Development of a Mexican online nutritional ecologic software for dietary assessment, automatic calculation of diet quality, and dietary environmental impact

Mariana Lares-Michel
Instituto de Investigaciones en Comportamiento Alimentario y Nutrición (IICAN), University Center of the South, University of Guadalajara / Institute of Nutrition and Food Technology "José Mataix Verdú", Biomedical Research Center, University of Granada https://orcid.org/0000-0002-1242-7752
Fatima Ezzahra Housni (fatima.housni@cusur.udg.mx)
Instituto de Investigaciones en Comportamiento Alimentario y Nutrición (IICAN), University Center of the South, University of Guadalajara https://orcid.org/0000-0003-0660-609X
Virginia Gabriela Aguilera-Cervantes
Instituto de Investigaciones en Comportamiento Alimentario y Nutrición (IICAN), University Center of the South, University of Guadalajara https://orcid.org/0000-0002-8576-6181
Rosa María Michel-Nava
Tecnológico Nacional de México, Campus Ciudad Guzmán https://orcid.org/0000-0001-9523-8449

Research Article

Keywords: dietary assessment, dietary pattern, diet quality, water footprint, nutritional software, dietary environmental impact, m-Health, ecologic software, nutritional technologies

Posted Date: September 29th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-2106147/v1

Abstract

Nutritional tools for dietary assessment are crucial elements for nutritional and diet-related study methodologies. Environmental indexes such as water footprint (WF) are essential for assessing diets' environmental impact. Currently, no available software in Mexico and the world simultaneously allows the evaluation of diet and its environmental impact. This study aimed to design and develop a Mexican online nutritional ecologic software for dietary assessment, automatic diet quality calculation, and diet's environmental impact. The software was developed using the waterfall life cycle methodology. A multi-stage process was followed. The program includes diet evaluation through a 24-hour recall and a validated and adapted Food Consumption Frequency Questionnaire (FFQ). The software also integrates automatic calculation of diet quality through an adaptation of The Mexican Diet Quality Index (ICDMx): the Alternate Mexican Diet Quality Index (IACDMx). An automatic WF assessment for Mexico's context was also included. The assessment accounts for multi and single-ingredient foods WF, cooking, food-washing water, and applying correction factors. We created Nutriecology®, a novel technology for assessing diet aspects and WF simultaneously, making data collection and analysis time efficient in transversal and longitudinal studies. Further environmental impact indices, clinic history, and socioeconomic elements will be added to the software in future actualizations.

1. Introduction

Dietary assessment is challenging in nutritional studies because of the complexity of estimating consumed food and the time and costs required to apply and analyze dietary instruments [1−4]. Recently, the evaluation of dietary environmental impact has also taken relevance, and every time is more common for nutrition experts to address the environmental impact of food consumption and sustainable diets [5−8].

Both for the assessment of diet and its environmental impact, the use of technologies is an emerging area that has helped improve evaluations and reduce time in the research [2−4]. At the international level, several online nutritional softwares have been developed, however, they do not consider ecological aspects [2−4, 9]. When assessing diet and its related environmental impacts, contextualization is essential, for which each country must have specific tools [1]. In Mexico's context, although some nutritional software exists, [10−12], up-to-date, no nutritional software has considered environmental aspects in their features, to the best of our knowledge. Also, softwares to assess diet, diet quality, and dietary environmental impact simultaneously, has not been identified.

When evaluating diet and its related environmental aspects, it is crucial to select adequate instruments to obtain clear and replicable data. In the nutritional context, three appropriate tools for dietary assessment and the evaluation of the environmental impact of diets have been highlighted. Those corresponds to 24-hour recalls [1, 5, 8], Food Consumption Frequency Questionnaires (FFQ) [1,6,13−16], and diet quality [1,17−19].

24-hour recalls consist of evaluating the food consumed a day before dietary assessment. Dietary assessment through this instrument includes food consumed in grams or established portions, as well as the preparations methods, ingredients, times, and places of eating. When applying this tool, using food replicas, food pictures, and household measurements (e.g., spoons, cups) is recommended [1].

The FFQ measures the frequency of consumption of various foods or food groups over a certain period. The questionnaire includes a list (usually close-ended) of foods, dishes, and beverages and a frequency category section [1, 20]. Using food examples (i.e., replicas and pictures) is also recommended [1]. Generally, the data obtained in dietary assessment is energy, macro, and micronutrients [21]. However, food classification in groups is common [1]. Although both 24-hour recalls and FFQ are valid dietary assessment methods, FFQ reports habitual food intake for specific periods and can be superior to 24-hour recalls when measuring dietary patterns through posteriori methods like cluster analysis, principal component analysis, or reduced rank regression [1, 22, 23]. 24-hour recalls must be applied on three or more occasions and non-consecutive days if assessing habitual diet [21, 24]. The 24-hour recalls and FFQ can be self or interviewer-administered [1]. Also, both instruments are complementary to each other to provide a detailed dietary assessment, for which using both tools can provide a more robust evaluation of the diet [1].

Diet quality is a relatively new term that has emerged in the scientific literature during the last two decades, especially in nutritional epidemiology, to assess the eating habits of the population, the efficacy of dietary interventions, the adherence to a specific dietary pattern, and to assess the risks of mortality or contracting chronic diseases [17, 25, 26]. Numerous dietary indices have been developed, tested, and validated to reflect various aspects of diet quality. Some indexes only measure the adherence to nutritional recommendations, meanwhile, others require substantial analysis of the macro and micronutrient intake [17, 27].

