# Optimised Diet and Imports Dependence in Tunisia

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## INTRODUCTION

Until the 70th, Tunisia faced a high poverty level and undernutrition problems. To tackle these issues, the Tunisian government has implemented social policies during these decades. Tunisian policies had the three objectives to improve (i) food security, (ii) health and (iii) schooling. Policy on food security was based on direct and indirect food subventions. In the direct system, families received cash transfers under conditions among which, the number of children in the scholar system. The indirect part of the subvention system is a price subsidy on staple food products (wheat, milk, oil seeds, sugar and tomato paste) and scholar paper. Moreover, public policies implemented in these decades were focused on the improvement of the health system access (Dhehibi and Gil, 2003).

These policies have been very effective in increasing the food calories availabilities, which increased steadily and reached in 2010 an average of 3,329 calories per capita and per day (according to the FAO apparent consumption see figure 1). The food subvention system was supposed to be progressive but inequality persists with poor population benefiting from fewer subventions in reality than in the theory. Poverty is still present and estimated at 15.5% of the population in 2010 (Ben Said *et al.*, 2011; Banque Africaine de Developpement, 2013b). Consequently, a gap remains between of rich and poor's caloric intake; respectively 2,594 kcal/capita/day and 1,903 kcal/capita/day (Banque Africaine de Developpement, 2013a).

[INSERT Figure 1]

However, this dietary trend has benefited more to high energy than nutritionally dense products, influenced by the food subsidy system, which has encouraged the consumption of affordable products largely imported from abroad: wheat flour, vegetable oils other than olive oil and sugar. Even if food transition in Tunisia (as in many developing countries) seemed unavoidable (Rayner *et al.*, 2007), the food subsidy system has certainly significantly amplified the dietary transition (Lobstein, 2002). This situation is all the more worrying that Tunisia has become net importer of cereals, meat, sugar, milk and vegetable oils (others than olive oil), i.e. the products, which are the main culprit of this transition (see table A5 in Appendix; Le Mouël and Schmitt, 2018). Observed transitions were accompanied with changes in both food consumption and trade. As a main example, the traditional olive oil consumption has been replaced by imported vegetable oils as maize, palm and soybean oils. Nowadays, almost all the olive oil produced in Tunisia is sold abroad mainly on the European Union

2

markets (Anania and Pupo d'Andrea, 2007). Tunisia is also a net importer of cereals to be processed for human consumption or animal feed. Finally, sugar displayed the most important evolution. Imports of sugar (in raw sugar equivalent) were multiplied by more than four in 40 years (FAOSTAT Food Balance Sheets, hereafter FBS).

These changings towards more westernized diets are understandable as Tunisian authorities aimed at supporting the consumption of cheap high caloric-density food to fight against undernourishment. In 30 years the percentage of people suffering from underweight was divided by five and reached less than 5% of the population (adults and children less than 5) from 1999 onwards. The situation evolves in such a way that the prevalence of undernourishment in total population was equal to 5% in 2015-2017 according to the FAO report on nutrition and food security situation (FAO *et al.*, 2018). But concomitantly, overweight increased and the prevalence of of overweighed people evolved from 10% in 1975 to nearly 30% of the population in 2016. As shown in figure 2, the two curves expressed in % of underweight and obese population crossed in the early 1980s. In addition, the prevalence of overweighed children aged less than 5 was 14% in 2012 (FAO *et al.*, 2018). The problem of overweight and obesity in Tunisia as a consequence of unbalanced diets and nutritional transition towards consuming more animal products, fat and sugar  and a loss of tradition Medieterranean diet adherence that is recognized as an healthy diet to prevent non communicable diseases (NCD). Consequently, in 2016 in Tunisia, NCD accounted for 86% of all deaths, among which cardiovascular diseases (44%) and diabetes (5%) (WHO, 2018).

[INSERT Figure 2]

In this context, the objective of the study was to assess a better dietary scenario - bringing caloric intake to recommendations and respecting a large set of nutritional recommendations- on trade. To build this scenario, we used mathematical programming which is a tool commonly used in the scientific literature to reach optimal diets in terms of nutrition, cost, consumer preferences or environmental impacts. Initiated by economists (Stigler, 1945 and Smith, 1959), this methodology was taken up essentially by researchers in nutrition and nowadays the literature in agricultural, food or health economics and policy deploying this type of method is more rare. In, the Gazan et al (2018) literature review, out of 67 articles published, only 2 were published in

76    economics journals. Apart from the seminal works of Stigler and Smith we can quote the works of Henson,

77    1991; Srinivasan *et al.*, 2006; Srinivasan, 2007; Shankar *et al.*, 2008; Arnoult *et al.*, 2010, Irz et al., 2015).

78    This literature assessed the impact of optimizing the diet essentially on consumption and except the work of

79    Arnoult *et al.* (2010) who translated dietary guidelines in agricultural production and land use, but no study

80    adressed the impacts on food supply and more particularly on trade. Our approach complemented these works

81    by enlarging the results at the country level and assessing their impact on international trade and thus on import

82    dependency. Our goal was, using the approach described in Srinivasan (2007), to optimize the Tunisian

83    apparent consumption under the ANSES (French agency for food, environmental and occupationnal health

84    and safety) set of nutritional constraints (hereafter, NC; ANSES, 2016 p. 94) and synthetized in table A1 in

85    Appendix. Then, once the optimized consumption identified, we used the GTAP Constant Elasticity of

86    Substitution (CES) parameters (Dimaranan *et al.*, 2006) to evaluate the impact of the adherence to the NC on

87    the Tunisian domestic and foreign supply of food.

88    The paper is organized as followed section 2 presents the sources and the matching of data, section 3 describes

89    the model. Results are presented in section 4 and discussion and conclusion are provided in section 5.

90

91    **THE DATA**

92    In order to perform this analysis, we had to reconcile three sources of data. The food balance sheets (FBS)

93    from the FAO, which give data estimates of production, utilization and trade for 111[2] food items (FAO, 2011)

94    and two French databases on food contents in macro- and micronutrients: Ciqual (Ciqual, 2012) and Nutrinet

95    (Nutrinet-Santé, 2013). They are composed of respectively 1,343 and 2,609 food products and 60 macro- and

96    micronutrients and other food compounds.

97    In order to reconcile the FBS and the nutrition datasets, a matching was necessary between the definitions of

98    the products in the three databases. In priority the Ciqual product description was considered. Where a product

99    was not available in Ciqual, the Nutrinet database was considered. When a food item was not available in both

100   nutritional databases, we used average foods, which categorize family of products or the closest product we

101   could associate based on the comparison of nutrients compounds. For instance, the nutrient composition of

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[2] We analyze only 62 items after selection of influent products on Tunisian trade.

102  pulses was elaborated by the ponderation of products from this food category according to the Tunisian

103  consumption of these products.

