

CRUNCHING THE NUMBERS: THE REAL COST OF A NUTRITIOUS DIET IN ECUADOR

*Andrea Bonilla^{*1}, Fernanda Salazar^{**2} and Yasmín Salazar^{*3}*

^{*}National Polytechnic School of Ecuador - Quantitative Economics Department

^{**}National Polytechnic School of Ecuador - Mathematics Department

Quito, Ecuador

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Abstract

This study aims to estimate the balanced dietary cost in the capital city of Ecuador, a country with high rates of malnutrition and food insecurity. By collecting retail food prices in Quito and using macronutrient composition data to set and solve a diet problem, the study identifies the cheapest combination of foods needed to meet nutritional requirements. Specifically, it identifies three options for minimum cost and nutritionally complete grocery shopping lists that are culturally adapted to Ecuadorian habits. The results show that the reported costs of affording a nutritionally complete diet in Quito, range from US\$ 3.09 to US\$ 3.64 per day, per person, in December 2022 dollars. However, between 28.23% and 32.75% of Ecuadorians cannot afford this cost even if they spend all their income on food, and undernutrition government programs are not sufficient to address the issue.

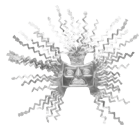
¹ORCID: 0000-0001-5191-8522. CRediT: Conceptualization, Formal Analysis, Research, Validation, Writing - Original Draft, Writing - Proofreading and Editing

²ORCID: 0000-0001-6896-1818. CRediT: Formal Analysis, Research, Methodology, Software, Validation, Writing - Original Draft

³ORCID: 0000-0001-5909-9234. CRediT: Conceptualization, Formal Analysis, Research, Project Management, Validation, Writing - Original Draft, Writing - Proofreading and Editing

E-mail: andrea.bonilla@epn.edu.ec; fernanda.salazar@epn.edu.ec; yasmin.salazar@epn.edu.ec

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HACIENDO NÚMEROS: EL COSTO REAL DE UNA DIETA NUTRITIVA EN ECUADOR

*Andrea Bonilla^{*1}, Fernanda Salazar^{**2} y Yasmín Salazar^{*3}*

^{*}Escuela Politécnica Nacional del Ecuador - Departamento de Economía Cuantitativa

^{**}Escuela Politécnica Nacional del Ecuador - Departamento de Matemáticas

Quito, Ecuador

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Resumen

Esta investigación utiliza herramientas de optimización matemática para estimar el costo de una dieta nutricionalmente balanceada, en Quito, capital del Ecuador. El enfoque en Ecuador permite considerar un país con altas tasas de desnutrición e inseguridad alimentaria. En términos metodológicos, en particular, este estudio recopila precios minoristas de alimentos en Quito y utiliza información sobre nutricional de macronutrientes requeridos promedio de un individuo para formular y resolver un problema de dieta. Así, los resultados del estudio identifican combinaciones de alimentos más baratas acorde a requerimientos nutricionales básicos. Específicamente, se proponen tres opciones de listas de compras de bajo costo y nutricionalmente completas, adaptadas culturalmente a los hábitos ecuatorianos. Los resultados muestran que el costo estimado de acceder a una dieta nutricionalmente completa en Quito oscila entre 3,09 y 3,64 dólares estadounidenses por día, por persona (a precios de diciembre de 2022), costo que revela ser no accesible para 28,23 %-32,75 % de los ecuatorianos, esto incluso si destinan todo su ingreso a la compra de alimentos. Por lo tanto, se provee evidencia de que los programas gubernamentales de lucha contra la desnutrición son insuficientes para abordar el problema en Quito-Ecuador.

¹ORCID: 0000-0001-5191-8522. CRediT: conceptualización, análisis formal, investigación, validación, redacción - borrador original, redacción - revisión y edición

²ORCID: 0000-0001-6896-1818. CRediT: análisis formal, investigación, metodología, software, validación, redacción - borrador original

³ORCID: 0000-0001-5909-9234. CRediT: conceptualización, análisis formal, investigación, administración del proyecto, validación, redacción - borrador original, redacción - revisión y edición

E-mail: andrea.bonilla@epn.edu.ec; fernanda.salazar@epn.edu.ec; yasmin.salazar@epn.edu.ec

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1. INTRODUCTION

Adequate nutrition is vital for maintaining a healthy life: quality nutrition improves immunity, diminishes disease susceptibility, allows physical and mental development, and increases productivity (Arthur et al., 2015). One in five adult deaths are related to suboptimal diets, through deficient intake of healthy foods and excess intake of unhealthy ones (Afshin et al., 2019). Indeed, a diverse and nutritionally complete diet is needed to sustain a healthy and active life, however, among others, food prices might contribute to poor diet quality and malnutrition (Bai et al., 2021; Darmon & Drewnowski, 2015; Hirvonen et al., 2020).

Ecuador ranks alarmingly high in malnutrition (FAO et al., 2022b, 2023). Is this due to food prices? According to FAO et al. (2022b), the daily cost of a healthy diet in Ecuador, based on 2020 prices, was \$ 2.93, and 21.4 % of the population could not afford it. Food prices do play a significant role, but they are part of a multidimensional issue. Unhealthy eating involves various factors, including individual aspects (e.g., taste preferences, self-discipline, time, and convenience) (Deliens et al., 2014; Whitelock & Ensaff, 2018); family and external environment influences (e.g., parents, friends, and peers) (Blades, 2001; Gottesman, 2002); and the macro environment (e.g., media, advertising, and socio-cultural influences) (Blades, 2001; Deliens et al., 2014).¹

Even though food prices are just part of a complex equation, affordability is key: an individual who cannot afford food is certainly poorly nourished. This study collects retail food prices and utilizes macronutrient composition data to identify the cheapest combination of foods required to meet nutritional needs in Quito, Ecuador. More specifically, it focuses on food products that are available in Quito's local markets, culturally accepted in the Andean Ecuadorian region, and matches each to its nutrient composition to solve the least-cost diet problem. By implementing a primary collection of retail prices and focusing on local and culturally accepted foods, this study contributes to previous research on the cost of a healthy diet in Ecuador in two key aspects: (i) it provides three options for minimum balanced dietary costs along with nutritionally complete grocery shopping lists culturally adapted to Ecuadorian habits, and (ii) it updates the balanced dietary costs in Quito up to December 2022, facilitating discussions on local public policy alternatives.

The paper is organized as follows: the next section is a literature review that integrates the food security, poverty, and malnutrition, and portrays the Ecuadorian panorama. Section 3 details the methodological approach. Sections

¹ The “eat-well” idea that includes, besides a balanced diet, aspects such as pleasure from taste and conviviality, regular meals, cooked food, and natural and pure products (Bildtgard, 2010) is out of the scope of the discussion. So, this study understands the eat-well idea as a healthy (nutritionally complete) diet.

4 and 5 report the minimum cost of alternative nutritional options and discuss the affordability of a healthy diet in Ecuador and the sufficiency of the current Ecuadorian social programs, respectively.