Regarding the environmental impact of diet, the most used indices at the international level have been the carbon footprint or the estimation of greenhouse gas emissions (GHGE) of diets [13], fossil energy use [28], and land and water use [29–31]. In Mexico's context, 24-hour recalls [5, 15, 16], FFQ's [15, 16, 32, 33], and diet quality indexes [19, 34, 35] have been developed and validated for dietary assessment and to evaluate the environmental impact of diet [5]. The assessment of water use in food production through water footprint (WF) (i.e., the volume of freshwater needed to produce a good or service, including food) has been prioritized among environmental impact indices because of its direct relationship with the population diets [14, 36]. Currently, the agriculture sector uses more than 76% of water resources in Mexico [37], which has generated the 85% of the Mexican territory to have a severe water shortage [36], with deficits of more than −600 million m^3 of water yearly [38].

Based on available information and the necessity for new dietary and ecological tools for dietary and environmental impact assessment in Mexico's context, the objective of this work was to design and develop a Mexican online nutritional ecologic software for dietary assessment, automatic calculation of diet quality and environmental impact of diet. This development aimed to provide a tool to evaluate food consumption and its environmental impact for nutritional and environmental studies, both at the individual and population levels. To facilitate field work, make data collection and analysis time efficient in studies, and improve standardization in research, both regarding data acquisition and analysis.

2. Materials And Methods

2.1 Software design

The software was named Nutriecology®, and its design started in May 2018. Development began in June 2019 and was concluded by December 2019. In January 2020, the final tests were carried out. The methodology waterfall life cycle for software development (a multi-stage process methodology) was used to design and develop Nutriecology®. Engineers in informatics and computer systems programmers collaborated in the programming of the software. The multi-stage process described in Figure 1 was used. As can be seen, we included the following five stages regarding requirements and analysis, design, coding, testing, and maintenance: 1) Formative research, 2) Definition of software features, 3) Development of Nutriecology®, 4) Tests for internal validation, and 5) Launch of Live Site. Stages 1 to 4 are presented as part of the methodology (features and development of the software). The results section shows stage 5. It is essential to mention that since the software was designed and developed for Mexico's context, it was all done in Spanish. This development is already registered in the National Institute of Copyright (INDAUTOR) under the name of Nutriecology® as computational software development with registration number: 03-2022-012812203100-01.

Insert Figure 1. Process followed for the development of the nutritional ecologic software Nutriecology®. Note: FFQ = Food Consumption Frequency Questionnaire.

2.1.1 Ethical considerations

Although no participants were involved in this study, since personal data questions are included in the interface of the software, the study was approved by the Ethics Committee of the University of Guadalajara CEICUC (registration number CEICUC-PGE-004). Also, data collected with this software will be protected by the Federal Law on Protection of Personal Data Held by Private Parties. For further validation studies, the Declaration of Helsinki will be followed. Also, informed consent will be obtained from all subjects involved.

2.2. Stage 1 (Requirements and analysis): Formative Research

Literature research was launched to define the requirements of the software. That included the search for other online nutritional or ecological software to identify the main features provided. Also, a search to identify complete 24-hour recalls, FFQ's and dietary quality indexes available internationally and those validated for Mexico's context was performed. Once identified, we interacted with the software available on the web. Besides, informal interviews were done with nutrition and software experts to decide the features to include in Nutriecology®.

At the formative research and international level, the more remarkable nutritional software identified was myfood24®, which is available for the UK, USA, Germany, Denmark, France, Middle East, Norway, Australia, Caribbean, and Peru [3,9]. In Mexico's context, some nutritional software has been designed, such as Nutrimind® [11], Aznutrition® [12], and Nutricloud Nutrición Digital® [10]. However, most of them are orientated to provide nutritional consultation, except for Nutricloud Nutrición Digital® [10], a platform designed for nutritional studies that evaluate diet and diet quality using a validated FFQ, 24-hour recall, and a diet quality index [15]. Although it does not consider dietary environmental impact assessment, that software was used as a reference for the development of Nutriecology®.

To identify available tools to measure dietary intake in Mexico, we consulted the Nutritools® platform to identify international dietary assessment tools. This platform reports over 20 types of 24-hour recalls and over 79 FFQ's, but only a Mexican validated FFQ was identified [39]. However, elsewhere other FFQ's used in Mexico at state and national levels were identified. Those include the ones from Macedo-Ojeda et al. [15] and Denova-Gutierrez et al. [5,16], which have been used in the country, both for dietary assessment and WF estimations [6]. Concerning diet quality, The most used indexes at the international level are the Healthy Eating Index (HEI) [40,41], the Alternate Index of Healthy Eating Index (AHEI) [42], and the 2015 Dietary Guidelines Adherence Index (DGAI) [43]. However, these were developed for specific populations out of Mexico. In the country, some indexes have been created, including the Mexican Diet Quality Index [44], the Mexican Alternate Healthy Eating Index [45], and the Mexican Diet Quality Index (ICDMx) [19].