104  To show the deviation between the observed quantity of nutrients apparent intake in Tunisia in 2010 and the

105  NC, we computed, as previously done by Hatloy *et al.* (1998) the Nutrient Adequacy Ratios (NAR)

$$106 \qquad NAR_j = \frac{N_j}{N_j'}$$

107  Where $N_j$ represents the observed intake of nutrient $j$ and $N_j'$ is the NC recommended intake of the same

108  nutrient. When $NAR_j$ is equal to 1 the need is covered; when it is greater than 1 the need is covered but the

109  nutrient exceeds the upper limit; when it is lower than 1 the need is not covered. The same calculation is made

110  with the optimized diet to evaluate the adequacy of the model results to the nutritional recommendations.

111  The FBS of Tunisia in 2010 have been used to estimate individual apparent consumption. Table A2 in

112  Appendix shows the observed food utilization by food items in 2010 in Tunisia per capita per day in grams. It

113  does not represent the exact food consumption in Tunisia but the apparent consumtion (defined as domestic

114  production + imports – exports +/- stocks variations). Del Gobbo *et al.* (2015) have shown that these

115  "guestimates" from the FAO are largely over or under estimated; the estimation error can attain (according to

116  country) +270% for whole grain and -50% for beans and legumes. In Tunisia, the food availabilities are

117  equivalent to 3,731 calories per inhabitant and per day. For this reason we did not use the quantities as the

118  actual consumption of food. We kept the proportion of each item for a daily intake of 2,702 calories (see table

119  A3 in Appendix) which corresponds of the mean adult daily intake in Tunisia (Perignon et al., 2017). This

120  restriction to 2,702 calories is not undertaken via the model but is a simple beforehand proportional

121  computation.

122  **THE MODEL**

123  We used the non-linear programming approach described in Srinivasan (2007) slightly modified. The

124  simulations are made using the GAMS software. The model is composed of 62 foods items detailed in table

125  A3 in Appendix, which represent the Tunisian diet observed in 2010 for 2,702 kcal. More accurately, it shows

126  the food utilization of 62 items equivalents. We proceed in two steps. In a first step, we optimized a theoretical

127  Tunisian food consumption to evaluate the diet quality and find out in what proportion the food items should

128    vary to insure the adequacy with the nutritional recommendations. In the second step we applied these

129    variations to the food supplies to assess what changes should be performed in terms of domestic production

130    versus imports.

131

132    To identify these changes, we minimized the following objective function ($Z$), which is the sum of the square

133    of the differences between the observed theoretical consumption $X_i$ and the optimized consumption $X_i'$ for

134    each item $i$ times a coefficient $\alpha_i$ which is the share of each item $i$ consumption quantity in the total observed

135    consumption quantity preventing the model to propose too much large variations in food relatively little being

136    consumed.

137

138
$$Z = \sum_i \alpha_i \left( \frac{X_i' - X_i}{X_i} \right)^2$$

139
$$\alpha_i = \frac{X_i}{\sum_i X_i}$$

140

141    $Z$ was minimized under a set of constraints, which corresponds to the NC recommendations summarized in

142    table A1 in Appendix. The recommendations concerned 34 macro- and micronutrients. We eliminated sodium

143    from the simulations. Indeed, the added salt is not taken into account in the FBS. However, in Tunisia as in

144    many other countries, the consumption of added salt is so high that it becomes a public health problem,

145    according to Mason *et al.* (2014), the average daily salt intake in Tunisia is 14 g. We thus guess that the need

146    of sodium is largely covered. The men/women median was considered as the minimum of nutrient constraint.

147    The upper limits (where they exist) have been defined as the safety limits for some nutrients. Some additional

148    constraints were taken into account to impede the model to increase or decrease too much the quantity of

149    particular products like tea, coffee, spices or alcohol which have been fixed at their observed level.

150    Once the diet has been optimized we used the GTAP constant elasticity of substitution (CES) parameter in

151    order to simulate the adoption of the NC recommendations on international trade and domestic supply.

152    Following Armington (1969), we assumed the imperfect substitutability of products from domestic or foreign

153    origins.

154     We computed the needed variations to insure an adequate diet these variations are equal to $\delta_i = \frac{X_i - X_i'}{X_i}$ and

155     multiplied the food apparent consumption $FAC$ (and not the diet) by these variations $FAC' = (1 + \delta) * FAC$.

156

157     We then, computed $d_i$ the ratios of imports to domestic demand for the different domestically produced goods:

158
$$d_i = \frac{Imports_i}{Domestic_i} = \left[\frac{PD_i}{PM_i} \frac{\beta_i}{\beta_i - 1}\right]^{\varepsilon_i}$$

159     In the GTAP database *PD* and *PM* are the same and equal to 1. Where $\varepsilon_i$ is the elasticity of substitution of good

160     *i*, $PD_i$ and $PM_i$ are respectively the prices or domestically produced and imported goods *i* and $\alpha_i$ the share

161     parameter: $\beta_i = \frac{G}{1+G}$ and $G = \left(\frac{Imports_i}{Domestic_i}\right)^{\varepsilon_i} \frac{PM_i}{PD_i}$

162

163     This ratio will allow disentangling the share of local and foreign origin in the optimised food apparent

164     consumption.

165
$$FAC'_{domestic} = \frac{FAC'}{1 + d_i}$$

166
$$FAC'_{imported} = FAC' \frac{d_i}{1 + d_i}$$

167

168     **RESULTS**

169     The simulation was done without considering age and gender but for an observed average adult consumption

170     of 2,702 kcal per day and per person. First, decreasing the daily caloric intake from 3,731 to 2,702 kcal is a

171     uniform decrease by 37% of each item. Then, we performed the simulations. The model simulates the

172     optimized diet keeping the actual proportion of each item in the total consumption. Results are displayed in

173     figures 4 and 5 for aggregated items. Detailed results are provided in tables A4 in Appendix.

174     Table 1 and figure 3 report the values of $NAR_j$ for each macro- and micronutrient listed in the French NC. We

175     confirmed that the mean Tunisian diet was too rich in carbohydrates and free sugar, while several nutrients

176     were under the ANSES dietary recommendations: fibres, vitamins (A, B1, B2, B12, C and D), calcium,

177     magnesium, zinc and iodine. Even if the *NAR* for free sugar is very close to 1, ideally the consumption of free

sugar should be null or very low. Once the optimization done, all the nutrients respect the upper and lower

limits; they are under 1 when we consider the upper limits and above 1 considering the lower limits.

Carbohydrates, free sugar and other nutrients have adequately evolved (see table 1).

[INSERT Table 1]

[INSERT Figure 3]

[INSERT Figure 4]

[INSERT Figure 5]

Reaching nutritional adequacy induced a strong reduction of sugar including honey and sweeteners (almost

100%). The consumption of carbohydrates should not exceed 40% to 55% of the total energy on average

according to the NC and free sugar should be limited to 10% of the total provision of calories. The FBS in

2010 displayed figures above these recommendations. The *NAR* is equal to 1.25-1.72 for carbohydrates but

1.11 for free sugar, for an intake of 2,702 kcal/day.

