**Table S3.** Summary of the human studies reporting biomarkers positively related to intake of different kinds of meat, found in the systematic literature search. The studies are grouped and classified according to the category for which the biomarkers have been discussed in the main text.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Dietary factor | Study  design | | Number  of  subjects | Analytical  platform | Sample type | Discriminating metabolites / Candidate biomarkers | Primary Reference(s) |
| General biomarkers of all meat intake | | | | | | | |
| Meat (vs. dairy and grain) | 3 x 1w crossover RCT with 18E% protein. | | 47 young men and women | LC-MS | 24-hour urine | Carnosine + 1-MH + 3-MH | [[1](#_ENREF_1)] |
| Terrestrial meats (beef, pork chicken, turkey) and fish oil vs. mixed lean seafood | 2 x 4w crossover RCT | | 20 healthy subjects (7 men), average age 51y | NMR | Morning spot urine | Guanidinoacetate  2,6-dimethylheptanoylcarnitine  Carnitine  N-methyl-2-pyridone-5-carboxamide  3-MH | [[2](#_ENREF_2)] |
| Mixed pork and chicken contrast with herring | 2 x 4w crossover intervention | | 15 obese men and women, 24-70y | GC-MS/MS profiling | Fasting plasma | Agmatine  x-MH | [[3](#_ENREF_3)] |
| Meat and seafood | 3 x 8d crossover RCT | | 14 young adults (6 men) | EA-IRMS | 24-hour urine  and stool | 13C/12C  15N/14N | [[4](#_ENREF_4)] |
| Meat (high, low or none) | 3 x 15d crossover RCT with 7d washout | | 12 men (25-74y) | NMR | 24-hours urine | Creatine  Carnitine  Acetylcarnitine  TMAO  Taurine  1- and 3-Methylhistidine | [[5](#_ENREF_5)] |
| Meat (vs. dairy) | 7d parallel meal study | | 24 boys | NMR | Urine | Creatine  Histidine  Guanidinoacetate | [[6](#_ENREF_6)] |
| Meat vs. milk and bread | 7-10 day parallel study | | 4 young men one young woman | IEC | Urine | 1-Methylhistidine  3-Methylhistidine  Carnosine  Anserine | [[7](#_ENREF_7)] |
| Meat vs. Sustacal | 4d + 7d sequential study | | 14 young men | Amino acid analyzer | 24-hours urine | 1-Methylhistidine | [[8](#_ENREF_8)] |
| Meat and seafood | 5d sequential study | | 5  (2 men), 22-30y | Amino acid analyzer | Urine | 1-Methylhistidine | [[9](#_ENREF_9)] |
| Meat and other protein | 2 x 4d sequential | | 4 adult males | IEC | 24-hour urine | Taurine | [[10](#_ENREF_10)] |
| Meat (rabbit) | Single meal study | | 2 subjects (no details) | paper chromatography | Sequential urine samples | Anserine  Methylhistidines  β-alanine | [[11](#_ENREF_11)] |
| Meat (red, fried and processed meat, fish, shellfish and poultry) | Cross-sectional | | 3559 female twins, 18-84y | LC-MS/MS | Fasting blood (serum and plasma) | Creatine  Pyroglutamine  Trans-4-hydroxyproline | [[12](#_ENREF_12)] |
| Meat (red and processed) | Cross-sectional association with validation group | | 1491 (11% male) | LC-MS/MS | Fasting blood | Trans-4-hydroxyproline  Creatine  Pyroglutamine | [[13](#_ENREF_13)] |
| Meat and processed meat (as component of various diet scores) | Cross-sectional (Baseline of ATBC prospective study) | | 1336 men, 50-69y | LC-MS | Serum | trans-4-hydroxyproline  Ergothioneine  + one unknown | [[14](#_ENREF_14)] |
| Meat or fish (dietary abundance) | Cross-sectional | | 1254 men and women, 40-80y | EA-IRMS | Serum | 15N/14N  13C/12C | [[15](#_ENREF_15)] |
| Meat (total) | Cross-sectional | | 1192 children, 6-11y | LC-MS and NMR | Urine  Serum | Creatine  PCs | [[16](#_ENREF_16)] |
| Meat (total) | Cross-sectional | | 909 (36% male) | LC-MS/MS | Overnight urine | 3-Methylhistidine | [[17](#_ENREF_17)] |
| Meat-based diet | Cross-sectional (baseline of prospective study, EPIC-Oxford) | | 379 men | LC-MS | Plasma | Acylcarnitines (C-0, C-4, and C-5)  Acylcarnitines (C-3, C-16)  Creatinine | [[18](#_ENREF_18)] |
| Meat or fish | Cross-sectional | | 297 (58% men) | NMR | Plasma | TMAO | [[19](#_ENREF_19)] |
| Meat (total intakes) | Cross-sectional | | 294 (101 men), 36-63y | LC-MS | Plasma | Anserine  Carnosine  3-MH | [[20](#_ENREF_20)] |
| Omnivorous diet | Cross-sectional study in vegetarians and omnivores | | 161 (83 men), 18-55y | NMR | Overnight urine | TMAO  Taurine  1- and 3-Methylhistidine | [[21](#_ENREF_21)] |
| Omnivorous diet | Cross-sectional study in vegetarians and omnivores | | 159  (80 men) | Colorimetry | Serum  Urine  Erythrocytes | Creatine  Creatinine (only in men)  Carnitine  Creatinine  Creatine | [[22](#_ENREF_22)] |
| Meat (high vs. low) | Cross-sectional | | 127 men and women, 20-68y | EA-IRMS | Hair | 13C/12C  15N/14N | [[23](#_ENREF_23)] |
| All meat vs. vegetarian | Cross-sectional study in vegetarians and omnivores | | 126 middle-aged  (46 men) | IEC | Overnight urine | 3-Methylhistidine | [[24](#_ENREF_24)] |
| Meat (omnivores vs. vegetarians) | Cross-sectional | | 121 men and women, 17-68y | EA-IRMS | Hair | 13C/12C  15N/14N | [[25](#_ENREF_25)] |
| Omnivorous diet | Cross-sectional study in vegetarians and omnivores | | 41  (22 men) | EA-IRMS | Hair | 15N/14N  13C/12C  34S/32S | [[26](#_ENREF_26)] |
| Omnivorous diet | Cross-sectional study in vegetarians and omnivores | | 30 (details not provided) | EA-IRMS | Hair keratin | 15N/14N  13C/12C | [[27](#_ENREF_27)] |
| Omnivorous diet | Cross-sectional study in vegetarians and omnivores | | 161 (83 men), 18-55y | NMR | Overnight urine | TMAO  Taurine  1- and 3-Methylhistidine | [[21](#_ENREF_21)] |
| Biomarkers of mammalian (red and offal) meat intake | | | | | | | |