Although all those were designed based on the Mexican dietary guidelines, each has some limitations, such as no differentiation of meat products, and only the ICDMx includes food sub-groups, was recently validated [19,46], is integrated into Nutricloud Nutrición Digital® (the base for this project) [10], and considers the "correct" diet Mexican term, which refers to a diet to meet the following characteristics: (1) Sufficient as it completely satisfies the nutritional needs, regarding energy, iron, calcium, fiber and water requirements intake; (2) Balanced regarding the proportions of nutrients that make it up (proteins, lipids, and carbohydrates); (3) Complete, as long as it includes foods from three groups: (a) vegetables and fruits, (b) cereals, (c) legumes and animal products; (4) Varied, as it includes different foods from each group, for example, fruits and vegetables of different colors (e.g., red: tomato, strawberries; blue-purple: blackberries, beetroot; yellow-orange: carrots, papaya; green: spinach, lime; and white: onion, banana); different cereals types (e.g., corn, wheat, rice), and different protein sources (e.g., beans, poultry, unsweetened milk); (5) Innocuous, regarding its regular consumption does not represents health risks, for example regarding saturated and polyunsaturated fatty acids, sodium and alcoholic beverages. The sixth aspect, "adequate," which refers to factors such as the tastes and culture of its consumers and the food's affordability, is not considered in the ICDMx (19,46). The ICDMx gives a score to the participant. A maximum of 100 points represents a diet of the highest quality. To calculate the 'ICDMx,' it is necessary to fill out an FFQ or a 24-hour recall (19). However, only the FFQ was considered for this study since it is a more robust instrument to assess the habitual diet (1).

Despite Nutricloud Nutrición Digital® having strengths such as dietary assessment through 24-hour recall and FFQ's, and diet quality evaluation by the ICDMx, this software has some limitations. The principal one is that the included FFQ lacks several highly consumed foods in the Mexican current and traditional diet, such as *pozole*, *tacos*, *sopes*, *chilaquiles*, *enchiladas* (5,6). Also, the ICDMx has significant limitations, especially regarding the aspects "complete", "innocuous," and "adequate". Currently, the "complete" aspect does not differentiate between the foods in the animal-based food group and provides points for consuming and exceeding 120 g of animal products and legumes. No differentiation between animal and plant foods is an important issue both from a nutritional and sustainability perspective. The nutritional composition of milk, yogurt, cheese, eggs, white meats (chicken and fish), red meats (pork and beef), and legumes vary greatly (19,47). Evaluating meats and legumes at the same level generates fundamental problems when addressing diet quality. For example, chronic disease prevention has been related to fish and legumes intake (48,49). Meanwhile, the development of certain cancers has been linked to red meat consumption (50). Regarding environmental impact, the WF of red meats is up to 6 times graters than fish and legumes, for example, a kilogram of fish has a WF of 3,110 liters, a kilogram of beans a WF of 5,789.87 liters, and a kilogram of beef has a WF of 21,566 liters (5,51).

On the other hand, the "innocuous" aspect of the ICDMx does not consider the recommendation of maximum sugar intake in the diet, although it is widely known that excessive sugar intake is related to chronic disease development (52,53). Finally, the ICDMx does not evaluate whether the diet is "adequate" or not according to the concept of the correct diet (19,46). This element is essential in sustainable diets, which must consider economic and social aspects, besides health, nutrition, and the environment (54).

Regarding environmental impact assessment of dietary aspects, the most remarkable softwares were Optimeal® and Agri-footprint® (55), which allow the design of sustainable diets by optimization, and the dietary environmental impact assessment, respectively. Those tools include several environmental impacts indexes, such as terrestrial acidification, freshwater eutrophication, land use, and water consumption (56). However, those tools are not considered nutritional instruments for assessing diet and diet quality in parallel with environmental impact. Also, although those are complete tools for environmental impact assessment, they are only based on the Life Cycle Assessment method and do not provide other environmental perspectives such as the Water Footprint Assessment method (WFA), which is the most used method for evaluating dietary WF (5). Also, the softwares were designed for the European context, for which they do not include highly consumed foods in Mexico and are not contextualized to the country's characteristics. For Mexico's context, a new methodological approach based on the WFA was recently proposed (5). However, software for dietary environmental impact assessment has not been identified.

2.3. Stage 2 (Design): Definition of software features

A user's and administrator sections were considered in the design of Nutriecology®. Table 1 presents the characteristics incorporated in Nutriecology® for the user's segment. In that segment, the following five sections compose the software:

1) Registration, 2) Sociodemographic and nutritional evaluation (body composition data, purchasing information, physical activity), 3) 24-hour recall, 4) FFQ, 5) Diet quality, and 6) Dietary environmental impact assessment.

Insert Table 1. Features of Nutriecology® in users' section

In section 1, we included the option for the user to register and log in later, as well as an informed consent. For section 2, general information is requested, including the name, last name, phone, email, age, date of birth, sex, place of birth, residence, time living there, and other comments. Educational level was included, with the option to respond according to the Autonomous University of Mexico (UNAM) [57] based on the last group of studies. Following, Nutriecology® included the National Institute of Statistic and Geography (INEGI) classification for occupational level (Supplementary material 1) [60].

Additionally, this section included the type of work, workdays, schedule, and monthly income of the user. All these aspects have been reported as reliable and practical data for assessing sociodemographic aspects in the Mexican population [61]. Other aspects relevant to nutrition were included, such as food purchasing data, monthly money spent on food, principal place of purchasing, days a week eating out of home, and types of food consumed out of the house. Also, physical activity evaluation was included, following the International Physical Activity Questionnaire (IPAQ), including questions related to the type of physical activity, weekly frequency, minutes a day, and intensity (low, moderate, and high) [59]. Finally, in section 2, an open-ended question about disease presence was added, which included asking for disease type, time since diagnosis, and medication used. Also, Nutriecology® incorporated a section for registering the user's anthropometric and body composition data. These data included estimated self-report (by the user) weight and height in case the user was not nutritional measured (i.e., weighed and measured by the study investigator). In case a nutritional evaluation was performed by the research team using Nutriecology®, blank spaces to fill in were established for information related to body composition. The data included were height, weight, body mass index, percentage of body fat, muscle mass, corporal water, metabolic rate, metabolic age, visceral fat, waist and hips circumferences, and bone mass. Nevertheless, the software allows users to provide self-reported data for these parameters for cases where the researcher asks subjects to enter their information.