We have used the results of the simulation to compute the impact in terms of macro-data and particularly in

terms of domestic versus foreign origin. We thus computed the new domestic supply and trade after the

reallocation of food items towards an optimised diet at the national level (see figures 6 and 7 and table A5 in

Appendix). In the scenario of adequate diet, Tunisia would decrease its foreign dependence in sugar and cereals

but would increase its dependence in all other goods. But it is worth stressing that changes in food patterns

would weigh on domestic agricultural production, which should be redirected towards the domestic market

rather than towards export

Our modelling exercise almost completely eliminated free sugar from the diet except honey. In Tunisia sugar

is largely supported by the food subsidy system and is totally imported from abroad. The second item to be

reduced was cereals. Their consumption should be decreased by 44%, particularly wheat, which is the main

cereal consumed in Tunisia. Wheat has also been supported by the Tunisian food subsidy system. Nowadays

Tunisia is largely dependent on imports to ensure food security, especially the needs in cereals. These

reductions are essentially met by decreasing imports by 600,000 tons of cereals and 350,000 tons of sugar (in

raw sugar equivalent).

206 Interesting results concerned (i) the dramatic increase of products from animal origin: fish and seafood

207 (+194%), meat and eggs (+148%, particularly eggs and red meats) and dairies (+107%) this is explained by

208 the important deficit in calcium, the weak availability of iron and the lack of other minerals as zinc, magnesium

209 and copper at baseline. The transition towards a Westernized diet seems to be not the main problem of

210 Tunisians whose consumption of proteins from animal origin is not too high at baseline and could thus be

211 increased. These shifts are based on the spectacular increase in domestic supply by 1,000,000 tons of milk,

212 222,000 tons of eggs and 100,000 tons of bovine meat and 142,000 tons of fish and seafood.

213 Concomitantly to the reduction in cereals, other plant products increased: legumes (+124%), fruits (+29%) and

214 vegetables (+57%), even if the consumption of fruits and vegetables was already adequate at baseline. Such

215 increases are probably due to achieve adequate recommendations in fibres, and compensate the reduction of

216 fibres provided by cereals. They would also impact domestic production by +1,405,000 tons of various

217 vegetables and +84,000 tons of legumes.

218

219                                        [INSERT Figure 6]

220                                        [INSERT Figure 7]

221


222 **CONCLUSIONS**

223 Nutritional transition in Tunisia (and in many countries) was often largely influenced by the food subsidy

224 system. Food security was insured by Tunisian social policies based on direct subventions to families and

225 indirect ones by lowering the prices of essential food products (wheat, milk, seed oils, sugar and tomato paste).

226 As stressed by Lobstein (2002) food policies often fail in delivering healthy diets. Our work proposed insights

227 for redesigning public food policies. We took into account the actual dietary pattern of the Tunisian population

228 at a macro-level and the capacity of production and the international trade to improve the food intakes. The

229 results of the optimisation show that if Tunisians would strictly adhere to the French nutrition

230 recommendations, thus the country would decrease its dependence to international markets for sugar and cereal

231 but would have to find the necessary means to cover its needs in products from animal origin, fruits, vegetables

232 and legumes. This conclusion reinforces the needs to improve the sustainable productivity of agriculture and

233 to redirect public funds.

234 In our scenario the strong increase in the consumption of certain products like products from animal origin,

235 fruits, vegetables, and legumes is supposed to be met by an increase of the domestic supply. These results

236 suppose that the factors (land, labor) released by the abandonment of the production of cereals would be

237 available for other agricultural productions and mobile within the agricultural sector. This also implies that the

238 domestic agricultural production should be reoriented towards the domestic market.

239 In this analysis we used the mathematical programming model described in Srinivasan (2007) to represent and

240 simulate changes in the Tunisian diet average pattern. Using data from the FBS in 2010 we computed a

241 reduction of the average caloric intake from 3,731 to 2,702 kcal per person and per day keeping the share of

242 each item constant. Then we optimized the diet to respect the adequacy with the French recommendations

243 (NC) on macro- and micronutrients. Finally, we recalculated the needs for each food items and the impact of

244 these diet recommendations in terms of foreign and domestic origin (detailed results are provided in table A5

245 in Appendix).

246     1- A first analysis of the Tunisian diet computing the ratios of nutrient adequacies showed that, the

247         Tunisian diet is almost adequate (according to the ANSES set of nutritional recommendation

248         constraints) but was too rich in free sugars and insufficient in fibres, certain vitamins and minerals.

249     2- Results of the optimization showed that the consumption of sugar and wheat must be reduced. But all

250         other food categories of the diet must be increased to achieve the nutritional references.

251     3- As a consequence, the adherence to nutritional recommendations would have impacts at macro-level

252         to ensure food security. The reduction in cereals and sugars would induce a decrease of 600,000 tons

253         of cereals and of 350,000 tons of raw sugar equivalent imports.

254     4- But, in order to maintain a safe level of calcium, iron and proteins, the results of the modelling do

255         recommend an increase in the consumption of products from animal origin particularly dairy products

256         (essentially milk) which imports would increase by 159,000 tons, but also fish and seafood (+63,000

257         tons), meats and eggs (+13,000 tons).

258      5- Finally, in line with the deficiency in several vitamins and fibres, Tunisian consumers should increase

259          their intakes of legumes, fruits and vegetables. It implies an increase in the importations of vegetables

260          (+20,000 tons), legumes (+14,000 tons) and fruits (+9,000 tons).

261      Such modelling is useful to re-orientate the current public policies. Tunisian public policies for food

262 security have been very efficient in cutting down under-nourishment. However, Tunisia is nowadays

263 confronted to the triple burden linked to the coexistence of undernourishment (reduced to 5% but still

264 remaining), nutrient deficiencies and obesity. Our work suggested that encouraging people to improve their

265 diet may have impact at a macro-level. Governments should rethink their food policies in a comprehensive

266 way to improve food accessibility, quality and sustainability. Reducing the consumption of sugars and refined

267 starchy foods would require strong nutritional policy actions aimed at jointly promoting public health goals of

268 NCD prevention and limiting the risks associated to high levels of food dependence (Le Mouel and Schmitt,

269 2018).

270 To reduce agricultural import dependence, it is necessary to integrate other actions than those promoting a

271 better diet. To ensure food and nutritional security, it is necessary to implement agricultural policies favouring

272 the adoption of nutritional-sensitive agriculture and technical innovations, improving agronomic and

273 zootechnical practices, and facing the climate change. Moreover, policies should address the reduction of waste

274 and losses. In conclusion, the combination of a better adherence to a healthy diet, and improvement of

275 agriculture practices and the avoidance of losses could slow the rise of agricultural import dependence.