| Red meat discontinued intake | 4w Crossover RCT | | 113  (44 men), 21-65y | LC-MS/MS | Blood plasma and urine | TMA and TMAO | [[28](#_ENREF_28)] |
| Red meat (pork and beef) | 3 or 15d crossover in metabolic ward | | 18 males, 24-74y | TEA | Faeces | ATNCs | [[29](#_ENREF_29)] |
| Red meat (pork and beef) | 3 or 15d crossover in metabolic ward | | 17 males, 24-74y | IEC | 24-hour urine | 1-MH  3-MH | [[30](#_ENREF_30)] |
| Pork vs no meat | 2 x 4w RCT | | 14 women, 20-30y | EA-IRMS | Hair  Plasma  Urine | 13C/12C  15N/14N | [[31](#_ENREF_31)] |
| Beef vs. fish | Crossover meal study | | 40 men, 21-50y | LC-MS/MS | fasting and postprandial plasma | TMAO  TMA  DMA | [[32](#_ENREF_32)] |
| Pork (ham) vs. non-meat | Crossover meal-study | | 24 (12 men), 18-65y | NMR | postprandial urine | Creatine | [[33](#_ENREF_33)] |
| Beef vs fish | Crossover meal-study | | 17 men, 41-67y | GC-MS | 0-7h postprandial blood plasma | β-alanine  4-hydroxyproline | [[34](#_ENREF_34)] |
| Beef vs chicken | Crossover meal-study | | 4 women (no details) | LC–MS/MS | Pre- and post-prandial urine | Anserine  Carnosine | [[35](#_ENREF_35)] |
| Red meat and  Offal meat | 15d sequential meals in metabolic ward | | 8 subjects, 24-74y | Competitive enzyme immunoassay | Urine | DHN-MA | [[36](#_ENREF_36)] |
| Red meat (fried beef and pork) vs- dairy and fish | 4-5d sequential meal studies with washout | | 10 adults, (5 men) | Amino acid analyzer | 24hr urine | 1-MH  3-MH | [[37](#_ENREF_37)] |
| Beef vs. no meat | Single meal study | | 18  (9 men), 18-25y | HPLC | Plasma (pre- and post-prandial) | Carnosine | [[38](#_ENREF_38)] |
| Beef | Single meal sequential study | | 7 (4 men), 25-60y | Amino acid analyzer | Urine (pre- and post-prandial) | 1-MH | [[39](#_ENREF_39)] |
| Pork | Single meal sequential study | | 1 male, 45y | HPLC | Urine (pre- and post-prandial) | Carnosine | [[40](#_ENREF_40)] |
| Beef | Single meal sequential study | | 1 male, 45y | HPLC | Urine (pre- and post-prandial) | Carnosine | [[40](#_ENREF_40)] |
| Red meat (beef steak and pork chops) | Cross-sectional study | | 3559 females | LC-MS/MS | Fasting blood (serum and plasma) | Trans-4-hydroxyproline  Pyroglutamine  Creatine | [[12](#_ENREF_12)] |
| Red meat | Cross-sectional study | | 1369 non-smoking women | LC-MS/MS | Urine | PE(P-18:0/20:4)  PE (P-18:0/18:1)  + one unknown | [[41](#_ENREF_41)] |
| Total red meat | Cross-sectional study | | 294 (101 men), 36-63y | LC-MS | Plasma | Carnosine  3-MH | [[20](#_ENREF_20)] |
| Red Meat | Cross-sectionally at baseline in a case-control colorectal cancer study (pearson correlations, FDR<0.1) | | 253 subjects, 125 cases and 128 controls (77 men), average age 18-74y | LC-MS or  GC-MS | 12 h overnight urine (no fasting) | Acetylcarnitine  Xylitol  3-dehydrocarnitine  Ethyl glucuronide  Carnitine  Cinnamoylglycine  Methyl-alpha-glucopyranoside  Sorbitol  + 10 unknowns | [[42](#_ENREF_42)] |
| Red meat | Cross-sectional at RCT baseline | | 125 (53 men), adults | NMR | Plasma and overnight urine | Acetylcarnitine | [[43](#_ENREF_43)] |
| Poultry |  | |  |  |  |  |  |
| Chicken | Parallel RCT meal study with 5 different meats | | 50 (5 x 10) subjects, 50% men, 51-64y | HILIC LC-MS | 24-hour urine | 3-MH  Anserine  + one unknown (pos; m/z=212.0914) | [[44](#_ENREF_44)] |
| Chicken | Crossover meal-study | | 4 women (no details) | LC–MS/MS | 6hr postprandial plasma  7hr postprandial urine | Anserine  Anserine  Carnosine | [[35](#_ENREF_35)] |
| Chicken vs. vegetarian | 24d sequential intervention and time-course study | | 35  (5 men), 20-30y | LC-MS | Plasma | 3-MH | [[45](#_ENREF_45)] |
| Chicken | 3w sequential dose-increase intervention study | | 10 (5 men), ~60y | NMR  LC-MS | Urine  Plasma | Guanidinoacetate  3-MH  1-MH | [[46](#_ENREF_46)] |
| Chicken | Single meal sequential study | | 1 male, 45y | HPLC | Urine (pre- and post-prandial) | Anserine  3-MH  Carnosine | [[40](#_ENREF_40)] |
| Poultry | Cross-sectional | | 3559 female twins, 18-84y | LC-MS/MS | Fasting blood (serum and plasma) | Creatine | [[12](#_ENREF_12)] |
| Poultry | Cross-sectional study | | 1369 non-smoking women, mean age 68y | LC-MS/MS | Urine | 3-MH  + one unknown | [[41](#_ENREF_41)] |
| Chicken | Cross-sectional study | | 565,  50% women, 18-90y | NMR | Fasting urine | Guanidinoacetate | [[46](#_ENREF_46)] |
| Poultry  Chicken  Turkey | Cross-sectional study | | 294  (101 men), 36-63y | LC-MS | Plasma | 3-MH  Carnosine  Anserine | [[20](#_ENREF_20)] |
| Poultry intakes | Cross-sectional study in vegetarians and omnivores | | 126 middle-aged subjects  (46 men) | IEC | Overnight urine | 3-MH | [[24](#_ENREF_24)] |
| Chicken vs. other meats | Cross-sectional study | | 46 (14 men), 40-70y | HILIC LC-MS | 24-hour urine | Seven unknowns (POS m/z= 178.0145,  255.0858, 259.1647, 124.0638,  240.1226, 282.1337, 185.0801) | [[44](#_ENREF_44)] |
| Biomarkers of highly heated meat intake | | | | | | | |
| Beef (fried), high/low doneness | 2 x 4w crossover intervention study | | 41 non-smokers (32 men),  18-63y | LC-MS/MS | Hair samples | PhIP (total) | [[47](#_ENREF_47)] |
| Beef (fried) vs no fried meat | 7w sequential diet intervention study w/o fried beef | | 44 ((36 men), >18y | LC-MS/MS | Hair samples | PhIP (total) | [[48](#_ENREF_48)] |