2. LITERATURE REVIEW

2.1. Food Security, poverty, and malnutrition

The term malnutrition is commonly accepted as a definition of an inadequate quality and insufficient quantity of food ingested by a person, but there is no unique definition (Soeters et al., 2017). According to the World Health Organization (WHO), “malnutrition is characterized by inadequate intake of protein, energy, and micronutrients and by frequent infections or disease” (p. 1) (WHO, 2000). In this sense, malnutrition reflects an imbalance between the nutrients required for the adequate functioning of the human body, both in quantity and quality, and it can appear as undernutrition or obesity (Ghosh, 2020). In children, malnutrition implies overweight, obesity, and undernutrition—it includes stunting, wasting, and deficiencies in essential micronutrients, while in adults, the main deficiencies are anemia and obesity (FAO et al., 2022b).

It has been widely documented that malnutrition affects all age groups and populations, especially the poor and vulnerable, causing death, disability, and ill health, and these consequences affect individuals, blocking economic growth and poverty reduction, especially in developing countries (Arthur et al., 2015). Despite inadequate caloric intake and high-burden disease are the leading causes of malnutrition, this condition results from the combination of diverse social and economic factors such as maternal education, socioeconomic status, and income.

Although maintaining a sufficient diet—in both energy (caloric) and nutritional requirements—is important, 3,1 billion people around the world cannot afford a healthy diet (Burki, 2022; FAO et al., 2022b). In other words, billions of people suffer from food insecurity, defined as “a situation that exists when all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life” (FAO, 2001).

Before the COVID-19 pandemic, the climate crisis, and the conflict in Ukraine, it was estimated that 112 million people were affected by food insecurity. Current figures reflect the impact of rising consumer food prices during the pandemic. According to the Food and Agriculture Organization (FAO), this reality poses significant challenges for countries worldwide in their efforts to end hunger and malnutrition by 2030 (Burki, 2022).

Food security is a complex situation. To better understand its mechanism, the (FAO, 2018) proposes four dimensions:

- I. Physical availability of food: related to the supply of food and is determined by the levels of food, production, stock, and net trade.
- II. Economics and physical access to food: to guarantee food security people must earn enough income and it is mandatory to implement policies about expenditure, markets, and prices.
- III. Food utilization: it is related to the process of absorption of nutrients by the body and it is the result of good care and feeding practices, food preparation, diversity of the diet, biological conditions, and intra-household distribution of food.
- IV. Stability of the three previous conditions over time independently of factors which could affected food security such as weather conditions, political instability, or economic factors (unemployment, rising food prices).

An analysis of all dimensions suggests that food insecurity, malnutrition, and poverty are deeply interconnected (FAO, 2018). Consequently, it is unreasonable to separate anti-poverty programs from food security policies, which should prioritize direct nutrition interventions alongside investments in health, water, and education. Furthermore, empirical evidence indicates that economic growth alone is insufficient to address the issue of food security (FAO et al., 2022a).

This paper focuses on Ecuador, a developing Latin-American country that has acquired a bad reputation for its malnutrition figures, food insecurity, and poverty. The scope limits to Quito-Ecuador, the country's main city. By presenting a general overview of the Equatorian situation regarding the three interrelated dimensions (i) malnutrition, (ii) food insecurity, and (iii) poverty; this study motivates the necessity of alleviation policies which must be based on a real balanced dietary cost.

2.1.5. Malnutrition in children

Ecuador ranks second among Latin American countries with the worst performance in chronic undernutrition among children under 5 years of age (Palma, 2018). According to the Ecuadorian National Institute of Statistics and Censuses (INEC-Spanish acronym), between 2014 and 2018, the prevalence of chronic malnutrition in children under five years of age fell from 25,3 % to 23 %. However, for infants under two years of age, the prevalence of chronic malnutrition increased from 24 % to 27,2 % (INEC, 2018). Additionally, the country has the highest prevalence of stunting (23,1 %), after Guatemala (42,8 %) (FAO et al., 2023). According to the same source, in emaciation ranking—the insufficient ingest of both energy and nutrients—Ecuador occupies the sixth place (3,7 %). Finally, other problematic conditions in children's

health are obesity and overweight—the latter is when a child has greater weight concerning his stature. Ecuador rises 5,3 % between 2000 and 2020, growing the 4,2 % to 9,5 %. Among all Latin American countries, Ecuador presented the highest increase.

2.1.6. Malnutrition in women

Anemia is a condition characterized by low levels of hemoglobin concentration in the blood (Chaparro & Suchdev, 2019). It can result from various causes, with iron deficiency being the most common, often due to inadequate dietary iron intake, malabsorption, or iron loss. Anemia has significant consequences, including increased morbidity and mortality in women and children, poor birth outcomes, reduced productivity in adults, and cognitive impairments. Women of reproductive age are particularly affected, with pregnant women being a group of special concern due to their higher iron requirements and increased susceptibility to anemia, which is linked to greater risks of maternal and infant mortality. In Ecuador, anemia prevalence decreased from 25% in 2000 to 18% in 2019 (FAO et al., 2023).

2.1.7. Malnutrition in adults

Obesity and overweight affect 64.4% of the adult population in Ecuador (INEC, 2018). The prevalence of obesity increased from 13% to 19% between 2000 and 2016. Adult obesity is more prevalent among women (25%) than men (15%). While obesity and overweight are conditions often associated with cultural factors, economic aspects also play a significant role. According to the World Health Organization, these conditions are risk factors for various chronic non-communicable diseases, including cardiovascular diseases, diabetes, respiratory diseases, depression, and certain types of cancer (Nyberg et al., 2018). Furthermore, obesity and overweight have aggregate impacts, such as reduced productivity and increased public health expenses.

2.1.8. Food insecurity

Regarding food insecurity, since 2014, moderate to severe food insecurity in the country has increased by 16 %, going from 22 % to 38 % in 2019-2021 (FAO et al., 2023).

2.1.9. Poverty

Related to poverty, in the same period, it increased from 22,5 % (poverty) and 7,7 % (extreme poverty) to 25% and 8,9 %, respectively (INEC, 2022).

During the COVID-19 pandemic, poverty rose 33 % while extreme poverty 15,4 %. Currently, poverty and extreme poverty rates are 25,2 % and 8,2 %, respectively.

Which are the consequences of such a situation? Can we design useful alleviation policies and programs? From an economic point of view, it is well known that the importance of eradicating malnutrition is to prevent harm in the formation of human capital to prevent future low levels of productivity and higher public health costs (Briceño, 2011). Specifically for Ecuador, the consequences of malnutrition are an affected gross motor development in infants (Cavagnari et al., 2022), shorter adult height, less schooling, and reduced economic productivity (Walrod et al., 2018). Moreover, malnutrition could increase the risk of being overweight as adults (because of smaller stature) and increase the mortality rate by diarrhea and respiratory illness.