276 However, our work had several limits. The analysis does not take into account gender and age or socio-

277 economic distribution in the computation. Yet, the nutritional needs will differ a lot according to the age or

278 gender. The model of trade used was static and did not include prices or budget constraint thus the ability of

279 Tunisians to switch from one diet to another has to be analysed in the future nor did it include an analysis of

280 production capacity.

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351    **A**PPENDIX

352                 [INSERT Table A1]

353

354                 [INSERT Table A2]

355

356                 [INSERT Table A3]

357

358                 [INSERT Table A4]

359

360                 [INSERT Table A5]

361

362    **Table 1. Observed and optimized Nutrient Adequacy Ratios**

| Nutrients | $NAR_j$ for observed average diet | $NAR_j$ after optimization |
|---|---|---|
| Calories | 1.1 | 1 |
| Proteins | 1.42 - 0.71 | 1.96 - 0.98 |
| Total fats | 0.88 - 0.61 | 1 - 0.88 |
| Carbohydrates | 1.72 - 1.25 | 0.65 - 0.89 |
| Linoleic acid | 1.73 | 1.84 |
| Linolenic acid | 1.68 | 1.53 |
| EPA + DHA | 0.61 | 1.63 |
| Saturated fatty acids | 0.5 | 0.69 |
| Free sugar | 1.11 | 0 |
| Fibres | 0.63 | 1 |
| Vitamin A | 1.35 - 0.32 | 2.26 - 0.53 |
| Vitamin B1 | 0.74 | 1.03 |
| Vitamin B2 | 0.7 | 1.21 |
| Vitamin B3 | 1.55 - 0.03 | 1.94 - 0.04 |
| Vitamin B6 | 1 - 0.07 | 1.44 - 0.1 |
| Vitamin B9 | 1.05 | 1.56 |
| Vitamin B12 | 0.93 | 2.37 |
| Vitamin C | 0.91 - 0.09 | 1.3 - 0.13 |
| Vitamin D | 0.67 - 0.07 | 1.77 - 0.18 |
| Calcium | 0.56 - 0.22 | 1 - 0 |
| Phosphorus | 1.53 | 2.28 |
| Potassium | 1.18 | 1.74 |
| Iron | 1.14 | 1.6 |
| Magnesium | 0.77 | 1.11 |
| Zinc | 0.67 - 0.33 | 1 - 0.5 |
| Selenium | 1.12 - 0.26 | 1.74 - 0.41 |
| Copper | 1.21 - 0.27 | 1.58 - 0.36 |
| Iodine | 0.64 - 0.16 | 1 - 0.25 |

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365 **Figure 1. Apparent consumption in calories, evolution in Tunisia from 1960 to 2010**
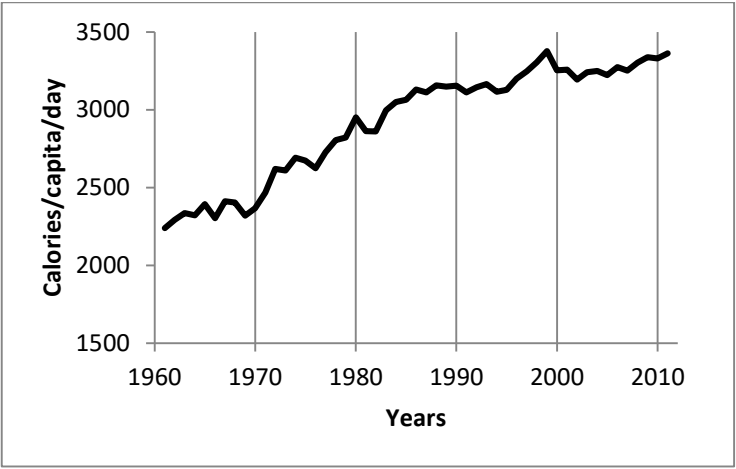


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367 Source: Data from FAOSTAT

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**Figure 2. Prevalence of underweight (BMI < 18) and obesity (BMI > 30) in adult population in**

**percentage (Tunisia, 1975-2015)**
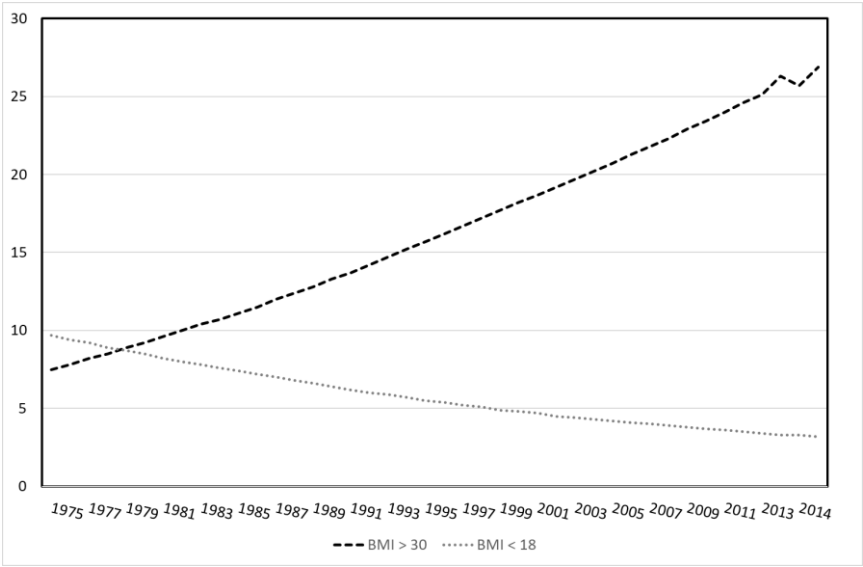


Source: data from the World Health Organization, BMI = Body Mass Index

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**Figure 3. NAR for selected nutrients in the observed diet**



Carbohydrates; 1.25 — Free Sugar; 1.11 — EPA+DHA; 0.61 — iodine; 0.64 — Fibers; 0.63 — Zinc; 0.67 — Vitamin A; 0.32 — Magnesium; 0.77 — Vitamin B1; 0.74 — Calcium; 0.56 — Vitamin B2; 0.70 — Vitamin D; 0.67 — Vitamin B12; 0.93 — Vitamin C; 0.91