| Beef (fried) vs no fried meat | 7w sequential diet intervention study w/o fried beef | | 44 ((36 men), >18y | LC-MS/MS | 0-12h postprandially | PhIP  MeIQx  N(2)-hydroxy-PhIP-N2-glucuronide  N(2)-hydroxy-PhIP-N3-glucuronide  2-amino-3-methylimidazo-[4,5-f]quinoxaline-8-carboxylic acid (IQx-8-COOH)  2-amino-8-(hydroxymethyl)-3-methylimidazo[4,5-f]quinoxaline (8-CH2OH-IQx) | [[49](#_ENREF_49)] |
| Beef (fried) | 7w sequential diet intervention study and hair dying | | 14 non-smokers, >18y | LC-MS/MS | Hair samples | PhIP (total) | [[50](#_ENREF_50)] |
| Beef (charbroiled) | 19d sequential diet intervention study | | 10 non-smoking men, 25-45y | GC-MS | Postprandial urine at intervals from 0-72h | N(2)-hydroxy-PhIP-N2-glucuronide  N(2)-hydroxy-PhIP-N3-glucuronide  PhIP-4’-sulphate | [[51](#_ENREF_51)] |
| Beef (charbroiled) | 19d sequential diet intervention study | | 10 non-smoking men, 25-45y | GS-MS | First morning voided urine samples | PhIP (total) | [[52](#_ENREF_52)] |
| Beef (charbroiled) | 19d sequential diet intervention study | | 10 non-smoking men, 25-45y | IAC- SFS | First morning voided urine samples | 1-OHPG | [[53](#_ENREF_53)] |
| Beef (fried) vs. no fried food | Sequential meal study study | | 66 non-smokers  (33 men), 27-62y | HPLC-MS | Post-prandial 24-hour urine | total MeIQx and PhIP | [[54](#_ENREF_54)] |
| Beef (fried) vs. no fried food | Sequential meal study study | | 66 non-smokers  (33 men), 27-62y | GC-MS | Post-prandial 24-hour urine | N-OH-MeIQx-N2-glucuronide | [[55](#_ENREF_55)] |
| Beef (fried) vs. no fried food | Sequential meal study study | | 66 non-smokers  (33 men), 27-62y | GC-MS | Post-prandial 24-hour urine | N-OH-MeIQx-N2-glucuronide | [[56](#_ENREF_56)] |
| Beef (fried) vs. no fried food | Sequential meal study | | 66 non-smokers  (33 men), 27-62y | GC-MS | Post-prandial 24-hour urine | N-OH-PhIP-N2-glucuronide | [[57](#_ENREF_57)] |
| Beef (fried) vs. no fried food | Sequential meal study | | 66 non-smokers  (33 men), 27-62y | HPLC | Pre and post-prandial 24-hour urine | PhIP | [[58](#_ENREF_58)] |
| Beef (fried) w/o broccoli diet | Sequential meal study, 12 days washout. | | 20 non-smoking men | LC-MS/MS | Postprandial 0-48h urine | N(2)-hydroxy-PhIP-N2-glucuronide  N(2)-hydroxy-PhIP-N3-glucuronide  PhIP (total)  MeIQx (total) | [[59](#_ENREF_59)]  [[60](#_ENREF_60)] |
| Beef (fried) vs. no meat | Sequential meal study study | | 8 men, 40-57y | GC-MS | Pre and post-prandial 12-hour urine | PhIP (total)  MeIQx (total)  4'-OH-PhIP (total) | [[61](#_ENREF_61)] |
| Beef (fried) w/o broccoli | Sequential meal intervention study | | 6 women (no details) | LC-MS | Pre and post-prandial 12-hour urine | N-2-OH-PhIP-N-2-glucuronide,  PhIP-N-2-glucuronide,  4'-PhIP-glucuronide  N-2-OH-PhIP-N3-glucuronide | [[62](#_ENREF_62)] |
| Beef (fried) vs. no fried food | Sequential meal study | | non-smokers (details not provided) | LC–MS/MS | Post-prandial 48-hour urine | IQ  MeIQx  Trp-P-2  Trp-P-1  PhIP  AαC  Norharman  Harman | [[63](#_ENREF_63)] |
| Meat (cooked) | Single meal study | | 100 nonsmoking men, 18-34y | LC-MS | 12h pre- and post-meal | PhIP (free) | [[64](#_ENREF_64)] |
| Chicken (Fried) | Single meal study | | 12 non-smoking males | LC-MS/MS | Pre and post-prandial 24-hour urine | N2-OH-PhIP-N2-glucuronide  N2-PhIP glucuronide  N2-OH-PhIP-N3-glucuronide  4'-PhIP-sulfate | [[65](#_ENREF_65)] |
| Lamb kebab | Single meal study | | 12 non-smoking students (6 men) | HPLC | Urine | 13 different monohydroxy PAH metabolites (OHPAHs) | [[66](#_ENREF_66)] |
| Chicken (Fried) | Single meal study | | 11 men and women (no details) | LC-MS | Spot urine and post-prandial urine | PhIP  4′-OH-PhIP  5-OH-PhIP | [[67](#_ENREF_67)] |
| Chicken (Fried) | Single meal study | | 10 men and women, 25-45y | LC-MS/MS | Pre and post-prandial 24-hour urine | N2-OH-PhIP-N2-glucuronide  N2-PhIP- glucuronide  N2-OH-PhIP-N3-glucuronide  4’-PhIP-Sulfate | [[68](#_ENREF_68)] |
| Beef (fried), high/low intensity | Two single-meal studies | | 9+6 non-smokers | 32P-postlabelling | 24h urine samples | 1-OHP | [[69](#_ENREF_69)] |
| Chicken (barbequed) | Single meal study | | 9 non-smokers  (5 men),  23-61y | GC/MS | Urine | 1- and 2-hydroxy-NAP  2-, 3-, and 9-hydroxy-FLU  1-, 2-, 3-, and 4-hydroxy-PHE  1-OHP | [[70](#_ENREF_70)] |
| Pork (charcoal-barbecued) | Two single meal studies with different PAH dose | | 8 (3 men) + 5 (2 men) nonsmoking students | HPLC-FLD | Pre and post-prandial 12-hour urine | 1-OHP | [[71](#_ENREF_71)] |
| Pork (charcoal-barbecued) | Two single meal studies with different PAH dose | | 8 (3 men) + 5 (2 men) nonsmoking students | HPLC-FLD | Pre and post-prandial 12-hour urine | 3-OHBaP | [[72](#_ENREF_72)] |
| Chicken (Fried) | Single meal study | | 8 non-smokers  (4 men),  28-59y | LC-MS/MS | Post-prandial 12-hour urine | PhIP  4′-OH-PhIP  5-OH-PhIP  Norharman | [[73](#_ENREF_73)] |
| Chicken (Fried) | Single meal study | | 8 non-smoking healthy females | LC-MS/MS | Pre and post-prandial 24-hour urine | N2-OH-PhIP-N3-glucuronide,  PhIP-N2-glucuronide  4'-PhIP-sulfate (minor)  N2-OH-PhIP-N3-glucuronide (minor) | [[74](#_ENREF_74)] |
| Meat (fried beef or fish) | Single meal study | | 7 volunteers (no details) | GC-MS | Post-prandial 12-hour urine | MeIQx free and conjugated | [[75](#_ENREF_75)] |
| Chicken (Fried) | Single meal study | | 6 male non-smokers, 20-30y | LC-MS/MS | Urine and fecal samples up to 72 h after the meal | PhIP  PhIP-MI | [[76](#_ENREF_76)] |
| Meat (barbequed) | Single meal study | | 5 non-smokers (3 men), 25-53y | HPLC | daily 8-h urine | 1-OHP | [[77](#_ENREF_77)] |