Although Ecuadorian' conditions in nutrition are alarming, policies have not accounted that malnutrition has at least a double burden: stunting and overweight. Indeed, Ecuadorian programs focus on stunting while ignoring overweight, and, consequently, they neglect the simultaneous problems of malnutrition, micronutrient deficiencies, and overweight or obesity (Freire et al., 2014). Additionally, it seems that the Ecuadorian public health system is unable to face the monetary and non-monetary (morbidity and mortality rates) costs of the stunting-obesity double burden, including the cost of the diseases associated with both (Walrod et al., 2018).

Regarding social policies to eradicate poverty, in 1998, Ecuador implemented a conditional cash transfer program (Armas, 2005) called *Bono de Desarrollo Humano* (BDH). The beneficiaries of the BDH are Ecuadorian citizens living in extreme poverty and they perceive US\$ 55 monthly. Additionally, the Ecuadorian Government presided by Guillermo Lasso founded a new cash transfer program named *Bono Infancia Futuro* destined to eradicate undernutrition. The amount is US\$ 50, and the group of beneficiaries is formed by pregnant women, girls, and boys under 2 years of age living in poverty or extreme poverty. The beneficiaries of the *Bono Infancia Futuro* receive the income from the pregnancy until the boy or girl turns 2 years old, plus three additional single payments will be made if the mother meets some parameters, such as early medical attention, enrollment in civil registration, and constant controls. The benefit is not accumulative, that is if a woman already has any other bonus or pension, she is not eligible for the program.

To evaluate whether policies aimed at eradicating poverty and undernutrition are sufficient, the monthly amount of a money transfer required to enable beneficiaries to afford a diet meeting basic nutritional requirements in Quito is calculated. This analysis represents a small but significant step in addressing malnutrition in Ecuador. It provides valuable insight into the necessary shifts in Ecuadorian public policy toward ensuring food security.

3. METHODOLOGY

Regarding the balanced dietary costs—cost of a complete diet considering nutritional criteria—in 2020, a previous work estimated that an average Ecuadorian inhabitant needed US\$ 109,2 (at August 2020 prices) each month (US\$ 3,64 per day) to fulfill the reference nutritional requirements established by FAO (2018)². Later, various United Nations organizations reported that the daily cost of healthy food in Ecuador, at 2020 prices, was US\$2.93 (FAO et al., 2022b). The discrepancy between these amounts is likely methodological: while Bonilla-Bolaños and Salazar-Mendez (2021) calculated the cost of a nutritionally complete diet based on FAO (2018) requirements—namely, energy (Kcal): 2,132.00; protein (g): 63,98; fat (g): 71,08; carbohydrate (g): 309,21; iron (mg): 11,6-27,4; zinc (mg): 8,3-14,00; vitamin A (µg RE): 400,00-600,00; fiber (g): 25,00-30,00—these requirements differ from the criteria for a so-called “healthy diet” considered by FAO et al. (2022). Furthermore, while FAO et al. (2022) provide globally comparable price estimates, they do not focus on a specific city in Ecuador and do not disclose the selected food products, which precludes the generation of a recommended shopping list.

It is worth noting that, although the knowledge of a daily cost is useful for public policy, people do not eat the same every day, so biasing the daily-monthly inference. Therefore, we prefer to work with weekly nutritional requirements and report monthly, weekly, and daily prices together with a weekly grocery shopping list of minimum cost. Moreover, we provide estimated prices up to December 2022 so that to consider the 2020-2022 inflationary process. Indeed, the cost of locally producing food has increased worldwide during 2020-2022 mainly because (i) the COVID-19 pandemic’s disruption of supply chains increased transportation and energy prices, and (ii) the Russia’s invasion of Ukraine since February 2022 caused agricultural commodities and fertilizers to become scarce.

This study considers both the nutritional and the cost dimensions. On the one hand, a wide list of food products is considered for price collection so that more than one menu can be proposed as an alternative (see Appendix A1). On the other hand, an optimization algorithm is used to select the nutritionally sufficient food combination of minimum monetary cost, which results in a recommended weekly grocery shopping list. So, two methodological steps are followed: (i) construction of a list with eligible food products including their nutritional contributions, price collection, and estimation of an average cost by-product; (ii) formulation of the optimization algorithm used to select the food products that allow a nutritionally adequate diet at a minimum cost for an average individual. Finally, three options of minimum-cost grocery shopping lists are reported.

² See Bonilla-Bolaños & Salazar-Mendez (2021) for details on this estimation.

3.1. Phase 1: Eligible food products and their prices

The selection of food products is based on the Food-Based Dietary Guidelines (GABA) for Ecuador established by the Food and Agriculture Organization of the United Nations (FAO) in 2018 (FAO, 2018). The original list was depurated according to availability criteria: a pilot price collection was implemented in representative markets and supermarkets located in Quito to detect the non-available products. Next, following the INEC (2019) Consumers Price Index (CPI) methodology, the prices of all the selected food products were collected 9 times in different outlets (only markets and supermarkets were included following the informant establishments list of the INEC (2019)). The price collection took place in Quito—retailers located at the North and Sud of the city were included—during September 2021. It is worth noting that the CPI methodology was used exclusively for price collection, indeed, while CPI intends to report prices based on consumption habits, the objective here is to report prices of a specific list of food products which are not necessarily the same that are including when reporting consumption habits. The price collection was held by undergraduate students of Economics after they passed a training phase. The Ecuadorian National Institute of Statistics and Censuses (INEC) cooperated with this training phase. Finally, average prices (9 times collected) by item were computed, a database was obtained including nutritional contributions and prices by food product according to its weight in grams (see Appendix A1).

The reference nutritional requirements established by FAO (2018)—namely, energy (Kcal): 2132,00; protein (g): 63,98; fat (g): 71,08; carbohydrate (g): 309,21—are used as a reference for the formulation of the optimization algorithm in the second stage.

3.2. Phase 2: The nutritional groceries shopping list of minimum cost

The problem of finding a nutritionally adequate diet of minimum cost, in terms of the monetary cost of acquiring it, is a problem widely studied in the field of Operations Research. As stated in Sakarovitch (2013), a Linear Program (LP) is an optimization problem in which: (i) the variables of the problem are constrained by a set of linear equations and/or inequalities, and (ii) subject to these constraints, a function—so-called the objective function—is to be maximized (or minimized). This function depends linearly on the variables. A linear program is often written as $\max\{cx: Ax \leq b, x \geq 0\}$ where $A \in R^{m \times n}$, $b \in R^m$, $c \in R^n$ and $x \in R^n$; cx denotes the scalar product of the vectors $c^T x$.

The so-called Diet Problem (DP) was introduced as a linear program by Stigler (1945). It sought to determine how much of 77 foods should be eaten daily so that they meet the daily nutritional needs of a moderately active human at minimal cost. Later, Dantzig (1990) developed the Simplex Algorithm (SA)

and used it to solve the DP: the DP was the first problem solved by the SA which is still the most widely used method for solving linear programming problems.

