 ± 4[2]	49 ± 8[2]	14 ± 8[2]	11 ± 4[3]	36 ± 8[2]	13 ± 4[2]	12 ± 3[2]	7[2]	196 ± 112	5 ± 6
	25–34	210	6.6 ± 1.6	16 ± 4[2]	49 ± 6[2]	12 ± 6[2]	12 ± 5[3]	35 ± 6[2]	13 ± 3[2]	12 ± 2[2]	7[2]	188 ± 83	4 ± 5
	35–49	318	6.7 ± 1.8	17 ± 3[2]	49 ± 7[2]	12 ± 7[2]	13 ± 5[3]	34 ± 6[2]	13 ± 3[2]	11 ± 3[2]	6[2]	214 ± 92	4 ± 5
	50–64	259	6.9 ± 1.7	17 ± 3[2]	48 ± 7[2]	11 ± 6[2]	14 ± 5[3]	35 ± 7[2]	13 ± 4[2]	11 ± 3[2]	6[2]	239 ± 93	4 ± 5
Reference values*				10–15**	>55	<10**	>25	<30	<10		6–10	<300**	

[1] Men and women, [2] % of total food energy (excl. alcohol), [3] Non-starchy polysaccharides, [4] added sugar.
* Eurodiet, 2000; ** WHO, 2003; n.a. = not available.

(European Nutrition and Health Report, 2004)

8.5 Annex 5: Vitamin intake (mean + SD) in adults of European countries (men)



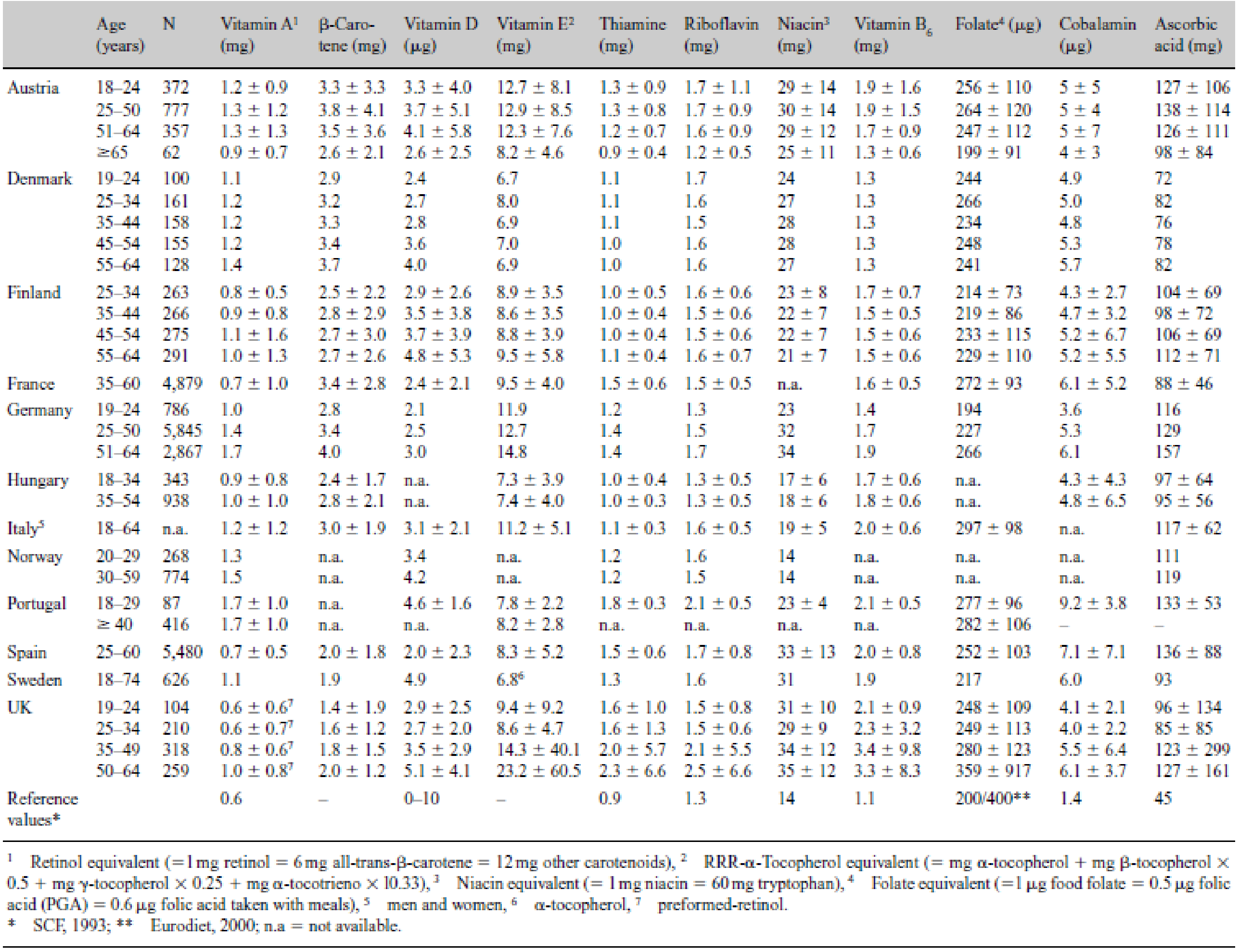
	Age (years)	N	Vitamin A^1 (mg)	β-Carotene (mg)	Vitamin D (µg)	Vitamin E^2 (mg)	Thiamine (mg)	Riboflavin (mg)	Niacin^3 (mg)	Vitamin B$_6$ (mg)	Folate^4 (µg)	Cobalamin (µg)	Ascorbic acid (mg)
Austria	18–24	188	1.4 ± 1.5	3.1 ± 2.8	3.3 ± 4.1	14.3 ± 10.3	1.7 ± 0.9	2.1 ± 1.5	42 ± 21	2.6 ± 2.3	286 ± 152	8 ± 9	161 ± 154
	25–50	511	1.3 ± 1.0	3.5 ± 3.5	4.1 ± 5.7	14.1 ± 9.2	1.6 ± 1.1	2.0 ± 1.2	39 ± 17	2.3 ± 1.6	294 ± 138	7 ± 8	156 ± 130
	51–64	263	1.4 ± 1.2	3.9 ± 4.0	4.9 ± 6.5	13.8 ± 8.7	1.5 ± 0.7	1.9 ± 1.1	36 ± 15	2.0 ± 1.0	277 ± 123	7 ± 7	142 ± 123
	≥65	51	1.3 ± 2.0	2.7 ± 2.6	5.4 ± 7.0	9.0 ± 4.6	1.1 ± 0.5	1.3 ± 0.6	30 ± 9	1.5 ± 0.5	217 ± 115	8 ± 10	108 ± 107
Denmark	19–24	86	1.3	2.6	3.2	8.4	1.5	2.3	34	1.9	313	7.0	65
	25–34	142	1.4	3.2	3.2	9.1	1.4	2.0	37	1.8	282	6.3	65
	35–44	135	1.9	4.4	3.2	8.8	1.5	2.0	38	1.8	329	7.1	77
	45–54	147	1.5	3.3	3.7	9.0	1.3	1.9	35	1.7	291	6.6	88
	55–64	140	1.8	2.9	3.9	9.7	1.4	2.1	35	1.6	313	7.7	82
Finland	25–34	190	1.0 ± 1.0	2.3 ± 2.2	4.2 ± 3.2	12.1 ± 5.6	1.4 ± 0.5	2.2 ± 0.9	34 ± 15	2.4 ± 2.9	281 ± 100	6.9 ± 5.1	104 ± 87
	35–44	215	1.1 ± 2.4	2.1 ± 1.9	4.9 ± 4.8	11.5 ± 5.2	1.4 ± 0.6	2.0 ± 0.9	32 ± 12	2.0 ± 0.8	275 ± 164	6.8 ± 11	95 ± 82
	45–54	232	1.0 ± 1.2	2.3 ± 2.4	6.1 ± 6.8	11.5 ± 4.9	1.3 ± 0.5	2.0 ± 0.8	30 ± 10	2.0 ± 0.8	274 ± 108	7.0 ± 5.9	87 ± 67
	55–64	275	1.0 ± 1.2	1.9 ± 2.0	7.3 ± 7.6	12.1 ± 6.4	1.4 ± 0.6	1.9 ± 0.7	29 ± 11	1.9 ± 0.8	267 ± 108	7.2 ± 6.1	83 ± 71
France	45–60	3,323	0.9 ± 1.4	3.6 ± 2.8	2.9 ± 2.4	11.2 ± 4.6	1.8 ± 0.7	1.8 ± 0.6	n.a.	2.0 ± 0.5	320 ± 101	8.2 ± 6.8	92 ± 50
Germany	19–24	926	1.0	1.8	2.3	15.2	1.3	1.5	26	1.6	195	4.8	101
	25–50	5,037	1.2	2.2	3.5	14.8	1.4	1.6	32	1.8	210	6.2	96
	51–64	2,785	1.5	2.7	4.5	16.6	1.6	1.8	38	2.1	254	7.7	120
Hungary	18–34	338	1.2 ± 1.4	2.6 ± 1.8	n.a.	9.0 ± 5.1	1.5 ± 0.5	1.9 ± 0.8	26 ± 10	2.4 ± 0.7	n.a.	7.9 ± 9.3	101 ± 70
	35–59	730	1.0 ± 1.2	2.7 ± 1.8	n.a.	7.8 ± 4.2	1.3 ± 0.7	1.6 ± 0.7	25 ± 8	2.3 ± 0.6	n.a.	6.3 ± 6.9	104 ± 76
Italy^5	18–64	n.a.	1.2 ± 1.2	3.0 ± 1.9	3.1 ± 2.1	11.2 ± 5.1	1.1 ± 0.3	1.6 ± 0.5	19 ± 5	2.0 ± 0.6	297 ± 98	n.a.	117 ± 62
Norway	20–29	248	1.6	n.a.	5.6	n.a.	1.7	2.3	21	n.a.	n.a.	n.a.	124
	30–59	748	1.6	n.a.	5.9	n.a.	1.6	1.9	20	n.a.	n.a.	n.a.	120
Portugal	18–29	159	1.5 ± 0.8	n.a.	4.8 ± 1.8	8.2 ± 2.2	2.1 ± 0.4	2.4 ± 0.6	27 ± 5	2.4 ± 0.5	305 ± 93	10.6 ± 4.1	125 ± 48
	≥40	310	1.5 ± 0.8	n.a.	n.a.	8.7 ± 2.4	n.a.	n.a.	n.a.	n.a.	296 ± 90	n.a.	n.a.
Spain	25–60	4,728	0.7 ± 0.5	1.8 ± 1.5	2.4 ± 2.6	9.1 ± 6.1	1.8 ± 0.8	1.8 ± 1.0	40 ± 15	2.3 ± 0.9	267 ± 108	9.5 ± 8.5	123 ± 85
Sweden	18–74	589	1.3	1.7	6.2	7.8^6	1.6	1.9	39	2.2	232	6.9	80
UK	19–24	108	0.6 ± 0.4^7	1.3 ± 0.9	3.0 ± 1.6	10.1 ± 4.3	1.6 ± 0.6	1.7 ± 0.8	40 ± 12	2.7 ± 1.0	305 ± 114	4.5 ± 1.7	67 ± 55
	25–34	219	0.9 ± 0.7^7	1.6 ± 1.1	4.1 ± 3.2	11.9 ± 7.2	2.3 ± 2.6	2.4 ± 2.2	49 ± 30	3.3 ± 2.2	376 ± 224	6.2 ± 4.3	84 ± 66
	35–49	253	1.1 ± 1.4^7	1.9 ± 1.1	4.2 ± 3.1	14.4 ± 27.4	2.3 ± 2.6	2.4 ± 1.8	47 ± 16	3.5 ± 5.1	355 ± 171	7.4 ± 7.3	108 ± 208
	50–64	253	1.3 ± 1.3^7	2.3 ± 1.8	4.9 ± 3.3	15.2 ± 27.7	2.4 ± 3.1	2.5 ± 3.7	46 ± 16	3.4 ± 4.6	373 ± 151	7.6 ± 6.6	125 ± 142
Reference values*			0.7	–	0–10	–	1.1	1.6	18	1.5	200/400**	1.4	45