Section 3 considered the most common characteristics used in 24-hour recalls. Those included food time divided into breakfast, morning snack, meal, evening snack, and dinner. Also, it included a space for the exact hour of the eating episode, the place of consumption, the menu (set of ingredients included in the dish), or the preparation method (grill, boiled, fried). Besides, it is presented a displayable list of foods with images and quantities of habitual consumption. A displayable list of food portions was included too, for a more precise dietary analysis. Additionally, it was added a question about water consumption.

Section 4 included an adaptation of two of the most used FFQs in Mexico. The base was the questionnaire of Macedo-Ojeda et al. [15], which was used in Nutricloud Nutrición Digital® and included 162 food items. Also, it provides more specific food options such as skim, semi-skim, whole, or condensed milk, or chicken with or without skin, instead of only milk or chicken, as in other FFQ [16,19,62]. That FFQ was adapted based on the questionnaire of Denova-Gutiérrez et al. [16], which is used in The National Survey of Health and Nutrition (ENSANUT) from Mexico and includes 140 food items. We also used the food list reported in an exploratory study searching for consumed foods in Mexico [5]. Some foods that were not included in the analyzed FFQs, but were reported in that list include *chilaquiles*, *burritos*, chickpeas hummus, vegetable drinks such as almond and coconut "milk", berries, peanut butter, rice cakes, quinoa, sweet potato cooked with sugar, oats prepared with milk and sugar, and whole versions of rice and wheat *tortillas*, among others [5]. Although some of those foods are not considered basics in the Mexican current diet, there is a growing trend toward its consumption [1].

In total, we included a food list of 248 items (Supplementary Materials 2 and 3). The consumption frequencies range options were also adapted to provide a more accurate and comprehensive analysis regarding the consumption temporality [63]. The frequencies were extended to yearly frequency, from 1 to 5 times and 6 to 11 times (3 and 8.5 times per year, respectively, on average). The monthly frequencies were divided into 1, 2, and 3 times a month. The same was done for the weekly frequency, from 1 to 7 times a week. In addition, in this adaptation of the FFQ, the frequency per day was included according to the frequency of consumption previously reported (annual, monthly, or weekly). Considered daily frequencies were 1, 2, 3, or 4 or more (4+) times by day. The number of eaten portions was also included, considering established units: ¼, ½, 1, 2, 3, 4, 5, or 6 or more (6+). Therefore, for calculating the average daily amount of consumption of a specific food, according to frequency and number of portions, the following formula must be followed:

$$G = \frac{g \, x \, m \, x \, d \, x \, p}{30} \qquad (1)$$

Where *G* is the average amount of food consumed a day*; g* is the reported consumed portion in grams or milliliters (establish portion in the FFQ); *m* is the frequency of consumption a month (i.e., five times a week will be multiplied for four weeks a month, so consumption of 5 times a week will be equal to 20 times a month); *d* is times consumed a day (i.e., in breakfast and dinner); *p* is the number of portions consumed (i.e., two cups each time the food is consumed); divide between 30 days a month.

The portions were obtained from both questionnaires [15,16] and the food list from Lares-Michel et al. [5] and correspond to portions of habitual consumption. Supplementary Material 3 presents the written version of the designed FFQ. For the digital version of the FFQ at Nutriecology®, reference images of each of the 248 foods were attached, which were taken by us or were obtained from free internet downland [64].

Both for 24-hour recalls and FFQ nutritional composition, we used the Mexican System of Equivalent Foods (SMAE) [47] and the Mexican Tables of Food Composition of Ledesma et al. [65]. Also, labels of foods from different brands not available in nutritional composition tables were consulted. Analyzed labels included cookies, sauces, sweet bread, packaged ice cream, milkshakes, granola bars, instant soups, candy, and chips, among others. Complete data regarding label analysis is presented in Supplementary material 4. For food groups and food sub-groups classifications, we also relied on the Mexican System of Equivalent Foods (SMAE) [47] and the Mexican Tables of Food Composition of Ledesma et al. [65]. However, the environmental impact of foods was also considered, especially in the food sub-groups classification [5,52]. Supplementary Material 2 provides the complete food classification.

Regarding section 5, which corresponds to the diet quality index, the Mexican Diet Quality Index (ICDMx) was used as a reference but was adapted. All the components of ICDMx were included, incorporating the aspects 1) sufficient, 2) balanced, 3) complete, 4) varied, and 5) innocuous. However, the index was modified in its "complete" and "innocuous" aspects. Nutriecology® also included the “adequate” aspect, which is not included in the ICDMx [46]. Table 2 presents the complete values considered for the calculations. Supplementary material 5 shows the specific instructions for the calculations. Based on the modifications performed, the adapted version of the ICDMx was called as the Alternate Mexican Diet Quality Index (IACDMx for its initials in Spanish). The dietary data for the automatic calculation of the IACDMx was taken only from the FFQ as it provides dietary data from a longer period regarding the 24-hour recall [1].