Scale: 1.40, 1.20, 1.00, 0.80, 0.60, 0.40, 0.20, 0.00
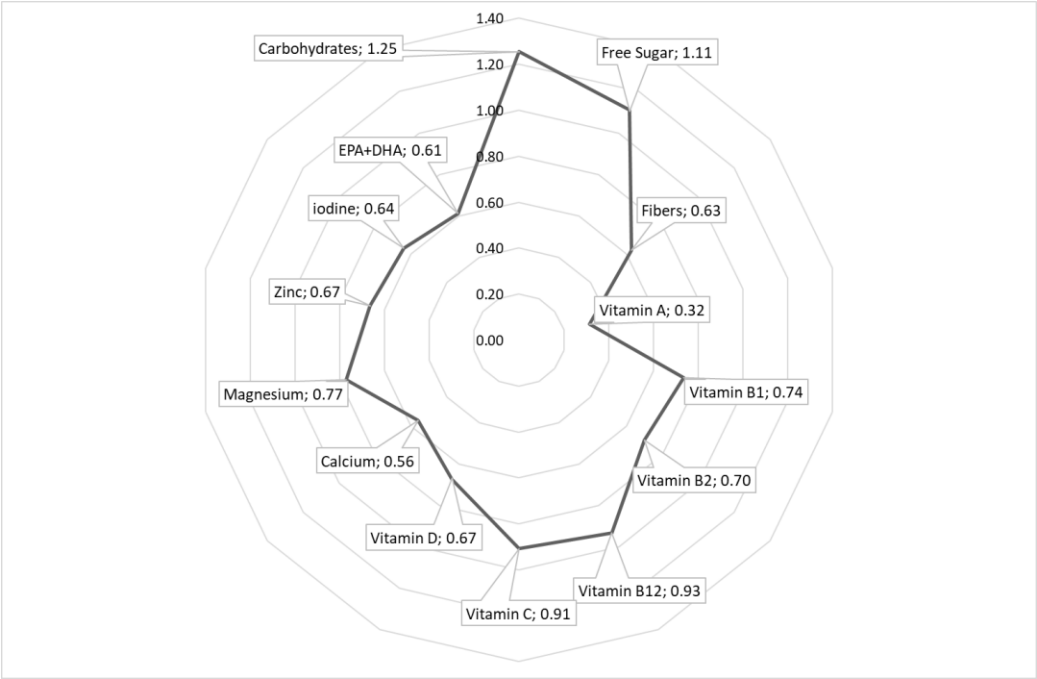
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377 **Figure 4. Consumption in grams per day and per person at baseline and after optimization (all**

378 **products)**
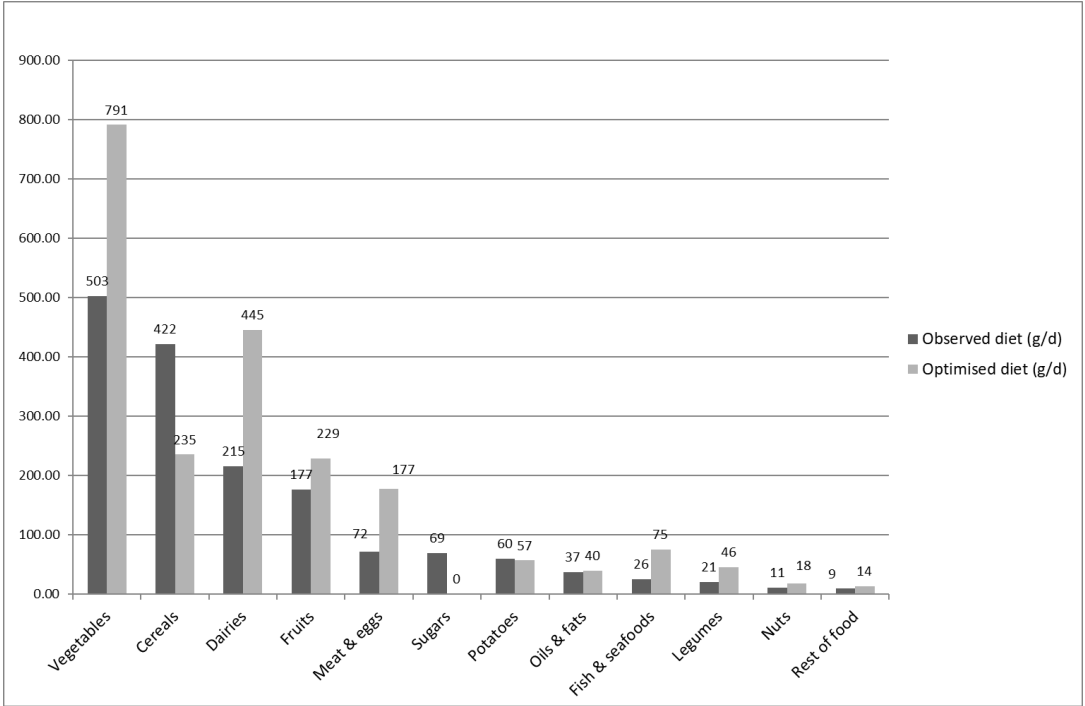


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381  **Figure 5. Consumption in grams per day and per person at baseline and after optimization (products**

382  **from animal origin)**

383



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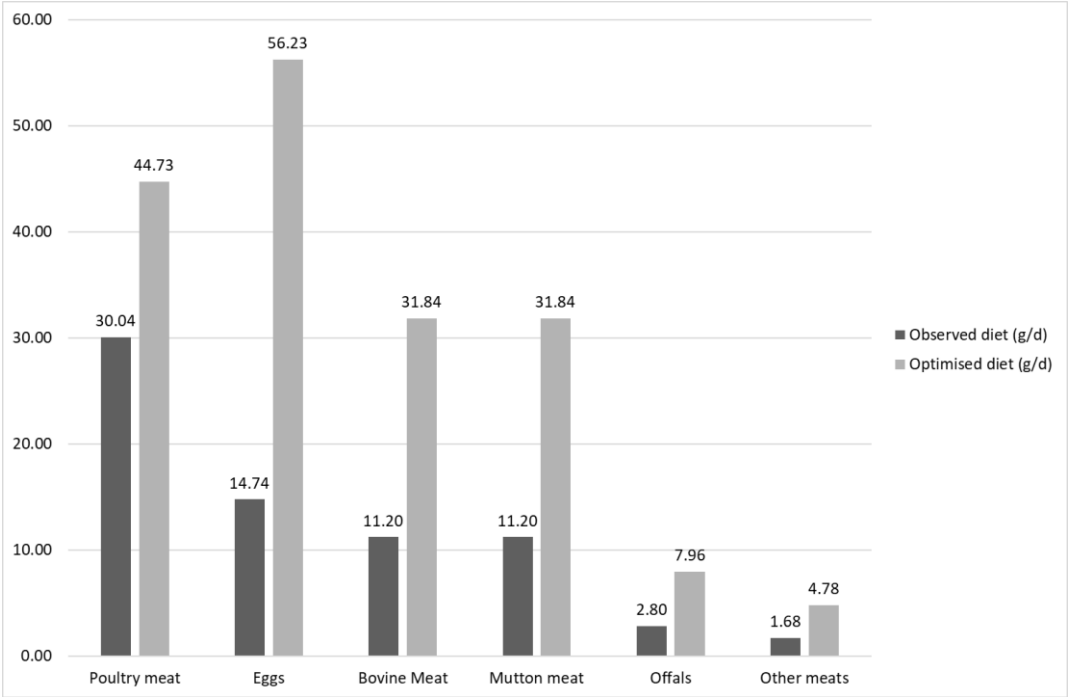
385 **Figure 6. variations of domestic demand in 1000 tons (D0 observed demand, D1 demand after**