[1] Retinol equivalent (=1 mg retinol = 6 mg all-trans-β-carotene = 12 mg other carotenoids), [2] RRR-α-Tocopherol equivalent (=mg α-tocopherol + mg β-tocopherol × 0.5 + mg γ-tocopherol × 0.25 + mg α-tocotrienol × 0.33), [3] Niacin equivalent (=1 mg niacin = 60 mg tryptophan), [4] Folate equivalent (=1 µg food folate = 0.5 µg folic acid (PGA) = 0.6 µg folic acid taken with meals), [5] men and women, [6]α-tocopherol, [7]preformed-retinol.

* SCF, 1993; ** Eurodiet, 2000; n.a. = not available.

(European Nutrition and Health Report, 2004)

8.6 Annex 6: Vitamin intake (mean +SD) in adults of European countries (women)



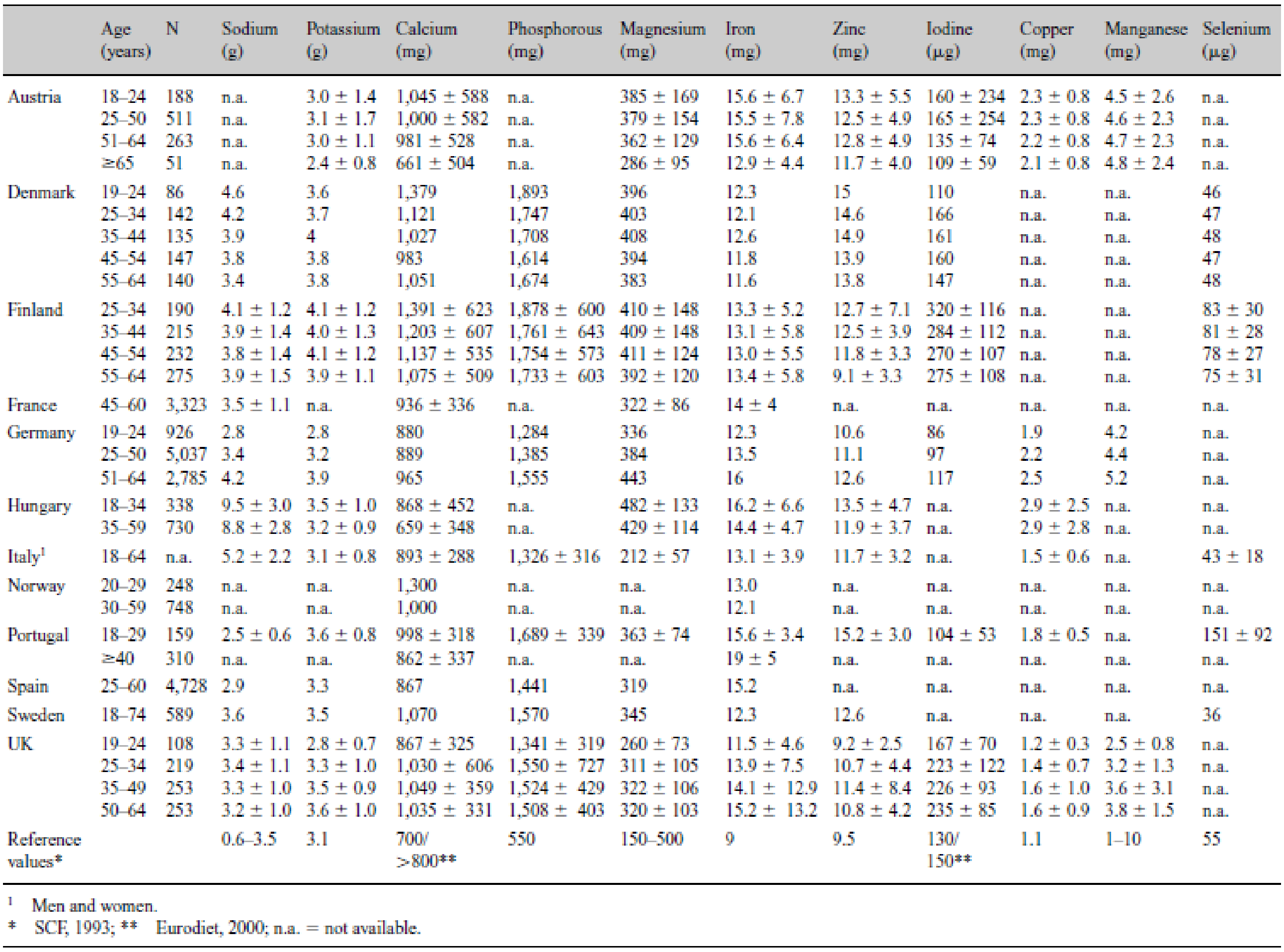
	Age (years)	N	Vitamin A[1] (mg)	β-Carotene (mg)	Vitamin D (µg)	Vitamin E[2] (mg)	Thiamine (mg)	Riboflavin (mg)	Niacin[3] (mg)	Vitamin B_6 (mg)	Folate[4] (µg)	Cobalamin (µg)	Ascorbic acid (mg)
Austria	18–24	372	1.2 ± 0.9	3.3 ± 3.3	3.3 ± 4.0	12.7 ± 8.1	1.3 ± 0.9	1.7 ± 1.1	29 ± 14	1.9 ± 1.6	256 ± 110	5 ± 5	127 ± 106
	25–50	777	1.3 ± 1.2	3.8 ± 4.1	3.7 ± 5.1	12.9 ± 8.5	1.3 ± 0.8	1.7 ± 0.9	30 ± 14	1.9 ± 1.5	264 ± 120	5 ± 4	138 ± 114
	51–64	357	1.3 ± 1.3	3.5 ± 3.6	4.1 ± 5.8	12.3 ± 7.6	1.2 ± 0.7	1.6 ± 0.9	29 ± 12	1.7 ± 0.9	247 ± 112	5 ± 7	126 ± 111
	≥65	62	0.9 ± 0.7	2.6 ± 2.1	2.6 ± 2.5	8.2 ± 4.6	0.9 ± 0.4	1.2 ± 0.5	25 ± 11	1.3 ± 0.6	199 ± 91	4 ± 3	98 ± 84
Denmark	19–24	100	1.1	2.9	2.4	6.7	1.1	1.7	24	1.3	244	4.9	72
	25–34	161	1.2	3.2	2.7	8.0	1.1	1.6	27	1.3	266	5.0	82
	35–44	158	1.2	3.3	2.8	6.9	1.1	1.5	28	1.3	234	4.8	76
	45–54	155	1.2	3.4	3.6	7.0	1.0	1.6	28	1.3	248	5.3	78
	55–64	128	1.4	3.7	4.0	6.9	1.0	1.6	27	1.3	241	5.7	82
Finland	25–34	263	0.8 ± 0.5	2.5 ± 2.2	2.9 ± 2.6	8.9 ± 3.5	1.0 ± 0.5	1.6 ± 0.6	23 ± 8	1.7 ± 0.7	214 ± 73	4.3 ± 2.7	104 ± 69
	35–44	266	0.9 ± 0.8	2.8 ± 2.9	3.5 ± 3.8	8.6 ± 3.5	1.0 ± 0.4	1.5 ± 0.6	22 ± 7	1.5 ± 0.5	219 ± 86	4.7 ± 3.2	98 ± 72
	45–54	275	1.1 ± 1.6	2.7 ± 3.0	3.7 ± 3.9	8.8 ± 3.9	1.0 ± 0.4	1.5 ± 0.6	22 ± 7	1.5 ± 0.6	233 ± 115	5.2 ± 6.7	106 ± 69
	55–64	291	1.0 ± 1.3	2.7 ± 2.6	4.8 ± 5.3	9.5 ± 5.8	1.1 ± 0.4	1.6 ± 0.7	21 ± 7	1.5 ± 0.6	229 ± 110	5.2 ± 5.5	112 ± 71
France	35–60	4,879	0.7 ± 1.0	3.4 ± 2.8	2.4 ± 2.1	9.5 ± 4.0	1.5 ± 0.6	1.5 ± 0.5	n.a.	1.6 ± 0.5	272 ± 93	6.1 ± 5.2	88 ± 46
Germany	19–24	786	1.0	2.8	2.1	11.9	1.2	1.3	23	1.4	194	3.6	116
	25–50	5,845	1.4	3.4	2.5	12.7	1.4	1.5	32	1.7	227	5.3	129
	51–64	2,867	1.7	4.0	3.0	14.8	1.4	1.7	34	1.9	266	6.1	157
Hungary	18–34	343	0.9 ± 0.8	2.4 ± 1.7	n.a.	7.3 ± 3.9	1.0 ± 0.4	1.3 ± 0.5	17 ± 6	1.7 ± 0.6	n.a.	4.3 ± 4.3	97 ± 64
	35–54	938	1.0 ± 1.0	2.8 ± 2.1	n.a.	7.4 ± 4.0	1.0 ± 0.3	1.3 ± 0.5	18 ± 6	1.8 ± 0.6	n.a.	4.8 ± 6.5	95 ± 56
Italy[5]	18–64	n.a.	1.2 ± 1.2	3.0 ± 1.9	3.1 ± 2.1	11.2 ± 5.1	1.1 ± 0.3	1.6 ± 0.5	19 ± 5	2.0 ± 0.6	297 ± 98	n.a.	117 ± 62
Norway	20–29	268	1.3	n.a.	3.4	n.a.	1.2	1.6	14	n.a.	n.a.	n.a.	111
	30–59	774	1.5	n.a.	4.2	n.a.	1.2	1.5	14	n.a.	n.a.	n.a.	119
Portugal	18–29	87	1.7 ± 1.0	n.a.	4.6 ± 1.6	7.8 ± 2.2	1.8 ± 0.3	2.1 ± 0.5	23 ± 4	2.1 ± 0.5	277 ± 96	9.2 ± 3.8	133 ± 53
	≥ 40	416	1.7 ± 1.0	n.a.	n.a.	8.2 ± 2.8	n.a.	n.a.	n.a.	n.a.	282 ± 106	–	–
Spain	25–60	5,480	0.7 ± 0.5	2.0 ± 1.8	2.0 ± 2.3	8.3 ± 5.2	1.5 ± 0.6	1.7 ± 0.8	33 ± 13	2.0 ± 0.8	252 ± 103	7.1 ± 7.1	136 ± 88
Sweden	18–74	626	1.1	1.9	4.9	6.8[6]	1.3	1.6	31	1.9	217	6.0	93
UK	19–24	104	0.6 ± 0.6[7]	1.4 ± 1.9	2.9 ± 2.5	9.4 ± 9.2	1.6 ± 1.0	1.5 ± 0.8	31 ± 10	2.1 ± 0.9	248 ± 109	4.1 ± 2.1	96 ± 134
	25–34	210	0.6 ± 0.7[7]	1.6 ± 1.2	2.7 ± 2.0	8.6 ± 4.7	1.6 ± 1.3	1.5 ± 0.6	29 ± 9	2.3 ± 3.2	249 ± 113	4.0 ± 2.2	85 ± 85
	35–49	318	0.8 ± 0.6[7]	1.8 ± 1.5	3.5 ± 2.9	14.3 ± 40.1	2.0 ± 5.7	2.1 ± 5.5	34 ± 12	3.4 ± 9.8	280 ± 123	5.5 ± 6.4	123 ± 299
	50–64	259	1.0 ± 0.8[7]	2.0 ± 1.2	5.1 ± 4.1	23.2 ± 60.5	2.3 ± 6.6	2.5 ± 6.6	35 ± 12	3.3 ± 8.3	359 ± 917	6.1 ± 3.7	127 ± 161
Reference values*			0.6	–	0–10	–	0.9	1.3	14	1.1	200/400**	1.4	45