The first adapted aspect (complete) was modified based on the subdivision of the group of foods of animal origin and legumes. Instead of evaluating the consumption of 120 g or more of those foods, as suggested in the ICDMx [19], we separately assessed the consumption of 1) at least 60 g of legumes, 2) less than 71 g of red, and industrialized meats, 3) less than 56 g of poultry (chicken and eggs), 4) at least 26 g of fish and shellfish, 5) less than 240 ml of milk, and yogurt, and 6) less than 40 g of cheeses. Additionally, the intake of 7) at least 400 g of fruits and vegetables and 8) at least 200 g of cereals without fats were evaluated. The recommended grams of consumption per day are shown in Table 2 and were obtained from Bonvecchio Arenas et al. [66] and the Ministry of Health [67]. This adaptation was carried out by what was suggested by Hawkes et al. [68], who insist that diet quality indexes should not only focus on complying with recommended portions of certain food groups or nutrients, as was traditionally carried out to combat undernutrition but evaluating not exceeding portions must be included, because of the obesity pandemic that the world is facing. In this sense, the evaluation of sugar intake concerning recommendations (not exceeding 10% of energy intake according to the World Health Organization, OMS) was added in the "innocuous" aspect [69].

Regarding the “adequate” aspect, we attached the previously described definition of normativity in Mexico [46]. Based on that, a literature search was performed to identify the average weight of Mexican traditional foods and dishes. From the revision, an average amount of 30 g was considered for Mexican foods since is the approximate weight of a corn *tortilla*, which is one of the most traditional Mexican foods consumed daily by the majority of the population [47,70]. An average weight of 180 g was identified for typical Mexican dishes such as *pozole*, *tamales*, *sopes*, *tacos*, and *enchiladas*, among others. Nevertheless, based on the revision, it was considered “adequate” to consume at least one traditional Mexican dish a week [47]. Therefore, the “adequate” aspect evaluates the consumption of 30 or more grams per day of foods considered Mexican and the intake of 180 g or more of Mexican dishes per week, equivalent to 26 g per day. Likewise, it was evaluated the consumption of less than 30 g of foods considered westernized and the intake of less than 180 g of westernized dishes (<26 g per day). For the determination of western foods' weights, a literature search was also performed, and similar trends were identified for foods such as packaged bread and chips (30 g), and burgers (180 g). Therefore, 30 g/day and 180 g/week (<26 g/day) were also considered for unifying Mexican and Western foods. Supplementary Material 2 (Table S2) shows the food classification of Mexican foods and dishes and western foods and dishes [47,70–75].

Unlike the quantitative diet quality proposed by Macedo-Ojeda et al. [19], this element was evaluated qualitatively. Instead of numbers, the diet was qualified as 'inadequate' or 'adequate' with letters from a to d, according to adherence to the parameters established and shown in Table 2. Additionally, for providing grades to the level of ‘adequate’, a tertile analysis was performed based on the nutritional data reported in Lares-Michel et al. [76], where a dietary and environmental impact assessment was performed in a representative sample of Mexican population. Full description of this analysis is shown in Supplementary Material 5.

It is worth mentioning that the scores of the other components of the ICDMx were rearranged to obtain a maximum score of 20 points per aspect in the IACDMx. In other countries, such as the United States, these modifications to diet quality indices have been reported. An example is the Healthy Eating Index and its modified version, the Alternative Healthy Eating Index (AHEI) [77].

Insert Table 2. Calculation and components of the Alternate Quality Index of the Mexican Diet (IACDMx)

Regarding dietary environmental impact assessment, Nutriecology® included dietary WF calculation. WF is the volume of freshwater needed to produce a good or service, including food. This index comprises three WF types: green, blue, and grey. In a food production context, green WF quantifies the amount of rainwater stored in the soil that is used by crops within the evapotranspiration process. The blue WF estimates the amount of water used for agricultural irrigation. Grey WF is considered the water necessary to assimilate a certain pollutant load, such as water used in food industries, food washing, and cooking (i.e., boiling, scalding, poaching, and stewing). The sum of those three WFs is considered the total WF of a product or food (5,30).

The method of Lares-Michel et al. (5), which is based on WFA method (30), was carefully followed and charged into Nutriecology® for the automatic calculation of the total, green, blue, and grey WF of each of the 248 foods from the FFQ. The first step for WF calculation is identifying the daily consumption of each food (g or ml), by the 24-hour recall or the FFQ. The software identifies if the food requires a process before consumption (washing, cooking, or peeling). For example, a cooked potato needs to be washed, peeled, and cooked; meanwhile, milk is directly consumed as was bought. For converting food already processed to its raw version, the formulas and correction factors provided in Lares-Michel et al. (5) were used (for example, 1.45 for meats). In Supplementary Material 2 we present the foods to which correction factors were applied into Nutriecology®. Once food raw weight is obtained, the software determines if washing and/or cooking is required before consumption. If washing and/or cooking were needed, the software considered the grey WF reported by Lares-Michel et al. (5). That corresponds to 10 liters/kg for cereals and legumes, 1 liter/kg for meats, and 14.44 liters/kg for food in general. The foods for which washing and/or cooking water was considered are presented in Supplementary Material 2. After those steps, the WF of each food is quantified using the formulas and databases provided in Lares-Michel et al. (5), which considers green, blue, and grey WFs. For foods composed of more than one ingredient, the individual's WF of each food was summed according to the corresponding formulas or using already calculated data for Mexican dishes (5).

Considering all those aspects in dietary WF calculation is essential for accurate dietary environmental impact assessments. In previous studies, the WF quantifications have been carried out in cooked (or ready-to-eat) versions, but the environmental data was calculated in raw food (5,78). That generates essential variations that can lead to WFs up to 135% higher or lower than the values calculated, considering correction factors and quantifying the water involved in washing and cooking food. An example of these variations can be provided for beef. Before cooking, beef has an average weight of 145 g, but after cooking, it loses water and weighs 100 g. That would generate to report a WF of 2,156.60 liters instead of 3,127.07 liters (5).