| Meat (grilled, roasted, or broiled) | Cross-sectional study | | 304 women, 27-80y | IAC- SFS | 24-hour urine | 1-OHPG | [[78](#_ENREF_78)] |
| Fried meats vs. no fried food | Cross-sectional  study | | 129 male non-smokers, >35y | GC-MS | 24h urine | MeIQx (free and acid labile) | [[79](#_ENREF_79)] |
| Fried meats vs. no fried food | Cross-sectional  study | | 129 male non-smokers, >35y | LC-MS  GC-MS | 24h urine | PhIP (free and acid libile)  MeIQx (free and acid labile) | [[80](#_ENREF_80)] |
| Red (fried) and processed meat | Repeated cross-sectional study | | 111 women, 40-75y | IAC- SFS | Single spot urine sample in two seasons | 1-OHPG | [[81](#_ENREF_81)] |
| Meat (fried) vs. vegetarian | Cross-sectional study | | 35 smoking or non-smoking subjects (no other details) | GC-MS | blood albumin  erythrocyte globin | PhIP adducts | [[82](#_ENREF_82)] |
| Beef (fried) | Cross-sectional study | | 20  (7 men), 25-57y | LC-MS | Hair samples collected twice | PhIP (total)  MeIQx (total) | [[83](#_ENREF_83)] |
| Meat (grilled/stir-fried) | Cross-sectional FFQ validation study | | 20  (7 men), 25-57y | LC-MS | Hair samples collected twice | PhIP | [[84](#_ENREF_84)] |
| Meat (fried/grilled) | Cross-sectional study | | 14 non-smokers (6 men), 21-51y | GC/MS | Hair | PhIP | [[85](#_ENREF_85)] |
| Meat (Cooked) vs. no meat | Cross-sectional study | | 12 non-smokers, 6 meat-eaters, 6 vegetarians | LC-MS/MS | Hair samples | PhIP | [[86](#_ENREF_86)] |
| Processed meat | | | | | | | |
| Processed meat | 2 x 14 days crossover RCT study in metabolic suite | | 16 non-smokers (5 men), 20-85y | TEA | Fecal sample | ATNC | [[87](#_ENREF_87)] |
| Ham (Cooked) w/o Ca and vit E | 2 x 4d cross-over intervention study | | 17 men, 40-75y | TEA (for ANTC)  UV-VIS spectrometry (for TBARS and heme) | Fecal sample | ATCN  TBARS  heme | [[88](#_ENREF_88)] |
| Processed meat vs. other meats | Parallel RCT meal study with 5 different meats | | 50 (5 x 10) subjects, 50% men, 51-64y | HILIC LC-MS | 24-hour urine | Two unknowns (POS m/z=240.1226,  160.0849) | [[44](#_ENREF_44)] |
| Nitrite-preserved meats vs. vegetarian | Sequential dietary change intervention study | | 6 (4 male, 2 female), 37-55y; 22 vegans, 18-65y and 14 vegetarians, 26-36y | GC-TEA | 4-day 24-hour urine collections | N-nitrosoproline | [[89](#_ENREF_89)] |
| Smoked food | Single-meal study | | 13 smokers and non-smokers (no details) | HPLC-FLD | Urine collections over 24 hours | 1-OHP | [[90](#_ENREF_90)] |
| Sausage and bacon | Cross-sectional study | | 3559 female twins, 18-84y | LC-MS/MS | Fasting blood (serum and plasma) | Pyroglutamine  Creatine | [[12](#_ENREF_12)] |
| Processed meat | Cross-sectional study | | 1369 non-smoking women | LC-MS/MS | Urine | X-18922 | [[41](#_ENREF_41)] |
| Processed meat | Cross-sectional analysis of nested case-control study | | 502 CRC cases and controls (281 men), 55-74y | LC-MS/MS  GC-MS | Serum | Lathosterol | [[91](#_ENREF_91)] |
| Processed meat | Cross-sectional | | 294 (101 men), 36-63y | LC-MS | Plasma | Anserine | [[20](#_ENREF_20)] |
| Processed meat | Cross-sectionally at baseline in a case-control colorectal cancer study (pearson correlations, FDR<0.1) | | 253 subjects, 125 cases and 128 controls (77 men), average age 18-74y | LC-MS or  GC-MS | 12 h overnight urine (no fasting) | Acetylcarnitine  Carnitine  + 3 unknowns | [[42](#_ENREF_42)] |
| Processed meat | Cross-sectional study | | 239 males, 55-79y | ESI-MS/MS | Blood sample | PC(38:4) | [[92](#_ENREF_92)] |
| Processed meat (bacon, pork/ham and sausage/  luncheon meats) | Cross-sectional study | | 131 subjects (61 smokers), >35y | GC-MS | Overnight urine | MeIQx (total) | [[93](#_ENREF_93)] |
| Processed meat | Cross-secttional study | | 46 (14 men), 40-70y | HILIC LC-MS | 24-hour urine | Carnosine  2-Methylbutyrylcarnitine  Propionylcarnitine  1-Methylhistidine  3-Methylhistidine  + two unknowns (POS m/z=240.1226,  160.0849) | [[44](#_ENREF_44)] |
| Biomarkers of fish intake | | | | | | | |
| New Nordic Diet (fish component) | | 3 mo. Crossover RCT | 834 school children, (434 boys) 9-11y | GC | Fasting whole blood | EPA  DHA | [[94](#_ENREF_94)] |
| Fish vs. meat | | 12w Parallel RCT | 415 adolescents (195 boys), 14-15y | GC | serum | EPA  DHA  DPA  omega3 index (n-3 PUFA/total FA) | [[95](#_ENREF_95)] |
| New Nordic Diet (fish component >43g/10MJ) vs. average Danish diet | | 6 mo. Parallel RCT | 181 centrally obese (52 men), 18-65y | LC-MS | Urine | TMAO | [[96](#_ENREF_96)] |
| Nordic diet with high fish vs. habitual | | 18-24w Parallel RCT | 166 middle-aged overweight subjects (63 men) | GC | Fasting blood samples | EPA  DHA | [[97](#_ENREF_97)] |
| Fatty fish vs. other meat  Salmon  Herring | | 8w Parallel RCT | 126 women, 35-70y | Capillary-GC | Fasting blood samples at baseline and after 8wks | DHA  EPA+DHA  n-3 FA  n-6/n-3 PUFA ratio  EPA  EPA | [[98](#_ENREF_98)] |
| Nordic diet (fish component) | | 12w Parallel RCT | 106 with metabolic syndrome (age and gender not provided) | HPLC-MS | Fasting blood plasma samples | CMPF | [[99](#_ENREF_99)] |
| High-protein Mediterranean-style diet vs. AHA control | | 6 mo Parallel RCT | 96 overweight subjects (52 men) average age 49y |  | plasma | CMPF  EPA | [[100](#_ENREF_100)] |
| Salmon Atlantic Farmed, 3 servings/wk vs control | | 6mo Parallel RCT | 95 male sexual offenders in custody, 21-60y | GLC | Fasting blood samples  (erythrocytes) | EPA+DHA | [[101](#_ENREF_101)] |