[1] Retinol equivalent (=1 mg retinol = 6 mg all-trans-β-carotene = 12 mg other carotenoids), [2] RRR-α-Tocopherol equivalent (= mg α-tocopherol + mg β-tocopherol × 0.5 + mg γ-tocopherol × 0.25 + mg α-tocotrieno × 10.33), [3] Niacin equivalent (= 1 mg niacin = 60 mg tryptophan), [4] Folate equivalent (=1 µg food folate = 0.5 µg folic acid (PGA) = 0.6 µg folic acid taken with meals), [5] men and women, [6] α-tocopherol, [7] preformed-retinol.

* SCF, 1993; ** Eurodiet, 2000; n.a = not available.

(European Nutrition and Health Report, 2004)

8.7 Annex 7: Mineral intake (mean +SD) in adults of European countries (men)



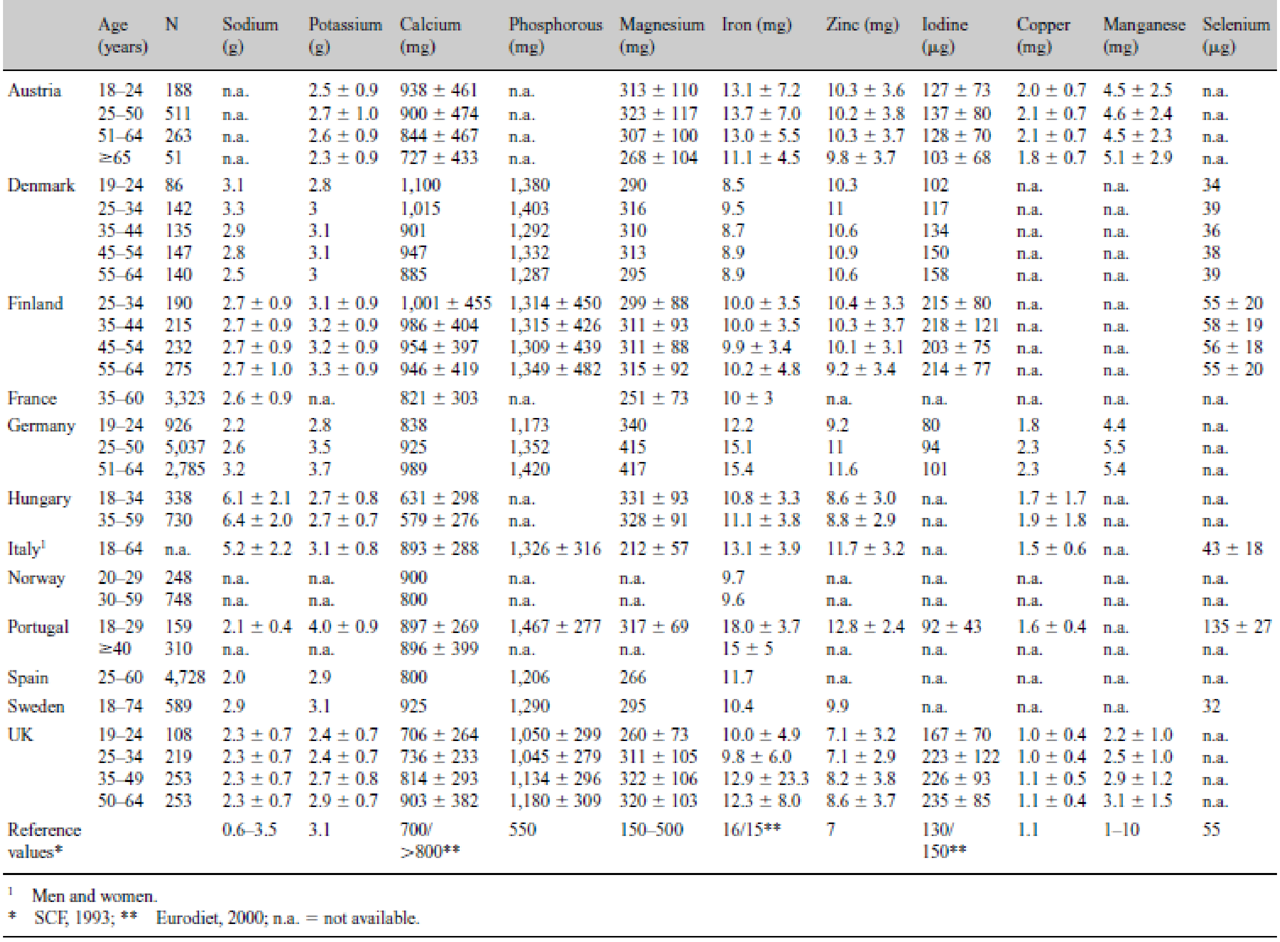
	Age (years)	N	Sodium (g)	Potassium (g)	Calcium (mg)	Phosphorous (mg)	Magnesium (mg)	Iron (mg)	Zinc (mg)	Iodine (µg)	Copper (mg)	Manganese (mg)	Selenium (µg)
Austria	18–24	188	n.a.	3.0 ± 1.4	1,045 ± 588	n.a.	385 ± 169	15.6 ± 6.7	13.3 ± 5.5	160 ± 234	2.3 ± 0.8	4.5 ± 2.6	n.a.
	25–50	511	n.a.	3.1 ± 1.7	1,000 ± 582	n.a.	379 ± 154	15.5 ± 7.8	12.5 ± 4.9	165 ± 254	2.3 ± 0.8	4.6 ± 2.3	n.a.
	51–64	263	n.a.	3.0 ± 1.1	981 ± 528	n.a.	362 ± 129	15.6 ± 6.4	12.8 ± 4.9	135 ± 74	2.2 ± 0.8	4.7 ± 2.3	n.a.
	≥65	51	n.a.	2.4 ± 0.8	661 ± 504	n.a.	286 ± 95	12.9 ± 4.4	11.7 ± 4.0	109 ± 59	2.1 ± 0.8	4.8 ± 2.4	n.a.
Denmark	19–24	86	4.6	3.6	1,379	1,893	396	12.3	15	110	n.a.	n.a.	46
	25–34	142	4.2	3.7	1,121	1,747	403	12.1	14.6	166	n.a.	n.a.	47
	35–44	135	3.9	4	1,027	1,708	408	12.6	14.9	161	n.a.	n.a.	48
	45–54	147	3.8	3.8	983	1,614	394	11.8	13.9	160	n.a.	n.a.	47
	55–64	140	3.4	3.8	1,051	1,674	383	11.6	13.8	147	n.a.	n.a.	48
Finland	25–34	190	4.1 ± 1.2	4.1 ± 1.2	1,391 ± 623	1,878 ± 600	410 ± 148	13.3 ± 5.2	12.7 ± 7.1	320 ± 116	n.a.	n.a.	83 ± 30
	35–44	215	3.9 ± 1.4	4.0 ± 1.3	1,203 ± 607	1,761 ± 643	409 ± 148	13.1 ± 5.8	12.5 ± 3.9	284 ± 112	n.a.	n.a.	81 ± 28
	45–54	232	3.8 ± 1.4	4.1 ± 1.2	1,137 ± 535	1,754 ± 573	411 ± 124	13.0 ± 5.5	11.8 ± 3.3	270 ± 107	n.a.	n.a.	78 ± 27
	55–64	275	3.9 ± 1.5	3.9 ± 1.1	1,075 ± 509	1,733 ± 603	392 ± 120	13.4 ± 5.8	9.1 ± 3.3	275 ± 108	n.a.	n.a.	75 ± 31
France	45–60	3,323	3.5 ± 1.1	n.a.	936 ± 336	n.a.	322 ± 86	14 ± 4	n.a.	n.a.	n.a.	n.a.	n.a.
Germany	19–24	926	2.8	2.8	880	1,284	336	12.3	10.6	86	1.9	4.2	n.a.
	25–50	5,037	3.4	3.2	889	1,385	384	13.5	11.1	97	2.2	4.4	n.a.
	51–64	2,785	4.2	3.9	965	1,555	443	16	12.6	117	2.5	5.2	n.a.
Hungary	18–34	338	9.5 ± 3.0	3.5 ± 1.0	868 ± 452	n.a.	482 ± 133	16.2 ± 6.6	13.5 ± 4.7	n.a.	2.9 ± 2.5	n.a.	n.a.
	35–59	730	8.8 ± 2.8	3.2 ± 0.9	659 ± 348	n.a.	429 ± 114	14.4 ± 4.7	11.9 ± 3.7	n.a.	2.9 ± 2.8	n.a.	n.a.
Italy[1]	18–64	n.a.	5.2 ± 2.2	3.1 ± 0.8	893 ± 288	1,326 ± 316	212 ± 57	13.1 ± 3.9	11.7 ± 3.2	n.a.	1.5 ± 0.6	n.a.	43 ± 18
Norway	20–29	248	n.a.	n.a.	1,300	n.a.	n.a.	13.0	n.a.	n.a.	n.a.	n.a.	n.a.
	30–59	748	n.a.	n.a.	1,000	n.a.	n.a.	12.1	n.a.	n.a.	n.a.	n.a.	n.a.
Portugal	18–29	159	2.5 ± 0.6	3.6 ± 0.8	998 ± 318	1,689 ± 339	363 ± 74	15.6 ± 3.4	15.2 ± 3.0	104 ± 53	1.8 ± 0.5	n.a.	151 ± 92
	≥40	310	n.a.	n.a.	862 ± 337	n.a.	n.a.	19 ± 5	n.a.	n.a.	n.a.	n.a.	n.a.
Spain	25–60	4,728	2.9	3.3	867	1,441	319	15.2	n.a.	n.a.	n.a.	n.a.	n.a.
Sweden	18–74	589	3.6	3.5	1,070	1,570	345	12.3	12.6	n.a.	n.a.	n.a.	36
UK	19–24	108	3.3 ± 1.1	2.8 ± 0.7	867 ± 325	1,341 ± 319	260 ± 73	11.5 ± 4.6	9.2 ± 2.5	167 ± 70	1.2 ± 0.3	2.5 ± 0.8	n.a.
	25–34	219	3.4 ± 1.1	3.3 ± 1.0	1,030 ± 606	1,550 ± 727	311 ± 105	13.9 ± 7.5	10.7 ± 4.4	223 ± 122	1.4 ± 0.7	3.2 ± 1.3	n.a.
	35–49	253	3.3 ± 1.0	3.5 ± 0.9	1,049 ± 359	1,524 ± 429	322 ± 106	14.1 ± 12.9	11.4 ± 8.4	226 ± 93	1.6 ± 1.0	3.6 ± 3.1	n.a.
	50–64	253	3.2 ± 1.0	3.6 ± 1.0	1,035 ± 331	1,508 ± 403	320 ± 103	15.2 ± 13.2	10.8 ± 4.2	235 ± 85	1.6 ± 0.9	3.8 ± 1.5	n.a.
Reference values*			0.6–3.5	3.1	700/ >800**	550	150–500	9	9.5	130/ 150**	1.1	1–10	55