386 **optimization)**
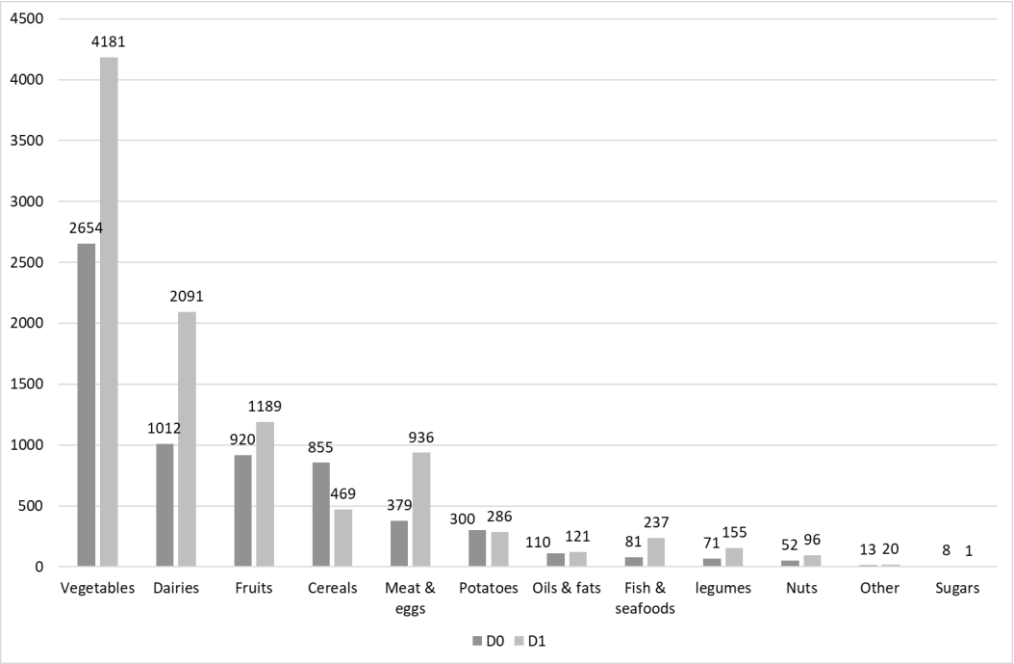


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389 **Figure 7. variations of imports in 1000 tons (M0 observed imports, M1 imports after optimization)**



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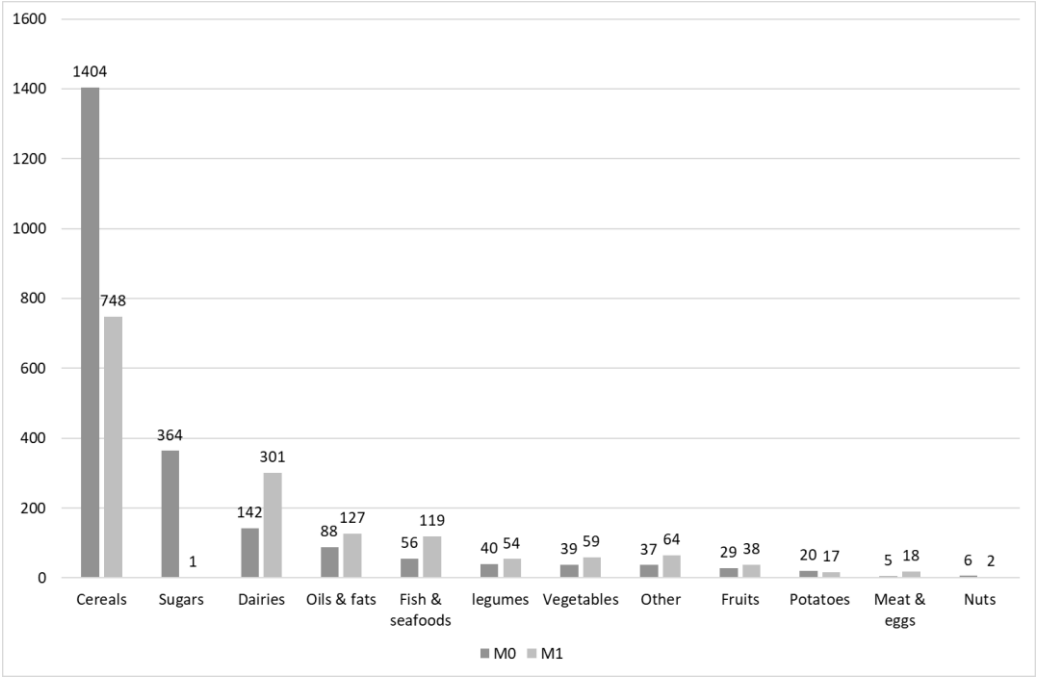
**Table A1. ANSES daily nutritional recommendations (NC)**

| Nutrient | Lower limits | Upper (or safety) limits |
|---|---|---|
| Protein (% total energy) | ≥ 10 | < 20 |
| Total fats (% total energy) | ≥ 35 | < 40 |
| Carbohydrates (% total energy) | ≥ 40 | < 55 |
| Linoleic acid (% total energy) | ≥ 4 | -- |
| Linolenic acid (% total energy) | ≥ 1 | -- |
| EPA+DHA (mg) | ≥ 500 | -- |
| Saturated fatty acids (% total energy) | -- | < 12 |
| Free Sugar (% total energy) | -- | < 10 |
| Sodium (mg) | -- | < 2633.5 |
| Fibers (g) | ≥ 30 | -- |
| Vitamin A (µg/d) | ≥ 700 | ≤ 3000 |
| Vitamin B1 (mg/kcal) | ≥ 0.00058 | -- |
| Vitamin B2 (mg/kcal) | ≥ 0.00071 | -- |
| Vitamin B3 (mg eq. niacin/kcal) | ≥ 0.0067 | ≤ 47 |
| Vitamin B6 (mg) | ≥ 1.65 | < 25 |
| Vitamin B9 (µg eq. folate) | ≥ 330 | -- |
| Vitamin B12 (µg) | ≥ 4 | -- |
| Vitamin C (mg) | ≥ 110 | -- |
| Vitamin E (mg) | -- | < 300 |
| Vitamin D (µg)[3] | ≥ 3 | < 50 |
| Calcium (mg) | ≥ 900 | -- |
| Phosphorus (mg) | ≥ 700 | -- |
| Potassium (mg) | ≥ 2633.5 | -- |
| Iron (mg) | ≥ 11 | -- |
| Magnesium (mg) | ≥ 390 | -- |
| Zinc (mg) | ≥ 12.5 | < 25 |
| Copper (mg) | ≥ 1.125 | < 5 |
| Iodine (µg) | ≥ 150 | < 600 |
| Selenium (µg) | ≥ 70 | ≤ 300 |
| Total energy (kcal/d) | -- | 2467.5 |

393 Source: ANSES (2016)

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[3] The constraint on vitamin D was too strict and made the model infeasible, we thus kept the previous lower limit of 3µg.