| Salmon (Atlantic) vs. lean fish | | 8-week Parallel RCT | 92 dyslipidemic men, 35-70y | GC | Fasting blood samples | EPA  DHA  DPA  n-6/n-3 PUFA ratio  n-3 PUFA | [[102](#_ENREF_102)] |
| Fatty fish vs. lean fish | | 12w Parallel RCT | 79 pre-diabetic subjects (40 men), 43-72y | GLC | Esterified FA in plasma | EPA  DPA  DHA | [[103](#_ENREF_103)] |
| Herring (5 meals/week) vs. chicken and pork | | 2 x 6w crossover RCT | 35 overweight men, 35-60y | GC | Whole blood | (EPA + DHA):AA  EPA  DHA | [[104](#_ENREF_104)] |
| Cod and haddock | | Parallel RCT meal study with five different meats | 46 (14 men), 40-70y | HILIC LC-MS | 24h-urine samples  Fasting plasma samples | 3-MH  TMAO  (no markers) | [[44](#_ENREF_44)] |
| Wild or farmed salmon | | 4w parallel double-blinded RCT | 28 healthy men, 20-49y | HPLC | Plasma on days 0, 3, 6, 10, 14 and 28 | Astaxanthin | [[105](#_ENREF_105)] |
| Mackerel | | 4w Parallel RCT | 28 men, 21-28y | Capillary GC | Plasma | n-3 FA  EPA  DHA | [[106](#_ENREF_106)] |
| Salmon | | 3 x 4w crossover RCT | 25 subjects (14m, 11f) | GC | Erythrocyte membranes | EPA  DHA | [[107](#_ENREF_107)] |
| Fatty fish (2x per week) | | 4w Crossover RCT | 25 (14 men), 23-65y | Capillary-GC | Fasting plasma PL | EPA  DHA | [[108](#_ENREF_108)] |
| Salmon (smoked) vs. non-meat meals | | 4 x Cross-over (latin squares) meal study | 24 healthy volunteers (sex and age not provided for all), >18y | FIE-MS and GS-MS | 0, 1.5, 3 and 4.5h urine samples | TMAO  Anserine  x-MH  + one unknown | [[109](#_ENREF_109)] |
| Fish (high vs. low) | | 24w parallel RCT | 22 (10 men), >40y | GC-MS | 12-h fasting blood samples | EPA  DHA | [[110](#_ENREF_110)] |
| Salmon (Atlantic farmed), 180, 360 or 540g/w | | 3 x 4w crossover RCT, 4-8w washout | 19 healthy men and women (numbers not provided), 40-65y | GC | Fasting plasma PL | EPA  DHA  n-3 PUFA  EPA+DHA  n-6/n-3 PUFA ratio | [[111](#_ENREF_111)] |
| Herring vs. pork and chicken | | 2 x 4w crossover RCT, 2w washout | 13 overweight or obese subjects, 24-70y | Capillary-GC | Fasting plasma samples | EPA/AA ratio  EPA  DHA  n-6/LCPUFA  n-6/n-3 | [[112](#_ENREF_112)] |
| Lean fish (cod) vs. beef | | Crossover meal study | 40 men, 21-50y | LC-MS/MS | fasting and postprandial plasma  Urine | TMAO  MA  DMA  TMAO | [[32](#_ENREF_32)] |
| Salmon (smoked) vs. non-fish meals | | Cross-over meal study | 24 healthy volunteers (gender not provided), >18y | FIE-MS, GS-MS | 1.5-, 3-,  and 4.5-h postprandial urine | x-MH  Anserine  TMAO  Unknown (m/z= 221.06445) | [[113](#_ENREF_113)] |
| Fish vs. animal or vegetable protein | | Crossover meal study (9 meals) | 17 (4 men), 20-30y | LC-MS | 24-hour urine | TMAO | [[114](#_ENREF_114)] |
| Lean fish (cod) | | Crossover RCT meal study | 11 obese pre-diabetics (3 men), 40-68y | GLC | Plasma | TMAO  N,N,N-trimethyllysine  1,2,3,4-Tetrahydro-β-carboline-3-carboxylic acid  Arsenobetaine (AsB)  Methylhistidines | [[115](#_ENREF_115)] |
| Salmon (Atlantic) vs. meat or vegetarian | | 3 x 3w sequential study with 3w washout | 29 healthy subjects (14 men), 22-52y | Capillary-GC | Fasting Serum  Blood phospholipids  Platelet phospholipid | DHA  EPA  EPA  DPA  DHA  AA/EPA  DHA  EPA  AA/EPA | [[116](#_ENREF_116)] |
| Fish vs other meals | | Sequential meal study | 8 volunters (no details) | NMR | Urine | TMAO | [[117](#_ENREF_117)] |
| Fish vs. other proteins | | Six Sequential meal studies | 7 (1 man), 28-45y | NMR | Urine samples (4 per day) | TMAO  Creatine  3-Methylhistidine | [[118](#_ENREF_118)] |
| Fish | | Sequantial meal study | 6 healthy non-smoking men, average 32y | GC | Urine | TMAO | [[119](#_ENREF_119)] |
| Eel | | Single meal sequential study | 1 man, 45y | HPLC | Urine (pre- and post-prandial) | Carnosine | [[40](#_ENREF_40)] |
| Tuna | | Single meal sequential study | 1 man, 45y | HPLC | Urine (pre- and post-prandial) | Anserine  1-Methylhistidine  Carnosine | [[40](#_ENREF_40)] |
| Fish (Total lean + fatty) | | 3y prospective study | 214 diabetics (112 men), >20y | GC | Plasma phospholipids (fasting at baseline, non-fasting at follow-up) | EPA  DPA  DHA  Sum n-3  Sum n-6  PLN3-index  n-6/n-3 LC-PUFA | [[120](#_ENREF_120)] |
| Fatty Fish | | 3y Prospective study | 214 diabetics (112 men), >20y | GLC | Plasma phospholipids (fasting at baseline, non-fasting at follow-up)) | EPA  DHA  n-3 FA  n-6 FA  Ratio of n-6/n-3 PUFA | [[120](#_ENREF_120)] |
| Lean Fish | | 3y prospective study | 214 diabetics (112 men), >20y | GC | Plasma phospholipids (fasting at baseline, non-fasting at follow-up) | EPA  DHA  n-3 PUFA  n-6 PUFA | [[120](#_ENREF_120)] |
| Fish intake level | | 9 mo. Prospective study | 90 mothers, 63 infants (1 mo.) | GC | Fasting serum | DHA  EPA  n-6/n-3 PUFA ratio | [[121](#_ENREF_121)] |
| Fatty fish  Lean fish Total fish | | Cross-sectional study | 3003 (1421 men), 45-64y | GLC | Plasma Phospholipids | DHA  EPA  DHA  DHA | [[122](#_ENREF_122)] |
| Fish | | Cross-sectional study | 1369 non-smoking women | LC-MS/MS | Urine | CMPF  DHA  EPA  Choline(C22:6)  Choline(C20:5)  MG(22:6/0:0/0:0)  +1 unknown | [[41](#_ENREF_41)] |
| Dark fish | | Cross-sectional study | 1369 non-smoking women | LC-MS/MS | Urine | CMPF  DHA  EPA  DPA  Choline(C22:6)  Choline(C20:5)  MG(22:6/0:0/0:0)  SM(d18:2/18:1)  +2 unknowns | [[41](#_ENREF_41)] |