[1] Men and women.

* SCF, 1993; ** Eurodiet, 2000; n.a. = not available.

(European Nutrition and Health Report, 2004)

8.8 Annex 8: Mineral intake (mean + SD) in adults of European countries (women)



	Age (years)	N	Sodium (g)	Potassium (g)	Calcium (mg)	Phosphorous (mg)	Magnesium (mg)	Iron (mg)	Zinc (mg)	Iodine (µg)	Copper (mg)	Manganese (mg)	Selenium (µg)
Austria	18–24	188	n.a.	2.5 ± 0.9	938 ± 461	n.a.	313 ± 110	13.1 ± 7.2	10.3 ± 3.6	127 ± 73	2.0 ± 0.7	4.5 ± 2.5	n.a.
	25–50	511	n.a.	2.7 ± 1.0	900 ± 474	n.a.	323 ± 117	13.7 ± 7.0	10.2 ± 3.8	137 ± 80	2.1 ± 0.7	4.6 ± 2.4	n.a.
	51–64	263	n.a.	2.6 ± 0.9	844 ± 467	n.a.	307 ± 100	13.0 ± 5.5	10.3 ± 3.7	128 ± 70	2.1 ± 0.7	4.5 ± 2.3	n.a.
	≥65	51	n.a.	2.3 ± 0.9	727 ± 433	n.a.	268 ± 104	11.1 ± 4.5	9.8 ± 3.7	103 ± 68	1.8 ± 0.7	5.1 ± 2.9	n.a.
Denmark	19–24	86	3.1	2.8	1,100	1,380	290	8.5	10.3	102	n.a.	n.a.	34
	25–34	142	3.3	3	1,015	1,403	316	9.5	11	117	n.a.	n.a.	39
	35–44	135	2.9	3.1	901	1,292	310	8.7	10.6	134	n.a.	n.a.	36
	45–54	147	2.8	3.1	947	1,332	313	8.9	10.9	150	n.a.	n.a.	38
	55–64	140	2.5	3	885	1,287	295	8.9	10.6	158	n.a.	n.a.	39
Finland	25–34	190	2.7 ± 0.9	3.1 ± 0.9	1,001 ± 455	1,314 ± 450	299 ± 88	10.0 ± 3.5	10.4 ± 3.3	215 ± 80	n.a.	n.a.	55 ± 20
	35–44	215	2.7 ± 0.9	3.2 ± 0.9	986 ± 404	1,315 ± 426	311 ± 93	10.0 ± 3.5	10.3 ± 3.7	218 ± 121	n.a.	n.a.	58 ± 19
	45–54	232	2.7 ± 0.9	3.2 ± 0.9	954 ± 397	1,309 ± 439	311 ± 88	9.9 ± 3.4	10.1 ± 3.1	203 ± 75	n.a.	n.a.	56 ± 18
	55–64	275	2.7 ± 1.0	3.3 ± 0.9	946 ± 419	1,349 ± 482	315 ± 92	10.2 ± 4.8	9.2 ± 3.4	214 ± 77	n.a.	n.a.	55 ± 20
France	35–60	3,323	2.6 ± 0.9	n.a.	821 ± 303	n.a.	251 ± 73	10 ± 3	n.a.	n.a.	n.a.	n.a.	n.a.
Germany	19–24	926	2.2	2.8	838	1,173	340	12.2	9.2	80	1.8	4.4	n.a.
	25–50	5,037	2.6	3.5	925	1,352	415	15.1	11	94	2.3	5.5	n.a.
	51–64	2,785	3.2	3.7	989	1,420	417	15.4	11.6	101	2.3	5.4	n.a.
Hungary	18–34	338	6.1 ± 2.1	2.7 ± 0.8	631 ± 298	n.a.	331 ± 93	10.8 ± 3.3	8.6 ± 3.0	n.a.	1.7 ± 1.7	n.a.	n.a.
	35–59	730	6.4 ± 2.0	2.7 ± 0.7	579 ± 276	n.a.	328 ± 91	11.1 ± 3.8	8.8 ± 2.9	n.a.	1.9 ± 1.8	n.a.	n.a.
Italy[1]	18–64	n.a.	5.2 ± 2.2	3.1 ± 0.8	893 ± 288	1,326 ± 316	212 ± 57	13.1 ± 3.9	11.7 ± 3.2	n.a.	1.5 ± 0.6	n.a.	43 ± 18
Norway	20–29	248	n.a.	n.a.	900	n.a.	n.a.	9.7	n.a.	n.a.	n.a.	n.a.	n.a.
	30–59	748	n.a.	n.a.	800	n.a.	n.a.	9.6	n.a.	n.a.	n.a.	n.a.	n.a.
Portugal	18–29	159	2.1 ± 0.4	4.0 ± 0.9	897 ± 269	1,467 ± 277	317 ± 69	18.0 ± 3.7	12.8 ± 2.4	92 ± 43	1.6 ± 0.4	n.a.	135 ± 27
	≥40	310	n.a.	n.a.	896 ± 399	n.a.	n.a.	15 ± 5	n.a.	n.a.	n.a.	n.a.	n.a.
Spain	25–60	4,728	2.0	2.9	800	1,206	266	11.7	n.a.	n.a.	n.a.	n.a.	n.a.
Sweden	18–74	589	2.9	3.1	925	1,290	295	10.4	9.9	n.a.	n.a.	n.a.	32
UK	19–24	108	2.3 ± 0.7	2.4 ± 0.7	706 ± 264	1,050 ± 299	260 ± 73	10.0 ± 4.9	7.1 ± 3.2	167 ± 70	1.0 ± 0.4	2.2 ± 1.0	n.a.
	25–34	219	2.3 ± 0.7	2.4 ± 0.7	736 ± 233	1,045 ± 279	311 ± 105	9.8 ± 6.0	7.1 ± 2.9	223 ± 122	1.0 ± 0.4	2.5 ± 1.0	n.a.
	35–49	253	2.3 ± 0.7	2.7 ± 0.8	814 ± 293	1,134 ± 296	322 ± 106	12.9 ± 23.3	8.2 ± 3.8	226 ± 93	1.1 ± 0.5	2.9 ± 1.2	n.a.
	50–64	253	2.3 ± 0.7	2.9 ± 0.7	903 ± 382	1,180 ± 309	320 ± 103	12.3 ± 8.0	8.6 ± 3.7	235 ± 85	1.1 ± 0.4	3.1 ± 1.5	n.a.
Reference values*			0.6–3.5	3.1	700/ >800**	550	150–500	16/15**	7	130/ 150**	1.1	1–10	55

[1] Men and women.