The DP is an adequate method for the purpose of this article because, on the one hand, it stands out for considering the nutritional properties of food products when optimally selecting a diet; that is, the calories, proteins, minerals, and vitamins that are accepted as adequate or optimal for a certain population group are considered as constraints of the problem. So, the DP result assures that the solution respects maximum and/or minimum bounds of micro and macronutrients. On the other hand, DP allows us to account for tastes and habits. This is important because “if we want diets that someone might be willing to eat, we need models that take account of tastes and habits” (Smith, 1959). Indeed, for a nutritional recommendation to be useful, it is important to consider that eating large quantities of the same food every day is not preferred. So, even if the Stigler (1945) version of the DP results in a minimum cost but restricts diet—because large portions of the cheapest food products are selected—, additional constraints related to palatability and cultural habits can be included to report a more realistic diet proposal.

Moreover, the DP has been widely used for research purposes including different population groups and a variety of distinct nutritional requirements. Just to mention a few, Briend et al. (2003) and Tharrey et al. (2017) presented feeding recommendations for Colombian and Indian children between six and 24 months, respectively. Ali et al. (2016) solved an Integer Programming model for planning menus for school children aged between 13 to 18 years in Malaysia, where given a set of foods they first formed dishes and then selected which dishes will be part of the optimal menus. Using linear programming, Dos Santos et al. (2018) obtained an optimized diet for adults with the least difference from the observed population mean dietary intake while meeting a set of nutritional goals. Regarding healthy diets, there are more dimensions to analyze such as the income level of the focus group, as addressed in Verly-Jr et al. (2019), where the goal is to improve nutritional intake without increasing the household expenses on food. Further evidence and details about the DP application can be found in, inter alia, Gazan et al., (2018) and Babalola et al. (2020).

In this study, the design of an optimal diet will be developed using the methodology that is usually applied in the field of Operation Research, so the steps of Phase 2 are (i) to formulate a linear programming (LP) model, (ii) to implement a solution algorithm, and (iii) to run computational validation tests.

In the context of this study, the DP is defined as follows: given a set of food products along with their costs and their set of macronutrients, the objective is to determine the amount of each product that must be on a diet to meet both the nutritional requirements of a person and an established energy value, at the lowest possible cost.

To formulate the optimization model, let I be defined as the set of foods containing the 145 food products which prices were collected in Phase 1, and let $x_i \in \mathbb{Z}_+$ be integer decision variables indicating the number of servings of food $i \in I$ to be consumed during a week. It is important to mention that the servings are set as directed by a nutritionist using measures like cups, spoons, slices, etc.

Thereafter, to represent all criteria that the DP formulation requires, for every food $i \in I$ the following parameters are defined:

Costs:

c_i : cost per serving of food i , $i \in I$.

Macronutrients:

p_i : amount of protein provided by a serving of i , $i \in I$.

b_i : amount of carbohydrates provided by a serving of i , $i \in I$.

f_i : amount of fat provided by a serving of food i , $i \in I$.

Energy:

e_i : amount of energy provided by a serving of food i , $i \in I$.

Diet diversity:

r_i : maximum number of weekly servings of food i , $i \in I$.

Furthermore, each food $i \in I$ belongs to exactly one category j , with $j \in [1,9]$. Table 1 shows the categories considered in this study where g_j represents a set containing food products of the stated category.

Table 1 Food products categories based on FAO (2018)

Category(1)	Group
Cereals	g_1
Meats (meat, fish, shellfish, and eggs)	g_2
Fruits	g_3
Vegetables	g_4
Dairy	g_5
Legumes	g_6
Fats	g_7
Sugars and sweets	g_8
Tubers, starchy roots, and plantain	g_9

Notes. (1) The food products were regrouped such that conventional nutritional portions could be accounted into the programming algorithm.

Note that the food groups form a partition on the set of foods I ; i.e., $I = g_1 \cup g_2 \cup g_3 \cup g_4 \cup g_5 \cup g_6 \cup g_7 \cup g_8 \cup g_9$; and the intersection of all the sets g_j , $j \in [1,9]$ is empty.

For minimizing the total cost of a weekly diet when it includes x_i number of servings of food $i \in I$ per week, the objective function is defined as $\min \sum_{i \in I} c_i x_i$ which measures the total cost associated with the use of servings of foods in the solution. The optimization problem DP is subject to the constraints that are described below.

Table 2. Set LB and UB for macronutrients and energy based on FAO (2018)

Macronutrient	Minimal Requirements		Margin (10 %)
	Daily	Weekly (LB)	Weekly (UB)
Energy (Kcal)	2.132	14.924	1,1(14.924) = 16.416,4
Protein (g)	63,98	447,86	1,1(447,86) = 492,65
Fat (g)	71,08	497,56	1,1(497,56) = 547,32
Carbohydrate (g)	309,21	2.164,47	1,1(2.164,47) = 2.380,92

Notes. LB: lower bound, UB: upper bound. The LB-UB restricts the allowed deviation of the solution from the nutritional recommendation.

According to the FAO's Food-Based Dietary Guidelines for Ecuador (FAO, 2018), for each macronutrient, the recommended daily consumption in grams is given by protein: 63,98; fat: 71,08, and carbohydrate: 309,21 whereas the total energy needed by an average individual is 2.132,00 Kcal. From a nutritional point of view, a margin of 10 % is allowed for such criteria. Table 2 shows the lower bounds (LB) and upper bounds (UB) for macronutrients and energy.

Therefore, the following constraints are included in the optimization model so that the recommendations are fulfilled.

$$14.924 \leq \sum_{i \in I} e_i x_i \leq 1,1(14.924) \quad (1)$$

$$447,86 \leq \sum_{i \in I} p_i x_i \leq 1,1(447,86) \quad (2)$$

$$497,56 \leq \sum_{i \in I} f_i x_i \leq 1,1(497,56) \quad (3)$$

$$2.164,47 \leq \sum_{i \in I} b_i x_i \leq 1,1(2.164,47) \quad (4)$$

In addition, restrictions on weekly portions of dairy, meats, cereals, sugars and sweets, and vegetables and fruits, are included according to standard dietary guidelines (Montagnese et al., 2015). These restrictions are necessary for reporting more diverse options, that is, for accounting the fact that people do not eat the same every day. The constraints are:

$$1 \leq \sum_{i \in g_2} x_i \leq 7 \quad (5)$$

$$7 \leq \sum_{i \in g_3} x_i \leq 14 \quad (6)$$

$$7 \leq \sum_{i \in g_4} x_i \leq 21 \quad (7)$$

$$14 \leq \sum_{i \in g_5} x_i \leq 21 \quad (8)$$

$$\sum_{i \in g_7} x_i \leq 7 \quad (9)$$

$$\sum_{i \in g_8} x_i \leq 7 \quad (10)$$

Constraint 5 ensures that during a week, at least one serving of meats and a maximum of seven servings will be consumed. Constraint 6 guarantees the daily consumption of one or two fruits. Analogously, constraints 7 and 8 impose upper and lower bounds on the weekly servings of vegetables and dairy products, respectively. Finally, constraints 9 and 10 determine that the maximum consumption of both, fats, and sugars, should not exceed seven servings per week.