Regarding Nutriecology® administrator section, Table 3 shows the sections integrated there. Section 1 allows the administrator's log in with a pre-established account and password. Once into the software, a menu is presented to the administrator. All available options are presented in Table 3, which includes viewing, editing, adding, or eliminating foods, food groups, and sub-groups. Also, a section for data exportation and importation from excel sheets is available.

Insert Table 3. Features of Nutriecology® in the administrator section

Nutriecology® included 33 nutrients and environmental aspects that are automatically calculated. Those are presented in Table 4, and include energy, macro, and micronutrients, including vitamins and minerals. Regarding the environmental aspect, Nutriecology® currently only includes green, blue, and grey WF, as well as water involved in cooking and food washing.

Insert Table 4. Nutritional composition and environmental impact aspects incorporated in Nutriecology®

2.4. Stage 3 (Coding): Development of Nutriecology®

The development of Nutriecology® was done in collaboration with software developers, engineers in informatics, nutritionists, environmental science researchers, behavioral science experts, and psychologists. The methodology for software development “waterfall life cycle”, was applied in all stages. This process was performed following the workflow shown in Figure 1. During the development of Nutriecology®, in-house testing and feedback were constantly done by the research team and the software programmers. In-house testing and feedback included aspects regarding interface colors, letter type, presentation of the tools, and excel sheets, among other aspects [(79)].

2.5. Stage 4 (Testing): Tests for internal validation

The validation of Nutriecology® was done by calculating nutritional composition and WF manually and using the software. Then both calculations were compared to ensure the software is providing accurate data. The manual calculations were performed using Excel® sheets and the formulas provided there. Both for the first and second sections of the software, the correct registration and user information were verified manually by checking entered data and exportable excel sheets. For the third section, the nutritional composition and WF of 24-hour recalls were calculated by multiplying or dividing the amounts consumed by each nutrient. For WF data, the method of Lares-Michel et al. [(5)] was manually performed, applying the correction factors suggested there, accounting for the water used in cooking and washing, and using the WF datasets which were loaded to Nutriecology®. For the fourth section, the nutritional composition and WF of the FFQ (Supplementary Material 3) were calculated according to formula 1, multiplying or dividing by datasets of nutrients and WF. For the five-section, diet quality was both calculated manually and by using Nutriecology®. Supplementary Material 5 presents the manual calculation steps followed for diet quality calculation using the IACDMx. Finally, for WF calculations, both the WF from the 24-hour recall and FFQ sections were re-checked by following the method of Lares-Michel et al. [(5)].

3. Results

3.1. Stage 5 (Maintenance): Launch of Live Site

Nutriecology® was launched on the website www.nutriecology.com. For access to the user’s section, it is necessary to ingress to www.nutriecology.com/invitados. Once there, users must register with their email and generate a password (Fig. 2), with which they can access their session later, in case they do not complete the survey at once. Subsequently, is presented a general informed consent for answering the asked questions. If the user accepts to answer the questionnaires presented, they must click on “accept”. Extended information in this section is presented in Supplementary Material 6 (Figure SM6.1 to SM6.3).

Insert Fig. 2. Users’ registration in the users’ section of Nutriecology®. The complete interface of Nutriecology® is presented in Supplementary Materials 6.

Once the user is registered, their general information is requested (Fig. 3). Extend data is shown in Supplementary Material 6, Figures SM6.4 to SM6.15.

Insert Fig. 3. General data of user’s section in Nutriecology®. The complete interface of Nutriecology® is presented in Supplementary Materials 6.

Following, Nutriecology® presents a section for the fill-in of the 24-hour recall (Fig. 4). The complete interface of this section is provided in Figures SM6.16 to SM6.19.

Insert Fig. 4. 24-hour recall of user's section in Nutriecology®. The complete interface of Nutriecology® is presented in Supplementary Materials 6.

After the 24-hour is filed in, Nutriecology® presents the adapted FFQ (Fig. 5). Once the user responds to all items, a thank you and farewell appear. Diet quality corresponds to an internal calculation that is only available for the administrator as well as the dietary WF. The complete FFQ interface is presented in Supplementary Material 6 in Figures SM6.19 to SM6.63.

Insert Fig. 5. Food Consumption Frequency Questionnaire (FFQ) of user's section in Nutriecology®. The complete interface of Nutriecology® is presented in Supplementary Materials 6.

The administrator section access is available at www.nutriecology.com (Fig. 6). An exclusive email and password were created to enter. Once there, a menu is provided for viewing, editing, adding, or deleting foods, food groups, food sub-groups, and adequate food sub-group. Also, a section for visualization of the sociodemographic and nutritional evaluation, 24-hour recall, and FFQ is available. A section for importing and exporting data in excel sheet format is also presented. By clicking on an option (i.e., foods, food groups, etc.), all the current charged data is present, incorporating all nutrients and WF data previously uploaded (Table 4, Table S2, and Table S3.1). The data presented is editable and can be erased. Also, new data can be added to the system. Then, in the exportation section, there is an option for downloading nine different excel sheets that correspond to 1) Exportable excel sheets with registration, sociodemographic, and anthropometric and body composition data; 2) Exportable excel sheet with total nutritional composition and WF from 24-hour; 3) Exportable excel sheet with the nutritional composition and WF by food registered from 24-hour; 4) Exportable excel sheet with the total nutritional composition and WF of FFQ; 5) Exportable excel sheet with nutritional composition and WF of FFQ by food registered; 6) Exportable excel sheet with the nutritional composition and WF of food groups classification; 7) Exportable excel sheet with the nutritional composition and WF of food sub-groups classification; 8) Food group "adequate" classification exportable to excel sheets, including nutritional composition and WF; 9) Diet quality total score and by component, exportable to excel sheet. Examples of downloaded excel sheets and exportable sheets are provided in Supplementary Materials 6 (Figure SM6.64 to SM6.110).