| Fish (as component of certain diet scores) | | Cross-sectional (Baseline of ATBC prospective study) | 1336 men, 50-69y | LC-MS | Serum | CMPF  DHA  DPA  EPA  PC(34:1)  MG(22:6/0:0/0:0)  FA(18:4n–3)  LPC(22:6)  N-acetyl-3-methylhistidine  3-Methylhistidine  Ergothioneine  Creatine | [[14](#_ENREF_14)] |
| Fish protein | | Cross-sectional | 1254 men and women, 40-80y | EA-IRMS | Serum | 15N/14N  13C/12C | [[15](#_ENREF_15)] |
| Fish-based diet (oily fish) | | Cross-sectional study | 44 Yup’ik Eskimos (14 men), >14y | EA-IRMS | Hair | 15N/14N  13C/12C | [[123](#_ENREF_123)] |
| Fish-based diet (oily fish) | | Cross-sectional study | 496 Yup’ik Eskimos (208 men), >14y | EA-IRMS | RBC | 15N/14N | [[124](#_ENREF_124)] |
| Fish (marine foods) vs. meat | | Cross-sectional study | 270 Chinese (135 men), average age ~51±12y | LC-MS, GC-MS | Fasting plasma | EPA DHA  CMPF  Hydroxyproline  PE(p36:5)  PC(36:5)  LPC(22:6)  LPE(22:6)  DHA-containing PCs, PEs and plasmalogens | [[125](#_ENREF_125)] |
| Fish-based diet (oily fish) | | Cross-sectional study | 230 Alaska natives (97 men), >14y | EA-IRMS | RBC | 15N/14N | [[126](#_ENREF_126)] |
| Dark fish | | Cross-sectional study | 1369 non-smoking women | LC-MS/MS | Urine | CMPF  DHA  EPA  DPA  Choline(C22:6)  Choline(C20:5)  MG(22:6/0:0/0:0)  SM(d18:2/18:1)  +2 unknowns | [[41](#_ENREF_41)] |
| Fish | | Cross-sectional study | 34 (16 men), 18-60y | ESI-MS/MS | Fasting serum and plasma | LPE(C18:2)  PE(C38:4) | [[127](#_ENREF_127)] |
| Fish intake (association) | | Cross-sectional (baseline in a case-control colorectal cancer study; Pearson correlations, FDR<0.1) | 253 subjects, 125 cases and 128 controls (77 men), average age 18-74y | LC-MS or  GC-MS  LC-MS | Serum  12h non-fasting urine | X - 02269 (X - 11469) (m/z= 255.1)  CMPF  DHA  X – 12644 (m/z= 524.3)  CMPF | [[42](#_ENREF_42)] |
| Salmon (frequency of intake) | | Cross-sectional study | 68 middle-aged Northumberland residents (33 men), | FIE-MS | 24-hour urine | 1-Methylhistidine  3-Methylhistidine  Creatine | [[128](#_ENREF_128)] |
| Fish-based diet (oily fish) | | Cross-sectional study | 44 Yup’ik Eskimos (14 men), >14y | EA-IRMS | Hair | 15N/14N  13C/12C | [[123](#_ENREF_123)] |
| Biomarkers of mixed fish and fish oil intake | | | | | | | |
| Salmon fed fish oil or rape seed oil | | 6w parallel RCT | 58 CHD patients (50 men), 46-75y | GC | Fasting blood samples at baseline and after 6wk | n-3 PUFA  DHA  EPA  Ratio (n-3/n-6)PUFA | [[129](#_ENREF_129)] |
| Salmon vs fish oil | | 8w Crossover RCT with 6 mo washout | 33 healthy Serbians (18 men), 44-64y | Capillary GC | Fasting platelets and RBCs | EPA  DHA | [[130](#_ENREF_130)] |
| Fish free diet, fish diet, fish diet+fish oil  Fish oil | | 3 x 6w crossover RCT with 6w waskout  6w parallel trial | 12 healthy men, 18-58y  11 healthy men, 18-58y | Flame ionization capillary-GC | Fasting blood samples | EPA  DPA  DHA  EPA  DPA  DHA | [[131](#_ENREF_131)] |
| Fish diet followed by fish oil | | 2 x 6 mo. sequential study | 191 patients (110 men), >50y | Not specified | Plasma samples | EPA  EPA:AA | [[132](#_ENREF_132)] |
| Fish spread | | 3y prospective study | 214 diabetics (112 men), >20y | GC | Plasma phospholipids (fasting at baseline, non-fasting at follow-up) | EPA  DPA  DHA  n-3 PUFA  n-6 PUFA | [[120](#_ENREF_120)] |
| Biomarkers of fish oil intake | | | | | | | |
| Fish oil 8-10g vs. placebo pills before surgery | | 2-10d Parallel RCT | 564 cardiac surgery patients (406 men), average age 63y | GC | Plasma PL | EPA  DPA  DHA  n-3 PUFA | [[133](#_ENREF_133)] |
| Fish oil (0.33-4.5g/d) vs. flaxseed oil | | 14d Parallel RCT and dose-response | 303 young women | GLC | Plasma PC | DHA  EPA | [[134](#_ENREF_134)] |
| Fish oil, 2.2g/d vs olive oil | | 12w Parallel RCT | 141 healthy, middle-aged | Capillary GC | Fasting erythrocyte PL | EPA  DPA | [[135](#_ENREF_135)] |
| Fish oil equaling 1, 2 or 4 fish servings/w | | 12mo Parallel RCT | 128 (79 men), 20-80 with no habitual fish intake | GC | Fasting blood, (red blood cells, mononuclear cells, platelets, plasma phosphatidylcholine, triglycerides, cholesteryl esters, and nonesterified fatty acids), buccal cell, abdominal subcutaneous adipose tissue samples | EPA  DHA | [[136](#_ENREF_136)] |
| Fish oil with 5g DHA + EPA vs. corn oil | | 4mo Parallel RCT | 124 psoriasis patients (80 men), aged 19-74y | GC | Serum PL | EPA  DPA  DHA  Sum n-3 PUFA  Sum n-6 PUFA  AA:EPA  n-6 PUFA /n-3 PUFA | [[137](#_ENREF_137)] |
| Fish oil, 0-1800mg DHA+EPA | | 5 mo Parallel RCT | 115 healthy subjects (60 men), 20-45y | GC | Erythrocyte membrane | EPA  DPA  DHA | [[138](#_ENREF_138), [139](#_ENREF_139)] |
| Fish oil (1.8g/d) vs. krill oil (1.8g/d) and controls (none) | | 4w Parallel RCT | 113 healthy subjects, (36 men), average age 40. | GC-MS | Plasma | EPA  DHA  DPA | [[140](#_ENREF_140)] |
| Fish oil vs. flaxseed, hempseed, or sunflower oil (all 2g/d). | | 12w Parallel RCT | 86 healthy adults (34 men), 30-35y | GLC | Fasting plasma | EPA  DHA | [[141](#_ENREF_141)] |
| Fish oil 1.5g/d vs. corn oil | | 8w Crossover RCT with 8w washout | 84 subjects (29 men), divided by a polymorphism in eNOS (40 wt) | GC | Fasting plasma and PL | EPA  DPA | [[142](#_ENREF_142)] |
| Fish oil, 125mg/kg/d | | 90d Parallel intervention study | 65 kids with phenylketonuria and 30 healthy controls (17 boys), 1-11y | Capillary-GLC | Blood plasma samples (4-hour fasting) at baseline and after intervention: plasma phospholipid fatty acid | EPA  DPA  DHA  n-3 PUFA  n-6 PUFA  n-3 PUFA /n-6 PUFA | [[143](#_ENREF_143)] |