The last methodological step is the analysis of the criterion related to the palatability of the diet which refers to defining what is the maximum serving of foods that a person can consume during a week. Such quantities determine the variety of the diet so that it is possible to obtain a miscellaneous shopping list and must correspond to portions that can be eaten in real life. In this study,

the variety parameter is fixed as constant for all foods, and it is noted by r . Consequently, the following constraints are included in the optimization model:

$$\begin{aligned} x_i &\geq r \\ \forall i \in I \end{aligned} \tag{11}$$

Note that the solution of the problem, i.e., the diet with minimum cost that respect all the constraints, will depend on the value of r . Once a final solution is obtained, it is possible to report more than one option of the weekly minimum cost of a balanced dietary, three options are reported. Moreover, the (non)affordability of the resulting options is estimated by using December-2022 data from the Ecuadorian official labor survey so-called ENEMDU (INEC, 2022)³, which provides data on households income. More specifically, the non-affordability proportion is estimated by calculating the proportion of the population which household per-capita income is less than the resulted minimum cost of a balanced diet.

4. RESULTS AND LIMITATIONS

The food products which prices were collected (133 in total as detailed in Appendix A1) are divided into 12 categories by FAO (2018):

1. Cereals (16 products)
2. Tubers, starchy roots, and plantain (7 products)
3. Vegetables with moderate energy intake (6 products)
4. Vegetables with low energy intake (18 products)
5. Fruits (26 products)
6. Lean meats, fish, shellfish, and eggs (14 products)
7. Low-fat meats and eggs (14 products)
8. Cooked dried legumes (5 products)
9. Full fat dairy (3 products)
10. Oilseeds and oily fruits (6 products)
11. Sugars and sweets in syrup (12 products)
12. Pastry sweets (6 products)

³ Data is available in: <https://www.ecuadorencifras.gob.ec/estadisticas-laborales-enemdu-empleo-diciembre-2022/>

For programming reasons, these 12 categories were regrouped into 9 (see Table 1). More specifically, all vegetables were regrouped into a single category—Vegetables (g_4)—in Table 3.1, which includes FAO (2018)’s categories 3 and 4. Similarly, all animal proteins were regrouped into the Meats category (meat, fish, shellfish, and eggs) (g_2), encompassing FAO (2018)’s categories 6 and 7. Additionally, all sugars FAO (2018)’s categories 11 and 12 are included in Sugars and sweets (g_8). However, the reported results are in line with FAO (2018)’s classification so that the disaggregated category can be identified.

As detailed in Section 3, the optimization exercise exclusively accounted for nutritional recommendations regarding energy and macronutrients—see relations (1) to (4). Even if no micronutrient restriction is included, relations (5) to (10) indirectly accounts for its inclusion and diversity by restricting the algorithm to report choices that respect minimum and maximum weekly portions of dairy, meat and fish, cereals, sugars and sweets, and vegetables and fruits.

The optimization model was solved to optimality using the integer programming solver Gurobi 9.1.1 in default settings, with its Python interface. All the experiments were performed in a matter of seconds on an Intel Core i7-8665U 2,10 GHz with 16 GB RAM running Windows 10 Pro.

The resulting grocery shopping lists of minimum cost are detailed in table 3. Three alternative nutritionally equivalent lists are provided. Although more than three options can be reported, the ones in Table 3 are enough for the purpose of this research: to estimate the cost of a nutritionally complete diet. The alternative shopping lists are all nutritionally complete, but its diversity is different: Option (A), the most diverse, is restricted to include a maximum of 5 weekly servings of the same product. It includes 34 products while Options (B) and (C), which include a maximum of 6 and 7 servings of the same food, consist of 32 and 24, respectively (see Table 4). As shown by Table 3, some food products—for instance, rice, raw oats (flakes), yuca, among others—appear in all shopping list because of its low cost, but also several other products as *machica* and quinoa, are both affordable and highly nutritious.

Table 3. Grocery shopping lists of minimum cost and nutritionally complete

Option (A): Maximum 5 weekly servings per food				Option (B): Maximum 6 weekly servings per food				Option (C): Maximum 7 weekly servings per food			
Food product	Por	Weekly weight (g)	Food Category	Food product	Por	Weekly weight (g)	Food Category	Food product	Por	Weekly weight (g)	Food Category
Rice	5	150	C	Rice	6	180	C	Rice	7	210	C
Raw oats (flakes)	5	225	C	Raw oats (flakes)	6	270	C	Raw oats (flakes)	7	315	C
Pearl barley	5	225	C	Pearl barley	6	270	C	Pearl barley	7	315	C
Salt crackers	5	160	C	Salt crackers	6	192	C	Salt crackers	7	224	C
Machica flour	5	150	C	Machica flour	6	180	C	Machica flour	7	210	C
Corn flour	5	150	C	Corn flour	6	180	C	Corn flour	7	210	C
Quinoa flour	5	175	C	Quinoa flour	3	105	C	Cornstarch	7	70	C
Cornstarch	5	50	C	Cornstarch	6	60	C	Wholemeal bread	7	175	T
Toasted corn or chulpi	5	225	C	Toasted corn or chulpi	1	45	C	Sweet potato	7	700	T
Bread	5	125	C	Wholemeal bread	6	150	C	Banana flour	7	210	T
Wholemeal bread	5	125	C	Raw quinoa	6	270	C	Average potato	6	600	T
Raw quinoa	5	225	C	Sweet potato	6	600	T	Green banana	7	490	T
Sweet potato	5	500	T	Banana flour	6	180	T	Yucca	7	490	T
Banana flour	5	150	T	Melloco	1	100	T	Paean onion	7	280	VegL

Average potato	5	500	T	Average potato	6	600	T	Banana	7	560	F
Green banana	5	350	T	Green banana	6	420	T	Chicken wings	7	210	LFME
Yucca	5	350	T	Yucca	6	420	T	Beef rib	7	210	LFME
Paean onion	5	200	VegL	Paean onion	6	240	VegL	Chicken eggs	7	385	LFME
Creole lettuce	1	50	VegL	Creole lettuce	1	50	VegL	Dry lentil	1	30	DLeg
Green pepper	1	75	VegL	Banana	6	480	F	Pasteurized milk	7	1.715	FFD
Banana	5	400	F	Orange	1	100	F	Natural yoghurt without sugar	7	1.715	FFD
Orange	2	200	F	Pork chop	3	90	MFE	Roasted peanuts with oil and salt	7	210	OS&F
Pork chop	3	90	MFE	Chicken wings	6	180	LFME	Cake	1	50	PS
Chicken wings	5	150	LFME	Beef rib	6	180	LFME	Waffer cookies	6	150	PS
Beef rib	5	150	LFME	Chicken eggs	6	330	LFME				
Chicken eggs	5	275	LFME	Pasteurized milk	6	1.470	FFD				
Dry bean	2	60	DLeg	Natural yoghurt without sugar	6	1.470	FFD				

Pasteurized milk	5	1.225	FFD	Light flavored yogurt	2	490	FFD
Natural yoghurt without sugar	5	1.225	FFD	Roasted peanuts with oil and salt	6	180	OS&F
Light flavored yogurt	4	980	FFD	Salted Peanut Butter	1	30	OS&F
Roasted peanuts with oil and salt	5	150	OS&F	Waffer cookies	1	18	PS
Salted Peanut Butter	2	60	OS&F	Cake	6	150	PS
Waffer cookies	3	75	PS				
Cake	4	200	PS				

Notes. The categories abbreviation are as follows: Cereal (C), Tubers, starchy roots, and plantain (T), Vegetables with moderate energy intake (VegM), Vegetables with low energy intake (VegL), Fruits (F), Lean meats, fish, shellfish, and eggs (MFE), Low-fat meats and eggs (LFME), Cooked dried legumes (DLeg), Full fat dairy (FFD), Oilseed and oil fruits (OS&F), Sugars and sweets in syrup (S) and Pastry sweets (PS).