* SCF, 1993; ** Eurodiet, 2000; n.a. = not available.

(European Nutrition and Health Report, 2004)

8.9 Annex 9 : European nutritional requirements for human

	Age	Genre	Ca	Fe	P	K	Zn	Se	I	Mg	Vit A	Vit D	Vit E	Vit K	Vit B1	Vit B2	Vit B3	Vit B5	Vit B6	Vit B8	Vit B9	Vit B12	Vit C
			mg	mg	mg	mg	mg	µg	µg	mg	µg	µg	mg	µg	mg	mg	mg	mg	mg	µg	µg	µg	mg
Belgium, Luxembourg (3)	19-59	H	900	9,1	800	3000-4000	11	70	200	420	600	okt/15	15	50-70	1,5	1,5	16	5/dec	2	30-70	200	1,4	110
	19-59	F	900	19,6	800	3000-4000	8	60	200	360	500	okt/15	15	50-70	1,1	1,2	14	5/dec	1,8	30-70	200	1,4	110
Romania (6)	19-64	H	800	7	1000	1950-5460	12	85	150	300	750		10		1,1	1,7	19		1,3-1,9		200	2	40
	19-54	F	800	dec/16	1000	1950-5460	12	70	120	270	750		7		0,8	1,2	13		0,9-1,4		200	2	30
Poland, Slovakia, Czech Republic, Bulgaria, Malta, Portugal, Greece **(4)**	19-30ans	H	1000	8	700	4700	11	55	150	400	900	5	15	120	1,2	1,3	16	5	1,3	30	400	2,4	90
	31-50	H	1000	8	700	4700	11	55	150	420	900	5	15	120	1,2	1,3	16	5	1,3	30	400	2,4	90
	19-30ans	F	1000	18	700	4700	8	55	150	310	700	5	15	90	1,1	1,1	14	5	1,3	30	400	2,4	75
	31-50	F	1000	18	700	4700	8	55	150	320	700	5	15	90	1,1	1,1	14	5	1,3	30	400	2,4	75
Denmark, Estonia, Finland, Latvia, Lithuania, Sweden, (9)	18-30	H	800	9	600	3500	9	50	150	350	900	7,5	10		1,5	1,7	20		1,6		300	2	75
	31-60ans	H	800	9	600	3500	9	50	150	350	900	7,5	10		1,4	1,7	19		1,6		300	2	75
	18-30	F	800	15	600	3100	7	40	150	280	700	7,5	8		1,1	1,3	15		1,3		400	2	75
	31-60ans	F	800	15/sep	600	3100	7	40	150	280	700	7,5	8		1,1	1,3	15		1,2		300	2	75
Spain (7)	20-39	H	800	10	700	3500	15	70	140	350	1000	5	12		1,2	1,8	20		1,8		400	2	60
	40-49	H	800	10	700	3500	15	70	140	350	1000	5	12		1,1	1,7	19		1,8		400	2	60
	20-39	F	800	18	700	3500	15	55	110	330	800	5	12		0,9	1,4	15		1,6		400	2	60
	40-49	F	800	18	700	3500	15	55	110	330	800	5	12		0,9	1,3	14		1,6		400	2	60
United-kingdom(5)	19-50	H	700	8,7	550	3500	9,5	75	140	300	700				1	1,3	17		1,4		200	1,5	40
	19-50	F	700	14,8	550	3500	7	60	140	270	600				0,8	1,1	13		1,2		200	1,5	40
Germany, Austria, Slovenia, Hungry (10)	20-25	H	1000	10	700	2000	10	30-70	200	400	1000	5	15	70	1,3	1,5	17	6	1,5	30-60	400	3	100
	26-51	H	1000	10	700	2000	10	30-70	200	350	1000	5	14	70	1,2	1,4	16	6	1,5	30-60	400	3	100
	20-25	F	1000	15	700	2000	7	30-70	200	310	800	5	12	60	1	1,2	13	6	1,2	30-60	400	3	100
	26-51	F	1000	15	700	2000	7	30-70	200	300	800	5	12	60	1	1,2	13	6	1,2	30-60	400	3	100
Cyprus, Italia (8)	19-65	H	1000	14			7	34	130	260	600	7,5	10	65	1,2	1,3	16		1,5	30	400	2,4	45
	19-50	F	1000	29			4,9	26	110	220	500	5	7,5	55	1,1	1,1	14		1,3	30	400	2,4	45
France (2)	20-65	H	900	9	750		12	60	150	420	800	5	12	45	1,3	1,6	14	5	1,8	50	330	2,4	110
	20-55	F	900	16	750		10	50	150	360	600	5	12	45	1,1	1,5	11	5	1,5	50	300	2,4	110
The Netherlands (1)	19-50	H	1000	11/sep	700		10	50-150		325	1000	2,5-5	13-11,8		1,1	1,5	17	5	1,5			2,8	70
	19-50	F	1000	15			9	50-150		275	800	2,5-5	13-11,8		1,1	1,1	13	5	1,5			2,8	70

1 Aanbevolen dagelijkse hoeveelheden, the food-based dietary guidelines, the health council of The Netherlands, 2006
2 Agence Française De Sécurité Sanitaire Des Aliments, Apports Nutritionnels Conseillés pour la Population Française, 3ème edition, 2004
3 Conseil Supérieur de la Santé, Recommandation Nutritionnelle pour la Belgique, révision 2009
4 Dietary Reference Intakes, the essential guide to nutrient requirements, institut of medicine, 2006
5 Dietary Reference Values (drv) for food energy and nutrients for the united kingdom, Committee on Medical Aspect of Food Policy, 1991
6 Doza Zilnica Recomandata, romedic,
7 Ingestas dietéticas de referencia (idr), nutrition hospitalaria, 2009
8 Livelli di assunzione giornalieri raccomandati di nutrienti per la popolazione italiana (l.a.r.n.), società italiana di nutrizione umana, revisione 1996
9 Nordic nutrition recommendation (nnr), norden, 2004
10 Referenzwerte für die nährstoffzufuhr, d-a-ch, 2008

8.10 Annex 10 : International requirements for human

Nutrients	Units		Europ. AJR	WHO/ FAO 2004	WHO 2007	FAO/WHO/ UNU 1985	DRI	UL	Vege-tarian Diet (Vegan) ADA-report 2003	Mal-nutrition	ISS up to 360 days	NASA Exploration mission require-ments
				Male (19-65y) Women (19-50y) pre-menopausal		Men	males / women (19-30y; 31-50 y)				Men	
Energy	kilojoules (kJ) kilocalories (kcal)	18-30 y				M : 1,7* (15,3*W+679) W : 1,6* (14,7*W+496)				35-40kcal. $kg^{-1}.d^{-1}$	M : 1.7* (15.3*W+679) W : 1,6* (14,7*W+496)	Based on DRI
		> 30 y				M : 1,7* (11,6*W+879) W : 1,6* (8,7*W+829)					M : 1,7* (11,6*W+879) W : 1,6* (8,7*W+829)	
Energy expenditure												
EVA	kJ/h										M : 500-1300 W : 670	
	kJ/kg/h										M : 10.5±2.4 W : 10.9±2.3	
Moon: Driving or riding in thelunar rover (Schoeller, 2000)	kJ/h (% less at earth)										510 -40%	
Moon : variuous experiments outside the lunar module (Schoeller, 2000)	kJ/h (% less at earth)										950 -49	
Moon : general activities (Schoeller, 2000)	kJ/h (% less at earth)										1150 -28	
Protein	% total energy consumed						okt/35		15-20		dec/15	0.8g/kg/d NTE 35% of calories Animal protein 2/3 Vegetal protein 1/3
	g						M : 56 W : 46					
	g.kg-1.J-1						0,8					
	N g/ energy (no protein)									1 g N / 150 to 200 kcal		

Indispensable amino acids							
Histidine	**mg/g protein**	**15**	**15**				
	mg/kg per day	**10**	**8/dec**				
Isoleucine	**mg/g protein**	**30**	**15**				
	mg/kg per day	**20**	**10**				
Leucine	**mg/g protein**	**59**	**21**				
	mg/kg per day	**39**	**14**				
Lysine	**mg/g protein**	**45**	**18**				
	mg/kg per day	**30**	**12**				
Methionine & Cysteine	**mg/g protein**	**22**	**20**				
	mg/kg per day	**15**	**13**				
Methionine	**mg/g protein**	**16**	**Nd**				
	mg/kg per day	**10**	**Nd**				
Cysteine	**mg/g protein**	**6**	**Nd**				
	mg/kg per day	**4**	**Nd**				
Phenylalanine & Tyrosine	**mg/g protein**	**38**	**21**				
	mg/kg per day	**25**	**14**				
Threonine	**mg/g protein**	**23**	**11**				
	mg/kg per day	**15**	**7**				
Tryptophane	**mg/g protein**	**6**	**5**				
	mg/kg per day	**4**	**3,5**				
Valine	**mg/g protein**	**39**	**15**				
	mg/kg per day	**26**	**10**				
Total indispensable amino acids	**mg/g protein**	**277**	**141**				
	mg/kg per day	**184**	**93,5**				
Mean nitrogen requirement	**mg N/kg per day**						
Carbohydrates	**% total energy consumed**			**45-65**		**50-55**	**50-55**
	g			**130**			
Added sugar	**% total energy consumed**	**Max 10**			**25**		
Total fiber				**M : 38** **W : 25**			**10-14g/1000 kcal**
Fat	**% total energy consumed**			**20-35**		**30-35**	**25-35**
n-6 polyunsaturated fatty acids (linoleic acid)	**% total energy consumed**	**5/aug**		**5/okt**			