395  **Table A2. Observed apparent consumption (3,731 kcal)**

| Items | Daily apparent consumption of food (g/cap.) | Items | Daily apparent consumption of food (g/cap.) |
|---|---|---|---|
| Apples | 28.77 | Molluscs | 0.27 |
| Bananas | 4.38 | Mutton Meat | 15.62 |
| Barley | 15.89 | Nuts | 13.70 |
| Beans | 1.64 | Offal | 4.11 |
| Bovine Meat | 15.62 | Oilcrops Oil | 0.55 |
| Butter | 1.64 | Olive Oil | 8.22 |
| Cephalopods | 0.27 | Onions | 33.97 |
| Cereals | 2.47 | Oranges | 35.62 |
| Citrus | 24.93 | Palm Oil | 6.30 |
| Cocoa | 1.10 | Peas | 3.84 |
| Coconut Oil | 1.10 | Pelagic Fish | 25.21 |
| Coffee | 4.93 | Pimento | 0.27 |
| Cream | 2.74 | Pineapples | 0.27 |
| Crustaceans | 0.27 | Potatoes | 82.47 |
| Dates | 15.34 | Poultry Meat | 41.64 |
| Demersal Fish | 7.95 | Pulses | 18.63 |
| Eggs | 20.27 | Rapeseed Oil | 1.37 |
| Fats | 0.55 | Rice | 2.47 |
| Freshwater Fish | 0.55 | Sorghum | 1.64 |
| Fruits | 90.41 | Soybean Oil | 27.40 |
| Grapefruit | 19.73 | Soybeans | 4.11 |
| Grapes | 16.16 | Spices | 4.38 |
| Groundnuts | 1.37 | Sugar | 92.60 |
| Honey | 1.10 | Sunflowerseed Oil | 2.74 |
| Lemons | 8.49 | Sweeteners | 2.19 |
| Maize Oil | 1.64 | Tea | 2.74 |
| Marine Fish | 0.82 | Tomatoes | 297.26 |
| Meat | 2.47 | Vegetables | 362.74 |
| Milk | 294.79 | Wheat | 559.45 |

396  Source: FAOSTAT Food Balance Sheets

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398 **Table A3. Observed diet for 2,702 kcal**

| Items | Daily guestimates of consumption (g/cap.) | Items | Daily guestimates of consumption (g/cap.) |
|---|---|---|---|
| Apples | 20.90 | Molluscs | 0.19 |
| Bananas | 3.17 | MuttonMeat | 11.20 |
| Barley | 11.57 | Nuts | 9.89 |
| Beans | 1.12 | Offals | 2.80 |
| BovineMeat | 11.20 | OilcropsOil | 0.37 |
| Butter | 1.12 | OliveOil | 5.97 |
| Cephalopods | 0.19 | Onions | 24.63 |
| Cereals | 1.87 | Oranges | 25.75 |
| Citrus | 18.10 | PalmOil | 4.48 |
| Cocoa | 0.75 | Peas | 2.80 |
| CoconutOil | 0.75 | PelagicFish | 18.29 |
| Coffee | 3.55 | Pimento | 0.19 |
| Cream | 1.87 | Pineapples | 0.19 |
| Crustaceans | 0.19 | Potatoes | 59.71 |
| Dates | 11.01 | PoultryMeat | 30.04 |
| DemersalFish | 5.78 | Pulses | 13.62 |
| Eggs | 14.74 | RapeOil | 0.93 |
| Fats | 0.37 | Rice | 1.87 |
| FreshwaterFish | 0.37 | Sorghum | 1.12 |
| Fruits | 65.50 | SoyabeanOil | 19.78 |
| Grapefruit | 14.37 | Soyabeans | 2.99 |
| Grapes | 11.76 | Spices | 3.17 |
| Groundnuts | 0.93 | Sugar | 66.99 |
| Honey | 0.75 | Sunflowerseed Oil | 2.05 |
| Lemons | 6.16 | Sweeteners | 1.68 |
| MaizeOil | 1.12 | Tea | 1.87 |
| MarineFish | 0.56 | Tomatoes | 215.15 |
| Meat | 1.68 | Vegetables | 262.55 |
| Milk | 213.47 | Wheat | 405.11 |

399 Source: Authors own calculations based on FAOSTAT Food Balance Sheets

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401 **Table A4. Optimized diet for 2,467.5 kcal**

| Items | Opt. consumption (g/d) | % variation | Items | Opt. consumption (g/d) | % variation |
|---|---|---|---|---|---|
| Apples | 25.14 | 20.29 | Molluscs | 1.84 | 886.40 |
| Bananas | 3.73 | 17.58 | MuttonMeat | 31.84 | 184.38 |
| Barley | 11.36 | -1.79 | Nuts | 18.30 | 85.03 |
| Beans | 2.78 | 148.40 | Offals | 7.96 | 184.38 |
| BovineMeat | 31.84 | 184.38 | OilcropsOil | 0.39 | 4.29 |
| Butter | 1.32 | 18.16 | OliveOil | 6.20 | 3.91 |
| Cephalopods | 0.64 | 243.46 | Onions | 35.15 | 42.69 |
| Cereals | 1.00 | -46.28 | Oranges | 35.28 | 36.99 |
| Citrus | 24.80 | 36.99 | PalmOil | 4.53 | 1.17 |
| Cocoa | 3.31 | 343.08 | Peas | 6.68 | 138.71 |
| CoconutOil | 0.78 | 4.29 | PelagicFish | 53.13 | 190.52 |
| Coffee | 3.81 | 7.41 | Pimento | 0.15 | -17.10 |
| Cream | 3.51 | 87.90 | Pineapples | 0.28 | 49.38 |
| Crustaceans | 0.72 | 288.22 | Potatoes | 56.85 | -4.80 |
| Dates | 17.05 | 54.91 | PoultryMeat | 44.73 | 48.88 |
| DemersalFish | 16.16 | 179.32 | Pulses | 29.30 | 115.10 |
| Eggs | 56.23 | 281.41 | RapeOil | 0.98 | 5.43 |
| Fats | 0.44 | 18.16 | Rice | 4.13 | 121.28 |
| FreshwaterFish | 1.04 | 179.32 | Sorghum | 1.24 | 10.79 |
| Fruits | 85.12 | 29.96 | SoyabeanOil | 21.97 | 11.09 |
| Grapefruit | 17.58 | 22.33 | Soyabeans | 7.25 | 142.95 |
| Grapes | 11.21 | -4.61 | Spices | 4.76 | 50.00 |
| Groundnuts | 0.10 | -89.28 | Sugar | 0.10 | -99.85 |
| Honey | 0.10 | -86.60 | Sunflowerseed Oil | 2.15 | 4.95 |
| Lemons | 8.37 | 35.95 | Sweeteners | 0.10 | -94.05 |
| MaizeOil | 1.18 | 5.43 | Tea | 2.03 | 8.68 |
| MarineFish | 1.56 | 179.32 | Tomatoes | 295.79 | 37.48 |
| Meat | 4.78 | 184.38 | Vegetables | 459.89 | 75.16 |
| Milk | 441.53 | 106.83 | Wheat | 217.61 | -46.28 |