Table 4. Macronutrients proportion and diet diversity

Weekly grocery shopping list option	(A)		(B)		(C)	
Maximum portions by category (r)	5		6		7	
Number of included food products	34		32		24	
Weekly energy (Kcal)	14.933,97	%	14.927,16	%	14.924,53	%
Protein (g)	492,24	13,18	492,61	13,20	491,04	13,16
Fat (g)	497,58	29,99	498,32	30,05	498,13	30,04
Carbohydrate (g)	2.185,30	58,53	2.179,43	58,40	2.185,31	58,57

Notes. The adequation percentages by macronutrient are superior to 90 %: the standard diet is composed by protein (15 %), fat (20 %) and carbohydrate (65 %) and diets associated to (A), (B) and (C) grocery shopping lists are composed by protein (13 %), fat (29 %) and carbohydrate (58 %). All diet options are nutritionally adequate.

As detailed in Table 4, the three options account for more than 14.000 kilocalories per week and the proportion of protein, fat, and carbohydrates is adequate. So, they are all good enough from a macro-nutritional point of view, but Option (A) is preferred for a diversity matter: a more diverse diet is preferred not only because of its adherence but also because of the wider spectrum of micronutrients it includes. Notwithstanding, diversity cost more: as reported by Table 5, Option (A) can be bought with US\$ 26,81 by week December 2022 US dollars while Option (B) costs US\$ 24,67 and Option (C) costs US\$ 22,74. For these amounts to become a monthly minimum monetary requirement for nutritionally eating we need to add, at least, the sugar, salt, and condiments monthly cost. Based on the items included by the Ecuadorian National Statics Institute in the so-called Vital Family Basket, we add US\$ 1,89 per person of December 2022 US dollars by month to all options. So, the minimum monthly balanced dietary cost is US\$ 103,13 December 2022 dollars (US\$ 100,58 and US\$ 92,83, respectively, for less diverse options). That is, US\$ 3,64 (US\$ 3,35 and US\$ 3,09) per person per day.

Thus, the results indicate that an average Ecuadorian requires between US\$3.09 and US\$3.64 per day in December 2022 dollars to meet nutritional requirements. As a point of comparison, previous estimates provide different figures: Bonilla-Bolaños and Salazar-Mendez (2021) reported a daily cost of US\$3.64 in 2020 dollars, while FAO et al. (2022b) reported US\$2.93 for the same year. Adjusted to December 2022 dollars, these figures correspond to

US\$3.98 and US\$3.20, respectively.⁴ Even if the food baskets used to compute these costs are not the same, their nutritional composition can be thought as equivalent. Other than reporting an updating amount of the balanced dietary cost in Ecuador, our study adds to previous estimations by reporting different weekly grocery shopping lists, so that the daily balanced dietary cost materializes into real cooking options for the population. All options detailed in Table 3 are nutritionally equivalent—regarding kilocalories and macronutrient requirements—and of minimum cost, the difference between options is because of diversity: more diverse options are more expensive. Moreover, all food products included in the proposed weekly shopping lists are culturally adapted to Ecuadorian food production.

Table 5. The minimum balanced dietary cost

Weekly grocery shopping list option	(A)	(B)	(C)
Optimum weekly cost (August 2021 prices)	\$ 24,76	\$ 22,78	\$ 20,99
August 2021-December 2022 inflation rate	8,29 %	8,29 %	8,29 %
Optimum weekly cost (December 2022 prices)	\$ 26,81	\$ 24,67	\$ 22,74
Optimum monthly cost (December 2022 prices)	\$ 107,24	\$ 98,69	\$ 90,94
Sugar, salt, and condiments monthly cost (CFV Dec 2022 INEC)	\$ 1,89	\$ 1,89	\$ 1,89
Monthly cost including sugar, salt, and condiments (Dec 2022 prices)	\$ 109,13	\$ 100,58	\$ 92,83

Notes. The price collection phase was held during August 2021, so, to report an updated price, the August 2021-December 2022 inflation rate of food (CCIF Code 011 from CPI Ecuadorian National Statistics Institute INEC) was accounted for. The sugar, salt, and condiments monthly cost (CFV December 2022 INEC) is \$7,57 per household. As INEC considers a representative household of 4 members, the monthly cost is divided by 4 so that to consider an individual amount.

Another question of interest when discussing the estimated balanced dietary cost is its affordability. So, are US\$ 3,09-US\$ 3,64 per person, per day, affordable for Ecuadorians? As a first answer clue, let's consider that, up to January 2023, the average income of a 4-member Ecuadorian household is 840,00 US dollars (INEC, 2023). So, a nutritionally complete diet in Ecuador

⁴ To update the 2020 prices, the December 2020–December 2022 inflation rate for food (CCIF Code 011 from the Consumer Price Index of the Ecuadorian National Statistics Institute, INEC) was applied. This corresponds to a 9,2641 % price increase.

(taking Quito as reference) appears to be affordable, in average. Okay, let's consider a broader picture: does this mean that all Ecuadorian inhabitants can afford it? A first technical estimation based on Quito's costs is: No, it does not. Table 6 reports the proportion of Ecuadorian inhabitants which monthly household per-capita income is less than \$ 109,13 (A), \$ 100,58 (B), and \$ 92,83 (C), respectively. It appears that 32,75 % (31,57 % and 28,23 %) of total population has a per-capita household income that amounts less than US\$ 109,13 (US\$ 100,58 and US\$ 92,83, respectively) by month. This estimated proportion of non-affordability reveals a crucial panorama: even spending all their income on food, it is not possible for 32,75 % (31,57 % and 28,23 %) of households to access complete nutrition in Quito—the panorama is even worse if including the cost of the rest of basic needs (e.g., dress, dwelling, health, education). Indeed, in Ecuador, the extreme income poverty line, as of December 2022, amounts to US\$ 50,00 per capita by month while the income poverty line amounts to US\$ 88,72 (INEC, 2022).