	g				M : 17 W : 12				
n-3 polyunsaturated fatty acids (a-linolenic acid)	% total energy consumed			1/feb	0,6-1.2		(risk of deficiency)		
	g				M : 1,6 W : 1.1				
Saturated and trans fatty acids	% total energy consumed				Nd				
Fluid	Litres				M : 3,7 W : 2.7	Nd			2
	ml per MJ consumed							238-357	
	ml per kcal							1-1.5	1.0-1.5
								at least 2000 ml/d	
Vitamin A (includes provitamin A carotenoids)	µg retinol equivalent	800	M : 600 W : 500		M : 900 W : 700	3000	(risk of deficiency)	1000	700-900
Vitamin D (calciferol)	µg	5	5		5	50	risk of deficiency	10	25
Vitamin E (a-tocopherol)	mg a-tocophérol equivalent	12	M : 10 W : 7.5		15	1000		20	15
Vitamin K	µg	75	M : 65 W : 55		M : 120 W : 90	Nd		80	90 women 120 men
Vitamin C (ascorbic / dehydro-ascorbic acid)	mg	80	45		M : 90 W : 75	2000		100	90
Vitamin B12 (cobalamin)	µg	2,5	2,4		2,4	Nd	risk of deficiency	2	2.4
Vitamin B6 (pyridoxal, pyridoxine, pyridoxamine, 5'-phosphates (PLP/PNP/PMP)	mg	1,4	1,3		1,3	100		2	1.7
Thiamin (B1; aneurine)	mg	1,1	M : 1,2 W : 1.1		M : 1,2 W : 1.1	Nd		1,5	1.1 women 1.2 1.2 men
Riboflavin (B2)	mg	1,4	M : 1,3 W : 1.1		M : 1,3 W : 1.1	Nd	(risk of deficiency)	2	1.3
Folate	µg	200	400		400	1000		400	400
Niacin	mg Niacin equivalents	16	M : 16 W : 14		M : 16 W : 14	35		20	16
Biotin	µg	50	30		30	Nd		100	30
Pantothenic Acid	mg	6	5		5	Nd		5	30
Calcium	mg	800	1000		1000	2500	1000	1000-1200	1200-2000

Phosphorus	**mg**		**700**		**700**	**4000**		**1000-1200**	**700 (NTE 1.5* calcium)**
Calcium/ Phosphorus		**max**						**1,5**	**< 1.5**
Magnesium	**mg**		**375**	**M : 260** **W : 220**	**M : 420** **W : 320**	**350**		**350**	**320 women** **420 men**
Sodium	**mg**				**1,5**	**2,3**		**1500-3500**	**1500-2300**
Chloride	**mg**		**800**		**2,3**	**3,6**			
Potassium	**mg**				**4,7**	**Nd**		**3500**	**4700**
Iron	**mg**		**14**	**M : 9,1-27,4** **W : 19.6-58.8**	**M : 8** **W : 18**	**45**	**DRI * 1,8**	**10**	**8/okt**
Copper	**mg**		**1**		**900**	**10000**		**1,5-3**	**0.5-9.0**
Manganese	**mg**		**2**		**M : 2,3** **W : 1.8**	**11**		**2/mei**	**1.8 Women** **2.3 men**
Fluoride	**mg**		**3,5**		**M : 4** **W : 3**	**10**		**4**	**2 women** **3 4 men**
Zinc	**mg**		**10**	**M : 4,2-14** **W : 3-9.8**	**M : 11** **W : 8**	**40**	**DRI +**	**15**	**11**
Selenium	**µg**		**55**	**M : 34** **W : 26**	**55**	**400**		**70**	**55-400**
Iodine	**µg**		**150**	**150**	**150**	**1100**	**(risk of deficiency)**	**150**	**0.15**
Chromium	**µg**		**40**		**M : 35** **W : 25**	**Nd**		**100-200**	**35**
Molybdene	**µg**		**50**		**45**	**2000**			
Choline	**mg**				**M : 550** **W : 425**				
Arsenic	**mg**				**Nd**	**Nd**			
Boron	**mg**				**Nd**	**Nd**			
Nickel	**mg**				**Nd**	**1**			
Silicon	**mg**				**Nd**	**Nd**			
Vanadium	**mg**				**Nd**	**1,8**			
Inorganic sulfate	**mg**				**Nd**	**Nd**			

8.11 Annex 11 : Nutritional intake of astronauts during space missions

Items	**Units**	**Missions**												
		Apollo	**Skylab**		**Shuttle**		**Shuttle-Mir Missions**							**ISS**
			Before flight	**In flight**	**Before flight**	**In flight**	**LDM -1**	**LDM -2**	**LDM -3**	**LDM -4**	**LDM -5**	**LDM -6**	**LDM -7**	
Number of subjects	n=	33		9		26								19
Energy	kJ	7,9±1,7		11,9±1,3		8,9±2								
	kcal	1880 ± 414		2845 ± 311		2150								2877±167
Predicted energy requirements	% WHO	64,2±13,6		99,1±8,2		74,0±16,2								99±13
Weight losses	kg	- 3.5 ± 1.3		- 2.4 ± 1.6		- 1.5 ± 1.3								
Protein	g	71,6±18,7		111,0±18,4		79,0±19								126±10
	%	16,3±2,1	15,9±1,6	15,5±1,2	14,8±1,8	14.5 ± 2.3								17±1
Animal protein	g													72±7
Carbohydrates	g	268,8±49,1		413,3±59,3		309,0±73								359±21
	%	58,1±7,1	50,2±5,7	58,1±4,4	54,5±6,6	59.2 ± 5.4								50±3
Total fibers	g													33±4
Fat	g	61,4±21,4		83,2±13,8		63,0±18								99±3
	%	28,8±5,4	33,8±5,3	26,4±3,8	30,8±5	26.9 ± 4.4								31±1
Water	ml	1647±188		2829±529		2153 ± 538								2155±206
Sodium	mg	3666±889,6		5185±947,9		4048±871,9	3466	5193	5530	5743	6047	5539	5088	5625±531
Potassium	mg	2039±672,7		3854±566,9		2437±564,0								3995±360
Calcium	mg	774±212,3		894±141,5		847±206,9	1067	1077	979	1035	858	997	927	1020±109
Phosphorus	mg	1122±324,6		1760±266,5		1242±294,9								1856±165
Magnesium	mg			310±57,8		297±72,3								424±40
P/Ca ratio														
Iron	mg					15,6±3,8	13	20	23	22	22	21	19	22,7±4,5
Zinc	mg					11,9±3,0								22,1±6,2
Copper	mg													3,6±0,9
Manganese	mg													5,7±0,7
Selenium	µg													146±16
Iodine	mg													1,0±2,8
Vitamin A	µg													1420±205
Vit D	µg													4,2±1,0
Vitamin E	mg													12,1±1,9
vitamin K	µg													105±19
Vitamin C	mg													191±39
Thiamin	mg													2,0±0,1
Riboflavin	mg													2,2±0,2
Niacin	mg													29,8±1,9
Pantothenic acid	mg													5,1±0,8

Vitamin B6	mg	2,3±0,2
Folate	µg	434±53
Vitamin B12	µg	4,6±0,7
Biotin	µg	

8.12 Annex 12 : Nutritional requirements estimates for moon and mars mission

Nutrients	Units	Moon	Mars
Energy expenditure [a]	**kilocalories (kcal)** **or kilojoules (kJ)** 1 kJ = 4.184 kcal	**40-45 kcal.kg^{-1}.d^{-1}** **Example :** **M :70 kg = 2800-3150 kcal** **W : 56 kg = 2240- 2520 kcal**	**40-45 kcal.kg^{-1}.d^{-1}** **Example :** **M :70 kg = 2800-3150 kcal** **W : 56 kg = 2240- 2520 kcal**
		M: < 30 y. 1.7*(15.3*W+679) **M: > 30 y. 1,7*(11,6*W+879)** **W: < 30 y. 1,6*(14,7*W+496)** **W: > 30 y. 1,6*(8,7*W+829)** **Example :** **M :70 kg < 30 y. = 2975 kcal** **M: 70 kg > 30 y. = 2875 kcal** **W : 56 kg < 30 y. = 2110 kcal** **W : 56 kg > 30 y. = 2105 kcal**	**M: < 30 y. 1.7*(15.3*W+679)** **M: > 30 y. 1,7*(11,6*W+879)** **W: < 30 y. 1,6*(14,7*W+496)** **W: > 30 y. 1,6*(8,7*W+829) Example :** **M :70 kg < 30 y. = 2975 kcal** **M: 70 kg > 30 y. = 2875 kcal** **W : 56 kg < 30 y. = 2110 kcal** **W : 56 kg > 30 y. = 2105 kcal**
EVA	**kJ/h (kcal/h)**	**M: 500 – 1300 (120-310)** **W: 670 (160)**	**TBD**
	kJ.kg^{-1}.h^{-1} **kcal.kg^{-1}.h^{-1}**	**M : 10.5±2.4 (2.5±0.6)** **W : 10.9±2.3 (2.6±0.6)**	**TBD**
Moon :Driving or riding in the lunar rover (Schoeller, 2000)	**kJ/h** **(% less at earth)**	**510** **(40%)**	**TBD**
Moon : various experiments outside the lunar module (Schoeller, 2000)	**kJ/h** **(% less at earth)**	**950** **(49)**	**TBD**
Moon : general activities (Schoeller, 2000)	**kJ/h** **(% less at earth)**	**1150** **(28)**	**TBD**
Protein [b]	**% total energy consumed**	**10-15 (max 25)**	**10-15 (max 25)**
	g	First 2 months : 1.5 to 1.7 g.kg^{-1}.d^{-1} after 1.2 g.kg^{-1}.d^{-1} Minimum 0.8 g.kg^{-1}.d^{-1}	First 2 months : 1.5 to 1.7 g.kg^{-1}.d^{-1} after 1.2 g.kg^{-1}.d^{-1} Minimum 0.8 g.kg^{-1}.d^{-1}
	N g/ energy(no protein)	**1g N / 150 – 200 kcal**	**1g N / 150 – 200 kcal**
Indispensable amino acids			
Histidine	**mg/g protein**	**15**	**15**
	mg/kg per day	**10**	**10**
Isoleucine	**mg/g protein**	**30**	**30**
	mg/kg per day	**20**	**20**
Leucine	**mg/g protein**	**59**	**59**
	mg/kg per day	**39**	**39**
Lysine	**mg/g protein**	**45**	**45**
	mg/kg per day	**30**	**30**
Methionine and Cysteine	**mg/g protein**	**22**	**22**
	mg/kg per day	**15**	**15**
Methionine	**mg/g protein**	**16**	**16**
	mg/kg per day	**10**	**10**
Cysteine	**mg/g protein**	**6**	**6**