Insert Fig. 6. Administrator section in Nutriecology®. The complete interface of Nutriecology® is presented in Supplementary Materials 6.

4. Discussion

The objective of this work was to design and develop a Mexican online nutritional ecologic software for the assessment of dietary elements and their environmental impact. With this development, we aimed to provide a tool for nutritional and environmental studies at the individual and population levels. We created a novel technology for Mexico's context that allows dietary assessment and automatically calculates diet quality and their environmental impact simultaneously and only by responding to a 24-hour recall or a FFQ. With these, we hope future research will collect and analyze data more easily and quickly, improving standardization. To the best of our knowledge, this is the first software to combine dietary and environmental aspects in Mexico and internationally. Compared with international tools for dietary assessment, such as the software myfood24® [(3)], we provided a tool that includes three dietary assessment instruments (24-hour recall, FFQ, and diet quality) and environmental impact assessment, in this case, water use by WF.

4.1 Strengths of Nutriecology®

Each of the features included in Nutriecology® was improved regarding available tools. In the first place, the user's general information provides a section for evaluating aspects that are not always considered in nutritional and environmental software's, such as sociodemographic aspects, physical activity, and body composition data [(3, 10)]. That could allow faster and more complete population and individual analyses. On the other hand, the 24-hour recall used provides not only close-end options, such as the food list included, but allows qualitative analysis by including preparation methods, times, and places of eating, and portion options. Also, although the design of that section was orientated for retrospective analysis, the 24-hour section can be also used for the analysis of dietary records in prospective studies where data was previously collected [1].

Regarding FFQ, besides of expanding the food list provided in other FFQ [15, 16], extending the frequencies of consumption options allows for providing more accurate data about food intake and environmental impact. Some foods hide important environmental impacts, although not usually consumed. An example is Christmas's Turkey, which, although often consumed once a year, involves environmental impacts that are not usually addressed in studies [80]. Also, regarding other FFQ [15, 16], Nutriecology® combines annually, monthly, and weekly frequencies of consumption with daily frequencies, and portion options, providing more accurate data about food intake and its environmental impact. Another important strength of Nutriecology® is that using two instruments, such as 24-hour recalls and a FFQ allows a more robust dietary assessment.

Diet quality assessment was also improved and orientated to sustainability aspects by modifying the ICDMx component's "complete", and "innocuous", and by adding the "adequate" aspect. The "complete" aspect improved from a health-nutritional perspective by dividing animal and plant-based foods and providing more points to the diet quality score by consuming more foods related to disease prevention (e.g., legumes, fruits, vegetables, whole grains), and taking points away for consuming superior quantities of meats (except for fish) and dairy regarding dietary guidelines. The differentiation made could be crucial for future studies assessing associations between cardiovascular and type 2 diabetes risks and diet, since saturated fats and fiber content varies significantly among white (chicken and fish) and red meats (beef, pork), and legumes [49, 52, 81, 82]. Concerning the environment, the differentiations made allowed to provide more accurate WF data since the WF of polygastric animals (cows, sheep, and goats) [83] differs significantly from monogastric animals (pork, chicken) [84]. For example, the WF of the boneless beef overpass 20,000 liters per kilogram. Meanwhile, chicken has a WF of close to 4,000 liter per kilogram, which is similar to the one of legumes [5, 51, 85].

The IACDMx also improved the evaluation of the innocuity of diet by adding the evaluation of sugar intake. Exceeding the recommended intake of 10% of energy intake has also been related to non-communicable diseases development (e.g., obesity, cardiometabolic diseases, and dental diseases) [86], for which this index could be used for future studies exploring the relationships between diet and those alterations. Besides, we included an aspect that can help to assess sustainable diets. That is the "adequate" aspect, which evaluates if the diet is in accordance with food culture and economic aspects in Mexico. This aspect can be useful for analyzing diet change processes such as nutrition transition [76]. Although the "varied" aspect was not modified, the inclusion of more foods in the FFQ, which were added to the food groups and sub-groups, indirectly improved that aspect by providing more "variety" options. An example is the inclusion of oats, quinoa, and amaranth among cereals, which consumption can increase the IACDMx score.

Regarding environmental impact assessment through WF calculation, the most crucial strength of Nutriecology® is that it provides an automatic calculation that will allow nutrition experts with little or no background in environmental impact assessment to evaluate this aspect when performing nutritional studies. Besides, this is the first nutritional ecologic software to account for the water involved in cooking and food washing, as well as applying correction factors to convert cooked food to raw, and peeled to unpeeled. These aspects have not been considered before in other studies and can cause WF variations of more than 135% [5,78]. Therefore, Nutriecology® provides a more accurate way of assessing dietary environmental impact. Also, Nutriecology® is loaded with a WF database that accounts for the WF of food composed of several ingredients. This will facilitate the calculation of the Mexican diet environmental impact, which includes a large number of dishes with many ingredients [70].