Table 6. Affordability of a nutritionally complete diet, December 2022

Shopping list option	Monthly cost	Non-affordability proportion			
		Estimate	Estimation Error	IC inf 95 %	IC sup 95 %
(A)	\$ 109,13	0,3275357	0,0122779	0,3034637	0,3516077
(B)	\$ 100,58	0,3157301	0,0125445	0,2911354	0,3403248
(C)	\$ 92,83	0,2823409	0,0122376	0,2583478	0,3063339

Notes. The non-affordability proportion is estimated by calculating the proportion of population which household per-capita income is less than \$ 109,13 (A), \$ 100,58 (B), and \$ 92,83 (C), respectively. The reported proportion is estimated using December-2022 data from the Ecuadorian official labor survey so-called ENEMDU (<https://www.ecuadorencifras.gob.ec/estadisticas-laborales-enemdu-empleo-diciembre-2022/>).

Clearly, poor people cannot afford nutrition in Quito, Ecuador. There is some room for public policy. The natural next question is: does the Ecuadorian social system guarantee its beneficiaries to eat a nutritionally complete diet? And again, it seems that the answer is: No, it does not. Table 7 summarizes the current Ecuadorian cash transfer programs revealing that the Ecuadorian social system, which exclusively includes targeted cash transfer programs, cannot assure the affordability of a nutritionally complete diet: the Bono Infancia Futuro—which main goal is to eradicate undernutrition and which beneficiaries are pregnant women, girls, and boys under 2 years of age living in poverty or extreme poverty—allocates US\$ 50,00 USD by month while the actual minimum balanced dietary cost ranges between US\$ 109,13 and US\$ 92,83, monthly. Furthermore, the *Pensión Desnutrición* (Undernutrition Pension), which is a complement of the *Bono Infancia Futuro*, allocates US\$ 240 in three single payments if, and only if, the mother had early medical attention,

enroll in civil registration and attend to constant controls. It is worth nothing that, the *Pensión Desnutrición* is not cumulative: if the mother is beneficiary of any other social program, she is not eligible for the undernutrition programs.

Table 7. Ecuadorian cash transfer programs (up to 2023)

	Cash transfer amount in USD
Bono de Desarrollo Humano	\$ 55
Pensión Mis Mejores Años	\$ 100
Pensión para Adultos Mayores	\$ 50
Bono Joaquín Gallegos Lara	\$ 240
Pensión Toda una Vida	\$ 100
Pensión para Personas con Discapacidad	\$ 50
Cobertura de contingencias	variable
Pensión desnutrición	240
Bono Infancia Futuro o Bono de los 1000 días	50

Source. Ministry of Economic and Social Inclusion-Ecuador.

5. CONCLUSIONS AND DISCUSSION

Ecuadorian inhabitant's nutrition state is alarming: by 2018, Ecuador ranked second among the Latin-American countries with the worst performance in chronic undernutrition in children under 5 years of age; by 2019, 18 % of Ecuadorian women had anemia; obesity in Ecuadorian adults increased from 13 % to 19 % in the period 2000-2016. Moreover, food insecurity in Ecuador increased from 22 % to 38 % during the period 2019-2021. Among other factors, malnutrition in Ecuador is caused by poverty: 25,2 % of Ecuadorians are poor and 8,2 % are extremely poor.

The cost of eating a nutritionally complete diet in Quito, Ecuador, ranges between US\$ 3.09 and US\$ 3.64 per day, per person, in December 2022 dollars. This amount reflects a minimum cost, calculated using a minimization algorithm that solves the dietary problem (DP) for a set of food products whose prices were determined through a primary data collection. It exclusively considers a selection of Ecuadorian food products, making it the cost of complete nutrition tailored to Ecuadorian culinary culture. The reported balanced dietary cost is accompanied by a weekly shopping list that translates the calculated amount into practical cooking options for the population.

A less encouraging finding is that, even if they spend all their income in food, between 28,23 % and 32,75 % of Ecuadorians cannot afford this cost. Moreover, the income poverty, and extreme poverty, lines are below the balanced dietary cost. An even more alarming concluding remark is that the undernutrition government programs are not sufficient: they allocate an amount of money that does not guarantee their beneficiaries to afford the minimum cost of a nutritionally complete diet in Quito.

Finally, it is worth reflecting on the nature of the Ecuadorian undernutrition programs. The current malnutrition state of Ecuadorian citizens is such that its eradication implies a structural transformation of the very conception of social policy. Indeed, the Ecuadorian social policy is characterized by income transfer programs that are not only limited by the allocated budget, but also designed to ignore the reality of households living in poverty and extreme poverty conditions: even if poor and extremely poor people do receive a cash transfer from the State, their labor income does not allow them to reach a minimum income to satisfy basic needs. Furthermore, in Ecuador, people living in poverty face various types of deprivation: little access to water, sewerage, health, and education services; they live in overcrowding. Consequently, social investment should include programs guaranteeing that people living in poverty not only can eat better, but also can live in decent conditions.

Although these conclusions are based exclusively on Quito's cost of eating, our contribution is an attempt to show the need of technically based public policy decisions. How do Ecuadorian policymakers decide the amount of money allocated to social programs? Are the chosen allocations amounts sufficient? Further research is surely needed to better understand these questions, notwithstanding, this study provides technical evidence of a negative answer.

This study's limitations allow us to provide, at least three, future research needs: (i) the scope here limits to price collection in Quito-Ecuador, a broader scope is required if a national public policy is to be settled; (ii) the reported balanced dietary costs are for an average Ecuadorian adult while a distinction among population's age and sex is recommended for targeting policy, as, for instance, the *Pensión Desnutrición* (Undernutrition Pension) program; and (iii) if a food security program is aimed, that is, for the aiming objective that "all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life", sufficiency is not enough. Moreover, even if people do have enough money to afford a balanced dietary cost, it is not possible to affirm that nutrition is guaranteed because of preferences, ignorance of nutrition principles, etc. This third extension can be extensively discussed, so, for concluding the purpose of this research, just two opposite arguments are briefly mentioned: (i) as asserted by WHO (2021), a policy for public food procurement should consider more than food affordability, and (ii) if affordability (or some kind of nutritious food provision) is not guaranteed,

it is impossible to aim for food security. So, it seems that Ecuador's primary need is for people to be able to afford at least the balanced dietary costs.

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APPENDIX

Appendix A1.