Nutrients	Units	Moon	Mars
	mg/kg per day	4	4
Phenylalanine & Tyrosine	mg/g protein	38	38
	mg/kg per day	25	25
Threonine	mg/g protein	23	23
	mg/kg per day	15	15
Tryptophane	mg/g protein	6	6
	mg/kg per day	4	4
Valine	mg/g protein	39	39
	mg/kg per day	26	26
Total indispensable amino acids	mg/g protein	277	277
	mg/kg per day	184	184
Carbohydrates	% total energy consumed	50 – 55 (45 – 65)	50 – 55 (45 – 65)
	g	4 – 6 g.kg^{-1}.d^{-1} Before EVA : 1-4 g.kg^{-1}.d^{-1}, 1-4 h before During EVA, at least 37g CHO/hour or 1 g CHO.kg^{-1}.h^{-1}	4 – 6 g.kg^{-1}.d^{-1} Before EVA : 1-4 g.kg^{-1}.d^{-1}, 1-4 h before During EVA, at least 37g CHO/hour or 1 CHO.kg^{-1}.h^{-1}
Added sugar	% total energy consumed	<10	<10
Total fiber	g	>30 g	>30g
Fat	% total energy consumed	20-35	20-35
n-6 polyunsaturated fatty acids (linoleic acid)	% total energy consumed	5 - 10	5 - 10
	g		
n-3 polyunsaturated fatty acids (a-linolenic acid)	% total energy consumed	0,6 – 1.2	0,6 – 1.2
	g		
Saturated and trans fatty acids	% total energy consumed	nd	Nd
Fluid	ml per kcal	1-1.5	1-1.5
	Litres	M : 3-4.5 W : 2,1-3.1 At least 2000 ml/d	M : 3-4.5 W : 2,1-3.1 At least 2000 ml/d
	If physical activity or EVA	Min 600 ml/h of effort	Min 600 ml/h of effort
Vitamin A (includes provitamin A carotenoids)	µg retinol equivalent	M: 1000 W: 1000 Max : 3000	M : 1000 W : 1000 Max : 3000
Vitamin D (calciferol)	µg	M : 5-10 W : 5-10 Max : 50 risk of deficiency	M : 5-10 W : 5-10 Max : 50 risk of deficiency
Vitamin E (a-tocopherol)	mg α-tocopherol equivalent	M : 10-20 W : 10-20 Max : 300	M : 10-20 W : 10 -20 Max : 300
Vitamin K	µg	M : 50-70 W : 50-70 Max : nd	M : 65-120 W :55-90 Max : nd
Vitamin C (ascorbic acid, dehydroascorbic acid)	mg	M : 75-100 W : 75 -100 Max : 2000	M : 75-100 W : 75 -100 Max : 2000

Nutrients	Units	Moon	Mars
Vitamin B12 (cobalamin)	**µg**	**M : 2.4 W : 2.4 Max : nd risk of deficiency**	**M : 2.4 W : 2.4 Max : nd risk of deficiency**
Vitamin B6 (pyridoxal, pyridoxine, pyridoxamine, 5'-phosphates (PLP, PNP, PMP)	**mg**	**M : 1.3 - 2 W : 1.3 - 2 Max : 100**	**M : 1.3 - 2 W : 1.3 - 2 Max : 100**
Thiamin (B1; aneurine)	**mg**	**M : 1.2 – 1.5 W : 1.1 -1.5 Max : nd**	**M : 1.2 – 1.5 W : 1.1 -1.5 Max : nd**
Riboflavin (B2)	**mg**	**M : 1.3 - 2 W :1.1 - 2 Max : nd risk of deficiency**	**M : 1.3 - 2 W :1.1 - 2 Max : nd risk of deficiency**
Folate	**µg**	**M : 400 W : 400 Max : 1000**	**M : 400 or more ? W : 400 or more ? Max : 1000**
Niacin	**mg Niacin equivalents**	**M : 16 - 20 W : 14 - 20 Max : 35**	**M : 16 - 20 W : 14 - 20 Max : 35**
Biotin	**µg**	**M : 30 W : 30 Max :nd**	**M : 30 W : 30 Max :nd**
Pantothenic Acid	**mg**	**M : 5 W : 5 Max :nd**	**M : 5 W : 5 Max :nd**
Calcium	**mg**	**M : 1200 W : 1200 Max : 2500**	**M : 1200 W : 1200 Max : 2500**
Phosphorus	**mg**	**M : 800 W : 800 Max : 4000**	**M : 800 W : 800 Max : 4000**
Calcium/Phosphorus		**1.5**	**1.5**
Magnesium	**mg**	**M :260 - 420 W : 220 - 320 Max : 3500**	**M :260 - 420 W : 220 - 320 Max : 3500**
Sodium	**mg**	**M : 2000-2500 W : 2000-2500 Max : 3500**	**M : 2000-2500 W : 2000-2500 Max : 3500**
Chloride	**mg**	**M : 3000-3800 W : 3000-3800 Max : 5400**	**M : 3000-3800 W : 3000-3800 Max : 5400**
Potassium	**mg**	**M : 3000-4000 W : 3000-4000 Max : nd**	**M : 3000 - 4000 W : 3000 - 4000 Max : nd**
Iron	**mg**	**M : 10 W : 10 Max : 45 risk of deficiency**	**M : 10 W : 19.6 Max : 45 risk of deficiency**
Copper	**mg**	**M : 1.5 – 3.0 W : 1.5 – 3.0 Max : 5.0**	**M : 1.5- 3.0 W : 1.5 – 3.0 Max : 5.0**
Manganese	**mg**	**M : 2.0 W : 2.0 Max : 5.0**	**M : 2.0 W : 2.0 Max : 5.0**
Fluoride	**mg**	**M : 3 W : 3 Max : 10**	**M : 3 W : 3 Max : 10**
Zinc	**mg**	**M : 4.2 - 15 W : 3 - 15 Max : 40**	**M : 4.2 - 15 W : 3 - 15 Max : 40**

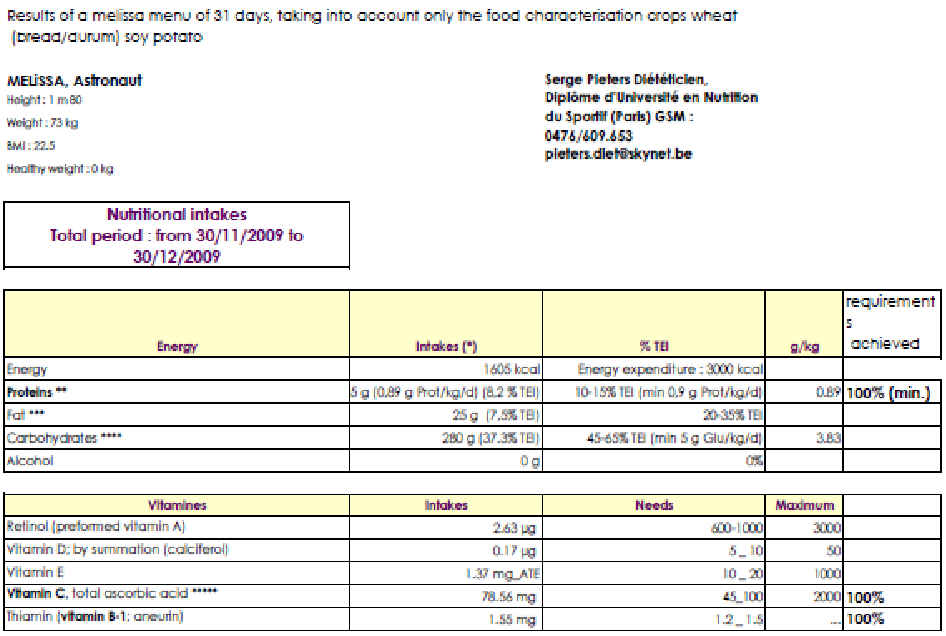
Nutrients	Units	Moon	Mars
Selenium	**µg**	**M : 70** **W : 60** **Max : 400**	**M : 70** **W : 60** **Max : 400**
Iodine	**µg**	**M : 150** **W : 150** **Max :1100** **Risk of deficiency**	**M : 150** **W : 150** **Max :1100** **Risk of deficiency**
Chromium	**µg**	**M : 35** **W : 25** **Max : 250 as supplement**	**M : 35** **W : 25** **Max : 250 as supplement**
Molybdene	**µg**	**M : 45 -50** **W : 45 - 50** **Max : 2000**	**M : 45 -50** **W : 45 - 50** **Max : 2000**
Choline	**mg**	**M : 550** **W : 425** **Max :nd**	**M : 550** **W : 425** **Max :nd**
Arsenic	**mg**	**M : nd** **W : nd** **Max :nd**	**M : nd** **W : nd** **Max :nd**
Boron	**mg**	**M : nd** **W : nd** **Max :nd**	**M : nd** **W : nd** **Max :nd**
Nickel	**mg**	**M : nd** **W : nd** **Max :1**	**M : nd** **W : nd** **Max :1**
Silicon	**mg**	**M : nd** **W :nd** **Max :nd**	**M : nd** **W :nd** **Max :nd**
Vanadium	**mg**	**M : nd** **W : nd** **Max : 1.8**	**M : nd** **W : nd** **Max : 1.8**
Inorganic sulfate	**mg**	**M : nd** **W : nd** **Max :nd**	**M : nd** **W : nd** **Max :nd**

Male astronaut weight preflight 75 kg, In flight 73kg

a) Proteins = 10-15 (max 25% of TEI)
Fats = 20-35 of TEI
Carbohydrates = 50-55% of TEI (45-65)
If we use only low percentage of the requirements we are not able to fulfill 100% of requirements. General habits are = Protein 15% of TEI + Fat 35% of TEI + Carbohydrates 50% of TEI => 100%. The range proposed permit to have more facilities to provide all nutrients. In the case of some days we have more proteins and fat (e.g. days with fat meat or served with sauce high in fat content), in this case we reduce CHO percentage.

b) We can expect that the requirements for proteins will be higher during the 2 - 3 first months to reduce the impact of the travel and to restore the muscle mass. On the other hand, at this time, we don't find any nutritional requirement as countermeasure before a long mission. Maybe a such approach must be tested.