| Fish oil (0.6-3.6 g/d) vs. flaxseed oil (1g/d) | | 12w Parallel RCT | 62 healthy male fire-fighters, around 30-50y | GLC | Plasma and erythrocyte PL | EPA  DPA  DHA | [[144](#_ENREF_144)] |
| Fish oil (4g EPA + DPA/d) vs soybean oil control | | 12w Parallel, blinded trial | 60 subjects (46 men), >18y; treatment/ control 45/15) | Capillary-GC | Plasma (RBC) | Omega-3 index (for compliance) | [[145](#_ENREF_145)] |
| Fish oil, 0-9g/d | | 12 mo Parallel RCT + 6 mo washout | 58 male monks, around 40-70y | GLC | Fasting serum cholesteryl esters, erythrocytes, and subcutaneous adipose tissue | EPA  DPA  DHA | [[146](#_ENREF_146)] |
| Fish Oil, flaxseed oil, or corn oil | | 180d 3-arm Parallel RCT | 53 T2D patients (19 men), average age 63y | GC-MS and LC-MS | Fasting serum  Fasting serum | CMPF  PC-EPA  EPA  CMPF  EPA  PC-EPA  DHA  DPA | [[147](#_ENREF_147)] |
| Fish oil vs. olive oil, 2g/d | | 6w Parallel RCT | 50 overweight subjects, (24 men), 30-75y | GC | Fasting granulocytes and subcutaneous adipose tissue samples | EPA  DPA  DHA  Sn-3 PUFA  n-3 PUFA /n-6 PUFA | [[148](#_ENREF_148)] |
| Fish oil, 1.7g/d vs. safflower oil. | | 4w Parallel RCT | 41 healthy men, BMI>23., 18-30y | GC | Plasma PL and RBC | EPA  DHA  EPA+DHA | [[149](#_ENREF_149)] |
| Tuna oil, 0.44-1.9g/d, linseed oil, or placebo | | 12w 5-arm Parallel RCT | 40 healthy men, 18-39y | GC | Fasting plasma PL | EPA  DHA | [[150](#_ENREF_150)] |
| Fish oil ± vit. B12 | | 8w Parallel RCT | 30 healthy adults (sex unknown), 20-26y | TLC (for PL) and GLC (for FA methyl esters) | PL and plasma | EPA  DHA  n-3 PUFA  n-6 PUFA  n-3 PUFA /n-6 PUFA | [[151](#_ENREF_151)] |
| Fish oil (5g) vs. EPA (3g) | | 3w Parallel RCT | 29 healthy low-fish consumers (18 men), around 30y | TLC and GC | Serum and PL | EPA  DHA | [[152](#_ENREF_152)] |
| Fish oil (600mg/d) vs. olive oil (600mg/d) | | 2 x 4w Cross-over trial | 24 hyperlipoproteinemic patients (no details) | GC-MS | plasma  urine | CMPF  CMPF | [[153](#_ENREF_153)] |
| Fish oil (1.3g EPA + DHA/d) | | 12w Parallel RCT | 23 middle-aged hemodialysis patients (18 men) | GC | Fasting plasma  RBC | EPA  DPA  DHA  n-6/n-3  EPA+DHA  n-6 PUFA | [[154](#_ENREF_154)] |
| Fish Oil (EPA + DHA at 0, 0.25, 0.5 or 1g/d) | | Parallel intervention study, partially sequential. | 20 subjects (11 men), aged 18-35y | GC | Fingerprick whole blood  Erythrocytes,  PL, WB | DHA  DPA  EPA  % EPA+DHA  % n-3 HUFA/total HUFA  DHA:EPA | [[155](#_ENREF_155)] |
| Fish oil with 380mg n-3 LC-PUFAs | | 4w Parallel RCT | 17 healthy subjects (sex unknown), 25-69y | GLC | Plasma PL | EPA  DPA  n-3 PUFA | [[156](#_ENREF_156)] |
| Fish oil (2.8 g EPA and 1.4 g DHA) vs. corn oil ± isoflavones | | RCT meal study | 10 overweight men, >45y | GLC | Serum | EPA  DHA  n-3 PUFA | [[157](#_ENREF_157)] |
| Fish oil, 3g/d, no control group | | 12w Sequential study | 27 hemo-dialysis patients (13 men), average age 61y | GC | Non-fasting plasma | EPA  DPA | [[158](#_ENREF_158)] |
| Fish oil, 6g/d | | 3w Sequential intervention study | 19 healthy subjects (2 men), 22-53y | GLC | Fasting plasma and plasma PL | EPA  DPA  DHA | [[159](#_ENREF_159)] |
| Fish Oil (1.2g EPA, 0.8g DHA) | | 20w sequential intervention study (12w suppl., 8w washout) | 12 men, 18-25y | GC | Serum and RBC | EPA  DHA  DPA | [[160](#_ENREF_160)] |
| Fish Oil (2g EPA + 1g DHA/d), no controls | | 3mo Sequential intervention study | 10 healthy men, average age 23y | GC | Fasted serum samples | EPA  DPA  DHA | [[161](#_ENREF_161)] |
| Fish oil, 5g/d (1g n-3 PUFA) | | Sequential intervention study, duration not provided. | 10 neurologically disabled children (9 boys), 2-13y | GLC | Serum and PL | EPA  DHA  n-3 PUFA | [[162](#_ENREF_162)] |
| Cod liver oil, 10-40ml/d | | 20w Sequential study with dose increase for 12w, then decrease for 8w | 6 healthy men, 26-36y | GLC | Plasma free FAs at multiple time points  Plasma PL  Erythrocyte membranes | EPA  DHA  EPA  DHA  EPA  DHA | [[163](#_ENREF_163)] |
| Cod-liver oil vs. none | | 3y Prospective cohort study | 214 diabetics (112 men), >20y | GC | Plasma PL (fasting at baseline, non-fasting at follow-up) | EPA  DPA  DHA  n-3 PUFA | [[120](#_ENREF_120)] |
| Mixed seafood markers (including As-compounds) | | | | | | | |
| Lean seafood and fish (cod, Pollack, scallop) vs. non-seafood diet with fish oil | | 2 x 4w crossover RCT | 20 healthy subjects (7 men), average age 51y | NMR | Morning spot urine  Fasting serum | TMAO  DMA  TMAO | [[2](#_ENREF_2)] |
| Seafood (cod, farmed salmon, or blue mussels) vs potato | | RCT meal study | 39 healthy volunteers (10 men), 20-40y | HPLC-ICPMS | Urine over 72 hours | Total As  iAs  DMA  AsB  Non-AsB As | [[164](#_ENREF_164)] |
| Mixed seafood compared with other protein sources | | 2w sequential study (before-after) | 153 postmenopausal women, around 75y | isotope ratio MS | Fasting serum sample | 15N/14N  13C/12C  34S/32S | [[165](#_ENREF_165)] |
| Seafood (Tropical) vs. no fish | | 2w sequential intervention study | 12 healthy Australian natives (2 men), mean age 24y | Capillary-GLC | Plasma fatty acids | DHA  DPA  EPA  AA | [[166](#_ENREF_166)] |
| Seafood (lean): lemon sole, wolfish, crabs | | Single meal sequential intervention study after 4 days without fish or shellfish | 3 healthy volunteers (1 man), 23-50y | HPLC-ICPMS | Urine | Total As  AsB  DMA | [[167](#_ENREF_167)] |