Table A1. FAO (2018)'s food products classification for Ecuadorian culture

	Category	Acronym	Food product
1	Cereal	C	Rice
2	Cereal	C	Raw oats (flakes)
3	Cereal	C	Pearl barley
4	Cereal	C	Breakfast cereal
5	Cereal	C	Wheat noodle
6	Cereal	C	Salt crackers
7	Cereal	C	Machica flour
8	Cereal	C	Corn flour
9	Cereal	C	Quinoa flour
10	Cereal	C	Cornstarch
11	Cereal	C	Toasted corn or chulpi
12	Cereal	C	Cooked mote
13	Cereal	C	Bread
14	Cereal	C	Whole meal bread
15	Cereal	C	Raw quinoa
16	Cereal	C	Tortilla de trigo
17	Tubers, starchy roots, and plantain	T	Sweet potato
18	Tubers, starchy roots, and plantain	T	Banana flour
19	Tubers, starchy roots, and plantain	T	Melloco
20	Tubers, starchy roots, and plantain	T	Average potato
21	Tubers, starchy roots, and plantain	T	Green plantain
22	Tubers, starchy roots, and plantain	T	Yucca
23	Tubers, starchy roots, and plantain	T	White carrot
24	Vegetables with moderate energy intake	VegM	Sweet pea

25	Vegetables with moderate energy intake	VegM	Corn
26	Vegetables with moderate energy intake	VegM	Tender bean
27	Vegetables with moderate energy intake	VegM	Beet
28	Vegetables with moderate energy intake	VegM	Little pod
29	Vegetables with moderate energy intake	VegM	Carrot
30	Vegetables with low energy intake	VegL	Chard
31	Vegetables with low energy intake	VegL	Celery
32	Vegetables with low energy intake	VegL	Eggplant
33	Vegetables with low energy intake	VegL	Broccoli
34	Vegetables with low energy intake	VegL	Paeon onion
35	Vegetables with low energy intake	VegL	Mushrooms
36	Vegetables with low energy intake	VegL	White cabbage
37	Vegetables with low energy intake	VegL	purple cabbage
38	Vegetables with low energy intake	VegL	Cauliflower
39	Vegetables with low energy intake	VegL	Asparagus
40	Vegetables with low energy intake	VegL	Spinach
41	Vegetables with low energy intake	VegL	creole lettuce
42	Vegetables with low energy intake	VegL	Turnip
43	Vegetables with low energy intake	VegL	Pickle
44	Vegetables with low energy intake	VegL	Green pepper
45	Vegetables with low energy intake	VegL	Radish

46	Vegetables with low energy intake	VegL	kidney tomato
47	Vegetables with low energy intake	VegL	zucchini
48	Fruits	F	Average peach
49	Fruits	F	Passion fruit
50	Fruits	F	Currant
51	Fruits	F	Soursop
52	Fruits	F	Guava
53	Fruits	F	Lemon juice
54	Fruits	F	Tangerine
55	Fruits	F	Mango
56	Fruits	F	Apple
57	Fruits	F	Passion fruit
58	Fruits	F	Melon
59	Fruits	F	Blackberry
60	Fruits	F	Orange
61	Fruits	F	Naranjilla (pulp)
62	Fruits	F	Papaya
63	Fruits	F	Sweet Cucumber
64	Fruits	F	Pear
65	Fruits	F	Pineapple
66	Fruits	F	banana silk
67	Fruits	F	Watermelon
68	Fruits	F	Tamarind
69	Fruits	F	tree tomato
70	Fruits	F	Pink grapefruit
71	Fruits	F	Tuna
72	Fruits	F	Grape
73	Fruits	F	Gooseberry
74	Lean meats, fish, shellfish, and eggs	MFE	Canned tuna
75	Lean meats, fish, shellfish, and eggs	MFE	Squid
76	Lean meats, fish, shellfish, and eggs	MFE	Shrimp
77	Lean meats, fish, shellfish, and eggs	MFE	Chicken's liver
78	Lean meats, fish, shellfish, and eggs	MFE	Cow liver

79	Lean meats, fish, shellfish, and eggs	MFE	Shrimp
80	Lean meats, fish, shellfish, and eggs	MFE	Chicken gizzard
81	Lean meats, fish, shellfish, and eggs	MFE	Turkey
82	Lean meats, fish, shellfish, and eggs	MFE	Skinless chicken breast
83	Lean meats, fish, shellfish, and eggs	MFE	White meat fish
84	Lean meats, fish, shellfish, and eggs	MFE	Chicken legs
85	Lean meats, fish, shellfish, and eggs	MFE	Octopus
86	Lean meats, fish, shellfish, and eggs	MFE	Beef kidney
87	Lean meats, fish, shellfish, and eggs	MFE	Canned sardines
88	Low-fat meats and eggs	LFME	Chicken wings
89	Low-fat meats and eggs	LFME	Mutton
90	Low-fat meats and eggs	LFME	Pork chop
91	Low-fat meats and eggs	LFME	Beef rib
92	Low-fat meats and eggs	LFME	Pork steak
93	Low-fat meats and eggs	LFME	Chicken eggs
94	Low-fat meats and eggs	LFME	Beef tongue
95	Low-fat meats and eggs	LFME	Smoked pork loin
96	Low-fat meats and eggs	LFME	Sausage
97	Low-fat meats and eggs	LFME	Mortadella
98	Low-fat meats and eggs	LFME	Fresh cheese
99	Low-fat meats and eggs	LFME	Mozzarella cheese
100	Low-fat meats and eggs	LFME	Grated Parmesan cheese
101	Low-fat meats and eggs	LFME	Ricotta cheese
102	Cooked dried legumes	DLeg	Cooked lupine (not dry)
103	Cooked dried legumes	DLeg	dry broad bean
104	Cooked dried legumes	DLeg	dried beans
105	Cooked dried legumes	DLeg	dried chickpea
106	Cooked dried legumes	DLeg	dried lentil
107	Full fat dairy	FFD	pasteurized milk
108	Full fat dairy	FFD	Plain unsweetened yogurt
109	Full fat dairy	FFD	Light flavored yogurt

110	Oilseeds and oily fruits	OS&F	Olives
111	Oilseeds and oily fruits	OS&F	Avocado
112	Oilseeds and oily fruits	OS&F	Almond
113	Oilseeds and oily fruits	OS&F	Roasted peanuts with oil and salt
114	Oilseeds and oily fruits	OS&F	Salted Peanut Butter
115	Oilseeds and oily fruits	OS&F	Nut
116	Sugars and sweets in syrup	S	Malt drink
117	Sugars and sweets in syrup	S	Canned fruit cocktail
118	Sugars and sweets in syrup	S	Caramel sauce
119	Sugars and sweets in syrup	S	Peaches in syrup
120	Sugars and sweets in syrup	S	Powdered gelatin
121	Sugars and sweets in syrup	S	Figs with honey (canned)
122	Sugars and sweets in syrup	S	Jam (strawberry, blackberry, pineapple)
123	Sugars and sweets in syrup	S	Honeybee
124	Sugars and sweets in syrup	S	Fruit nectar (pear, apple, or peach)
125	Sugars and sweets in syrup	S	Pineapple in syrup (canned)
126	Sugars and sweets in syrup	S	Iced tea
127	Sugars and sweets in syrup	S	Powdered iced tea
128	Pastry sweets	PS	Cake
129	Pastry sweets	PS	Chocolate bar
130	Pastry sweets	PS	Cocoa powder
131	Pastry sweets	PS	Waffle biscuit
132	Pastry sweets	PS	Vanilla ice cream
133	Pastry sweets	PS	Cake in ears form

Supplementary Materials: Phyton code and data is available as supplementary material.

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