In this annexe, we used only the first four crops (Potatoes, soybean and wheat) with the nutritional content of raw product. This is a first extrapolation. So in this table we can see the maximum amount than we can expect without losses during cooking preparations. With the amount that people generally consumed, we can observe the amount of nutrients obtained and thus we can compare with MELiSSA nutritional requirements. More explanation will be included in the WP6000 Requirements achieved are the percentage of what we can expect for each nutrient with thiskind of menu. For example for protein we can provide minimum requirements, but we have to complete with animal proteins sources form space food. For fat, if we use only crops it will not be possible to cover requirements, eventually if we add oil extraction from MELISSA crops (soybean, wheat, rice) but in this extrapolation it was not include. For carbohydrates, with wheat and potatoes we can provide a large amount of starch, with rice (MELiSSA) and other ISS products we can maybe provide 50% of requirements. For Vitamin C, this extrapolation will cover more than the low range requirement, but this will not take into account losses of vitamin C during storage of potatoes and during food process.



Results of a melissa menu of 31 days, taking into account only the food characterisation crops wheat (bread/durum) soy potato

MELiSSA, Astronaut
Height : 1 m 80
Weight : 73 kg
BMI : 22.5
Healthy weight : 0 kg

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Nutritional intakes
Total period : from 30/11/2009 to 30/12/2009

Energy	Intakes (*)	% TEI	g/kg	requirements achieved
Energy	1605 kcal	Energy expenditure : 3000 kcal		
Proteins **	5 g (0,89 g Prot/kg/d) (8,2 % TEI)	10-15% TEI (min 0,9 g Prot/kg/d)	0.89	**100% (min.)**
Fat ***	25 g (7,5% TEI)	20-35% TEI		
Carbohydrates ****	280 g (37.3% TEI)	45-65% TEI (min 5 g Glu/kg/d)	3.83	
Alcohol	0 g	0%		

Vitamines	Intakes	Needs	Maximum	
Retinol (preformed vitamin A)	2.63 µg	600-1000	3000	
Vitamin D; by summation (calciferol)	0.17 µg	5 _ 10	50	
Vitamin E	1.37 mg_ATE	10 _ 20	1000	
Vitamin C, total ascorbic acid *****	78.56 mg	45_100	2000	**100%**
Thiamin (**vitamin B-1**; aneurin)	1.55 mg	1.2 _ 1.5	...	**100%**

TEI = Total Energy Intake
* This represents 53% of total energy intake
**Necessity to determine the amino acid profile
*** i.e. fat contained in cereals and soy milk
**** this represents all starch needed
***** this represents the amount contained in part in raw potatoes

(1) requirement achieved but phosphorus uptake should be balanced with the other elements to prevent bone decalcification
(2) without added salt
(3) this represents a large amount, but does not include heaminic iron sources
(4) requirement achieved but the maximum could be exceeded when taking into account the amount from the others MELiSSA crops (vegatables)
(5) not including preparation water (e.g. water to cook pasta: one has to multiply dry pasta weight by 2.5)

This table represent the amount of protein per each crop to obtain 100% of the amino acids requirements. The aim of this table is to determine the risk of amino acids deficiencies for each crop. The first column for each crop represents the amount of amino-acids contained in 100 g of products. The second column the amount per 1 g of protein. It is possible for some crops that the total amount of amino-acids are not exactly the content of whole protein of the product. This is due to the average and the range of each amino-acid and also that all of the 20 amino-acids are not always analyzed. The third column for each crop represents the amount obtained if we multiply the amount for 1g of protein by the amount of protein needed to cover requirements for each essential amino acids. (Souci-Fachmann-Kraut food composition and nutrition tables 2010; Spirulina : USDA food composition table SR22)

		SOLANUM TUBEROSUM L.			GLYCINE HYSPIDA MAXIM.			TRITICUM VULGARE VILL.			ORYZA SATIVA L.			Nutritional requirements for an astronaut of 75 kg		
		per 100g of product	per 1 g of protein	amount of protein needed	per 100g of product	per 1 g of protein	amount of protein needed	per 100g of product	per 1 g of protein	amount of protein needed	per 100g of product	per 1 g of protein	amount of protein needed		requirements	
Amount of protein	g	2,4		61,0	38,2		46,0	11,4		63,0	7,8		55,0			
Alanine	mg	110	45,8	2796	1530	40,1	1842	510	44,7	2818	550	70,7	3888			
Arginine	mg	120	50,0	3050	2360	61,8	2842	620	54,4	3426	600	77,1	4242			
Aspartic acid	mg	430	179,2	10929	3990	104,5	4805	700	61,4	3868	840	108,0	5938			
Cystine	mg	20	8,3	508	590	15,4	710	290	25,4	1603	100	12,9	707	300	4	mg/kg
Glutamic acid	mg	460	191,7	11692	6490	169,9	7815	4080	357,9	22547	1640	210,8	11594			
Glycine	mg	120	50,0	3050	1420	37,2	1710	720	63,2	3979	460	59,1	3252			
Histidine	mg	40	16,7	1017	830	21,7	999	280	24,6	1547	190	24,4	1343	750	10	mg/kg
Isoleucine	mg	100	41,7	2542	1780	46,6	2143	540	47,4	2984	340	43,7	2404	1500	20	mg/kg
Leucine	mg	140	58,3	3558	2840	74,3	3420	920	80,7	5084	690	88,7	4878	2925	39	mg/kg
Lysine	mg	130	54,2	3304	1900	49,7	2288	380	33,3	2100	300	38,6	2121	2250	30	mg/kg
Methionine	mg	30	12,5	763	580	15,2	698	220	19,3	1216	170	21,9	1202	750	10	mg/kg
Phenylalanine	mg	100	41,7	2542	1970	51,6	2372	640	56,1	3537	420	54,0	2969	1875	25	mg/kg
Proline	mg	110	45,8	2796	1820	47,6	2192	1560	136,8	8621	390	50,1	2757			
Serine	mg	100	41,7	2542	1690	44,2	2035	710	62,3	3924	470	60,4	3323			
Threonine	mg	90	37,5	2288	1490	39,0	1794	430	37,7	2376	330	42,4	2333	1125	15	mg/kg
Tryptophan	mg	30	12,5	763	450	11,8	542	150	13,2	829	90	11,6	636	300	4	mg/kg
Tyrosine	mg	80	33,3	2033	1250	32,7	1505	410	36,0	2266	320	41,1	2262			
Valine	mg	130	54,2	3304	1760	46,1	2119	620	54,4	3426	500	64,3	3535	1950	26	mg/kg
Total	mg	2340	975	59475	34740	909	41834	13780	1209	76153	8400	1080	59383	13725		

		ALLIUM CEPA L.			LACTUCA SATIVA L.			LYCOPERSICUM ESCULENTUM			Nutritional requirements		
		per 100g of product	per 1 g of protein	amount of protein needed	per 100g of product	per 1 g of protein	amount of protein needed	per 100g of product	per 1 g of protein	amount of protein needed	for an astronaut of 75 kg	requirements	
Amount of protein	g	1,2		105	1,19		100	0,95		286,0			
Alanine	mg							26	27,4	7827			
Arginine	mg	160	136	14237	62	52	5210	18	18,9	5419			
Aspartic acid	mg							121	127,4	36427			
Cystine	mg							1	1,1	301	300	4	mg /kg
Glutamic acid	mg							337	354,7	101455			
Glycine	mg							18	18,9	5419			
Histidine	mg	13	11	1157	21	18	1765	13	13,7	3914	750	10	mg /kg
Isoleucine	mg	19	16	1691	70	59	5882	23	24,2	6924	1500	20	mg /kg
Leucine	mg	33	28	2936	77	65	6471	30	31,6	9032	2925	39	mg /kg
Lysine	mg	57	48	5072	70	59	5882	29	30,5	8731	2250	30	mg /kg
Methionine	mg	12	10	1068	12	10	1008	7	7,4	2107	750	10	mg /kg
Phenylalanine	mg	35	30	3114	54	45	4538	24	25,3	7225	1875	25	mg /kg
Proline	mg							16	16,8	4817			
Serine	mg							28	29,5	8429			
Threonine	mg	20	17	1780	56	47	4706	23	24,2	6924	1125	15	mg /kg
Tryptophan	mg	19	16	1691	11	9	924	6	6,3	1806	300	4	mg /kg
Tyrosine	mg	41	35	3648	34	29	2857	12	12,6	3613			
Valine	mg	28	24	2492	66	55	5546	23	24,2	6924	1950	26	mg /kg
Total	mg		370	38886		448	44790		795	227295	13725		

		'Spirulina spp			BRASSICA OLERACEA L.			SPINACIA OLERACEA L.			Nutritional requirements		
		per 100g of product	per 1 g of protein	amount of protein needed	per 100g of product	per 1 g of protein	amount of protein needed	per 100g of product	per 1 g of protein	amount of protein needed	for an astronaut of 75 kg	requirements	
Amount of protein	g	5,9		43,0	4,3		63,0	2,8		50,0			
Alanine	mg	465	78,5	3378									
Arginine	mg	427	72,1	3102	300	70	4395	130	46	2313			
Aspartic acid	mg	597	100,8	4336									
Cystine	mg	68	11,5	494	69	16	1011	38	14	676	300	4	mg /kg
Glutamic acid	mg	864	145,9	6276									
Glycine	mg	319	53,9	2317									
Histidine	mg	112	18,9	814	100	23	1465	53	19	943	750	10	mg /kg
Isoleucine	mg	331	55,9	2404	140	33	2051	120	43	2135	1500	20	mg /kg
Leucine	mg	509	86,0	3697	250	58	3663	190	68	3381	2925	39	mg /kg
Lysine	mg	312	52,7	2266	240	56	3516	160	57	2847	2250	30	mg /kg
Methionine	mg	118	19,9	857	52	12	762	43	15	765	750	10	mg /kg
Phenylalanine	mg	286	48,3	2077	140	33	2051	110	39	1957	1875	25	mg /kg
Proline	mg	245	41,4	1780									
Serine	mg	309	52,2	2244									
Threonine	mg	306	51,7	2223	130	30	1905	110	39	1957	1125	15	mg /kg
Tryptophan	mg	96	16,2	697	64	15	938	41	15	730	300	4	mg /kg
Tyrosine	mg	266	44,9	1932	180	42	2637	80	28	1423			
Valine	mg	362	61,1	2629	230	53	3370	140	50	2491	1950	26	mg /kg
Total	mg	5992	1012	43523		441	27764		432	21619	13725		