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**Table A5. Production, trade and apparent consumption by food item in 1000 tons**

| Items | Observed food apparent consumption | Optimized food apparent consumption | Observed Production | Domestic origin of optimized food apparent consumption. | Observed Importation | Importation of optimized food apparent consumption |
|---|---|---|---|---|---|---|
| Wheat and products | 2171 | 1166 | 822 | 442 | 1349 | 725 |
| Rice (Milled Equivalent) | 10 | 22 | | 0 | 10 | 22 |
| Barley and products | 62 | 61 | 237 | 21 | 40 | 40 |
| Sorghum and products | 6 | 7 | 1 | 1 | 5 | 6 |
| Cereals, Other | 10 | 5 | 48 | 5 | 0 | 0 |
| Potatoes and products | 320 | 305 | 370 | 286 | 20 | 19 |
| Sugar (Raw Equivalent) | 359 | 1 | 0 | 0 | 359 | 1 |
| Sweeteners, Other | 9 | 1 | 4 | 0 | 5 | 0 |
| Honey | 4 | 1 | 4 | 1 | 0 | 0 |
| Beans | 6 | 15 | 0 | 0 | 6 | 15 |
| Peas | 15 | 36 | 13 | 31 | 2 | 5 |
| Pulses, Other and products | 73 | 157 | 78 | 124 | 16 | 33 |
| Nuts and products | 53 | 98 | 54 | 96 | 1 | 2 |
| Soybeans | 16 | 39 | | 0 | 16 | 39 |
| Groundnuts (Shelled Eq) | 5 | 1 | | 0 | 5 | 1 |
| Soybean Oil | 106 | 118 | 68 | 76 | 38 | 42 |
| Sunflower seed Oil | 11 | 12 | 2 | 2 | 9 | 9 |
| Rape and Mustard Oil | 5 | 5 | | 0 | 5 | 5 |
| Palm Oil | 24 | 24 | | 0 | 24 | 24 |
| Coconut Oil | 4 | 4 | | 0 | 4 | 4 |
| Olive Oil | 32 | 33 | 196 | 33 | 0 | 0 |
| Maize Germ Oil | 6 | 6 | | 0 | 6 | 6 |
| Oil crops Oil, Other | 2 | 2 | 2 | 1 | 2 | 2 |
| Tomatoes and products | 1153 | 1585 | 1296 | 1550 | 25 | 35 |

| Items | Observed food apparent consumption (3684 kcal) | Optimized food apparent consumption (3684 kcal) | Observed Production | Domestic origin of optimized food apparent consumption. | Observed Importation | Importation of optimized food apparent consumption |
|---|---|---|---|---|---|---|
| Onions | 132 | 188 | 147 | 188 | 0 | 0 |
| Vegetables, Other | 1407 | 2465 | 1667 | 2441 | 13 | 23 |
| Oranges, Tangerines | 138 | 189 | 174 | 179 | 8 | 10 |
| Lemons, Limes and products | 33 | 45 | 37 | 45 | 0 | 0 |
| Grapefruit and products | 77 | 94 | 87 | 94 | 0 | 0 |
| Citrus, Other | 97 | 133 | 104 | 133 | 0 | 0 |
| Bananas | 17 | 20 | | 0 | 17 | 20 |
| Apples and products | 112 | 135 | 126 | 131 | 3 | 4 |
| Pineapples and products | 1 | 1 | | 0 | 1 | 1 |
| Dates | 59 | 91 | 174 | 91 | 0 | 0 |
| Grapes and products (excl wine) | 63 | 60 | 97 | 60 | 0 | 0 |
| Fruit, Other | 351 | 456 | 423 | 456 | 0 | 0 |
| Coffee and products | 19 | 20 | | 0 | 19 | 20 |
| Cocoa Beans and products | 4 | 18 | | 0 | 4 | 18 |
| Tea (including mate) | 10 | 11 | | 0 | 10 | 11 |
| Pimento | 1 | 1 | 12 | 1 | 0 | 0 |
| Spices, Other | 17 | 26 | 13 | 20 | 4 | 6 |
| Bovine Meat | 60 | 171 | 56 | 159 | 4 | 11 |
| Mutton & Goat Meat | 60 | 171 | 59 | 168 | 1 | 3 |
| Poultry Meat | 161 | 240 | 161 | 240 | 0 | 0 |
| Meat, Other | 9 | 26 | 10 | 26 | 0 | 0 |
| Offal, Edible | 15 | 43 | 15 | 43 | 0 | 0 |
| Butter, Ghee | 6 | 7 | 6 | 7 | 0 | 0 |
| Cream | 10 | 19 | 20 | 19 | 0 | 0 |
| Fats, Animals, Raw | 2 | 2 | 6 | 2 | 0 | 0 |
| Eggs | 79 | 301 | 92 | 301 | 0 | 0 |
| Milk - Excluding Butter | 1144 | 2366 | 1069 | 2072 | 142 | 294 |

| Items | Observed food apparent consumption (3684 kcal) | Optimized food apparent consumption (3684 kcal) | Observed Production | Domestic origin of optimized food apparent consumption. | Observed Importation | Importation of optimized food apparent consumption |
|---|---|---|---|---|---|---|
| Freshwater Fish | 2 | 6 | 2 | 6 | 0 | 0 |
| Demersal Fish | 31 | 87 | 29 | 81 | 2 | 6 |
| Pelagic Fish | 98 | 285 | 58 | 131 | 53 | 154 |
| Marine Fish, Other | 3 | 8 | 3 | 8 | 0 | 0 |
| Crustaceans | 1 | 4 | 3 | 3 | 0 | 1 |
| Cephalopods | 1 | 3 | 7 | 3 | 0 | 0 |
| Mollusks, Other | 1 | 10 | 1 | 5 | 1 | 5 |

Source: Authors own calculations based on Food balance sheet from FAOSTAT (2010)