| Seafood (comparing also environmental exposures and other food sources) | | 5mo Cohort study with weekly urine collections | 6 healthy Italian men | HPLC-ICPMS | Morning urine | AsB  iAs  DMA  MMA | [[168](#_ENREF_168)] |
| Seafood (fish, shellfish) intake estimates | | Bladder cancer case-control study (retrospective) in Michigan, USA | 343 local participants, 151 cases and 192 controls, (242 men) | HPLC-ICPMS | Spot urine | AsB | [[169](#_ENREF_169)] |
| Seafood and plant protein (as component of various diet scores) | | Cross-sectional (Baseline of ATBC prospective study) | 1336 men, 50-69y | LC-MS | Serum | CMPF  DHA  DPA  EPA  PC(34:1)  MG(22:6/0:0/0:0)  FA(18:4n–3)  LPC(22:6)  N-acetyl-3-methylhistidine  3-Methylhistidine  Creatine  Ergothioneine | [[14](#_ENREF_14)] |
| Seafood (fried and non-fried fish, raw shellfish) | | Cross-sectional study (baseline from MESA cohort) | 900 participants (387 men), average age ~60y | GC | Plasma PL | EPA  DHA  DHA+ EPA | [[170](#_ENREF_170)] |
| Seafood (fish, raw oysters, shellfish) | | Cross-sectional study (baseline of NHANES 2003-2004) | 788 participants (417 men), >20y | HPLC-ICP-DRC-MS | Spot urine | Total As  DMA  AsB  Non-AsB As | [[171](#_ENREF_171)] |
| Mixed fish and shellfish | | Cross-sectional study | 270 Chinese (135 men), average age ~51±12y | * LC-MS, GC-MS | Fasting plasma | Hydroxyproline  Valine  Lysine  EPA DHA  CMPF  PE(P-36:5)  PC(36:5)  LPC(22:6)  LPE(22:6)  DHA-containing PCs, PEs, and plasmalogens | [[125](#_ENREF_125)] |
| Japanese coastal diet baseline values | | Cross-sectional study (baseline of astaxanthin intervention) | 20-30 healthy male subjects, 40-69y | LC-MS | Fasting heparin plasma (20 subjects) and erythrocytes (30 subjects) | Astaxanthin | [[172](#_ENREF_172), [173](#_ENREF_173)] |
| Shellfish markers (including As-compounds) | | | | | | | |
| Shellfish (oysters, clams, crabs, mussels, squid and shrimps) | | 3 x 21w Parallel RCT with sequential diets where each period contained only one shellfish | 18 men, 23-38y | GC | Plasma and erythrocyte membrane | EPA  DHA | [[174](#_ENREF_174)] |
| Blue mussels | | Single meal intervention study | 4 men, 5 women | HPLC-ICPMS | Urine over 72 hr | AsB  DMA+As(V)  As sugars  Sum of unknowns As compounds | [[175](#_ENREF_175)] |
| Shellfish | | Cross-sectional study | 1369 non-smoking women | LC-MS/MS | Urine | CMPF | [[41](#_ENREF_41)] |
| Shellfish | | Cross-sectional analysis of nested case-control study | 502 CRC cases and controls (281 men), 55-74y | LC-MS/MS  GC-MS | Serum | CMPF | [[91](#_ENREF_91)] |
| Shellfish | | Cross-sectional study | 270 Chinese (135 men), average age 51±12y | * LC-MS, GC-MS | Fasting plasma | PE(P-36:4) | [[125](#_ENREF_125)] |
| Shellfish | | Cross-sectional analysis of samples from a case-control colorectal cancer study | 253 subjects, 125 cases and 128 controls (77 men), 18-77y | LC-MS  GC-MS   * LC-MS or GC-MS | Serum  12h non-fasting overnight urine | CMPF  + one unknown (POS m/z= 255.1)  Lysine  2-aminoethylphosphonate  2-hydroxybutyrate  Creatine  3-hydroxybutyrate  Taurine  N-acetylglycine  Alpha-hydroxyisovalerate  Sulforaphane-cysteine | [[42](#_ENREF_42)] |

Abbreviations: 1-OHP, 1-hydroxypyrene; 1-OHPG, 1-hydroxypyrene glucuronide; 1-MH, 1-methylhistidine (-methylhistidine); 3-MH, 3-methylhistidine (-methylhistidine) ; AA, arachidonic acid; AC, 2-amino-9H-pyrido[2,3-b]indole; AsB, arsenobetaine; ATNC, apparent total nitroso compounds; CMPF, 3-​carboxy-​4-​methyl-​5-​propyl-​2-​furanepropanoic acid; DHA, docosahexaenoic acid; DMA, dimethylamine; DHM-MA, ; DPA, docosapentaenoic acid; EA-IRMS: elemental analyzer coupled online via a conflow interface with an isotope ratio MS; EPA, eicosapentaenoic acid; FA, fatty acid; FIE-MS: flow infusion electrospray–ionization mass spectrometry; FLD: fluorence detector; FLU, fluoranthene; GC-MS: gas chromatography coupled with mass spectrometry; HPLC: high pressure liquid chromatography; IAC: immunoaffinity chromatography; iAs, inorganic As; IEC: ion-exchange chromatography; LC-MS: liquid chromatography coupled with mass spectrometry; LPC(x:y), lysophosphatidylcholine with one esterified fatty acid having in total x carbons and y double bonds; LPE(x:y), phosphatidylethanolamine with one esterified fatty acid having in total x carbons and y double bonds; MeIQx, 2-amino-3,8-dimethylimidazo[4,5-f]quinoxaline; MG(x:y/0:0,0:0), monoacylglycerol with a fatty acid of x carbons and y double bonds in position 1; MMA, monomethylamine; NAP, naphtalene; NMR: nuclear magnetic resonance spectrometry; PC(x:y), phosphatidylcholine with two esterified fatty acids having in total x carbons and y double bonds; PC-EPA, PC-containing esterified EPA; PE(x:y), phosphatidylethanolamine with two esterified fatty acids having in total x carbons and y double bonds; PHE, phenanthrene; PhIP, 2‑Amino-1-methyl-6-phenylimidazo[4,5‑b]pyridine; PL, phospholipids; PUFA, polyunsaturated fatty acids (n-3 and/or n-6); SFS : synchronous fluorescence spectroscopy; SM(x:y), sphingomyelin with two esterified fatty acids having in total x carbons and y double bonds; TEA: thermal energy analyzer; TLC: thin layer chromatography; TMA, trimethyl amine; TMAO, trimethylamineoxide; Trp-P-1, 3-amino-1,4-dimethyl-5H-pyrido[3,4-b]indole; Trp-P-2, 3-amino-1-methyl-5H-pyrido[3,4-b]indole; WB, whole blood; \* free and conjugated metabolites

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