One of the principal strengths of Nutriecology®, both from a nutritional and environmental perspective, is that the charged nutritional/environmental database is editable. This means that new foods can be added, as well as new nutritional data (e.g., other vitamins, phytochemicals, food additives), and environmental indicators (e.g., greenhouse gas emissions, land use, biodiversity loss, eutrophication potential). Also, already foods and data charged can be edited or erased. This feature of Nutriecology® also has an essential application for future studies outside of Mexico, since any food and its characteristics (nutritional and environmental), can be added. Therefore, if, for example, performing a Mediterranean diet assessment, as far as the administrator includes the appropriate and national data, the software can perform the evaluation.

4.2 Limitations of Nutriecology®

Despite the strengths of Nutriecology®, the software has some limitations. The first one is that currently, among environmental impact indexes, the software only allows the assessment of WF. Also, Nutriecology® resulted in a long tool to respond. In field research, this could be a problem causing bias if participants do not provide accurate data. Besides, unless data is collected by trained personnel, self-reported data could likely introduce measurement errors. For this reason, it is recommended that the response of Nutriecology® is made by trained personnel only or that users get specific instructions to answer the instrument correctly.

It is important to mention that, although we used validated instruments, the software must be validated as we adapt them. Another limitation is that currently, the IACDMx is only calculated based on the dietary data from the FFQ, and diet quality from 24-hour recalls is not currently available. It is important to mention too that, after the development of Nutriecology® a novel diet quality index was launched. That is the Global Diet Quality Score [(87)], which classified diet quality by healthy and unhealthy foods, an interesting classification that was not considered in Nutriecology®. Also, Valerino-Perea et al. [(88)], recently proposed an index for assessing adherence to the traditional Mexican diet. That index provides a deeper analysis of the consumption of Mexican foods that were not included in the “adequate” aspect of the IACDMx.

4.3 Maintenance of Nutriecology®: Planned Future Work

Within the methodology for software development we used, the waterfall life cycle, the maintenance of the software is essential [(79)]. Therefore, the first maintenance activity for Nutriecology® is its first version's validation and feasibility assessment. Also, we are working on improving the current limitations of the program. The first one is separating FFQ’s food groups to answer the questionnaire in sections on different occasions if it would be necessary. Answering the FFQ by sections could reduce the bias generated by the software being long to respond. The second one is regarding environmental impact assessment. Initially, Nutriecology® was thought to contain several environmental metrics. However, it was decided to launch the first version with WF only. Nevertheless, we are currently calculating greenhouse gas emissions expressed in kilograms of carbon dioxide equivalents (kg CO_2/eq), land use in square meter-year (m^2*y), fossil energy use in megajoules, and a weighted score of the three (pReCiPe score), of the food list shown in Table 2[(28)]. For future actualizations, other environmental impact indexes, such as biodiversity loss, acidification, and eutrophication, will be considered.

The third limitation we are working on is evaluating diet quality from 24-hour recalls besides FFQ. In the fourth place, the IACDMx will be updated based on the Global Diet Quality Score [(87)], and the index for assessing adherence to the traditional Mexican diet [(88)]. In fifth place, we are working on extending food nutritional information since we will include food additives, bioactive compounds, economic aspects of foods, and glycemic aspects, among other features. Sixth, we plan to expand the evaluation of the “adequate” aspect, where we are currently working on providing ranges to assess the level of "adequate" of the diet. We already have a beta version of that part, shown in Table 2 and Supplementary Material 5. In seventh place, the general user’s information will be expanded regarding the addition of a complete clinical history, including personal and familiar pathologies history, medicaments and supplements use, nutritional signs and symptoms, food preferences, allergies and intolerances, clinical indicators, etc. Displayable options will also be incorporated to educational level according to national classification, including displayable options, and work options will also be expanded. In general, all questions will include displayable options for a better user experience. Finally, we are working on the development of a new dietary sustainability index that will be added to Nutriecology®. A further challenge of this project is to replicate the work in other countries, so, future collaborations will be done to expand the frontiers of Nutriecology®.

5. Conclusions

We created Nutriecology®, providing the first nutritional ecologic software for Mexico's context that allows the evaluation of diet, and provides automatic calculations of diet quality and dietary environmental impact simultaneously. The diet quality index, ICDMx, was improved and orientated to sustainable food consumption through the formulation of the IACDMx. Additionally, an automatic assessment of dietary WF is available for the first time, considering correction factors from cooked to uncooked food and peeled to un-peeled food. Also, this is the first time a software for dietary WF assessment considers water involved in food washing and cooking. As well as the accounting for the WF of each ingredient included in the diet. We are continuously working on other features of Nutriecology®, that will improve their functions and the addressed environmental aspects.

6. Patents

This development is registered in the National Institute of Copyright (INDAUTOR) under the name of Nutriecology® as computational software development with the number of registration 03-2022-012812203100-01.

Declarations

Supplementary Materials: Supplementary Material 1. Educational and occupational level classification; Supplementary Material 2. Classification of food groups and sub-groups of foods integrated into Nutriecology®; Supplementary Material 3. Written version of the Food Consumption Frequency Questionnaire; Supplementary Material 4. Labels consulted for the calculation of nutritional composition and dietary water footprint in the database of Nutriecology®.; Supplementary Material 5. Calculation and components of the Alternate Quality Index of the Mexican Diet; Supplementary Material 6. Nutriecology® interface.

Funding: This research was funded by the SNI-SNCA Permanence Scholarship Program (PROSNI) by the University of Guadalajara. However, the financial support did not influence the design and results of the study.

Author Contributions: Conceptualization, M.L-M., and F.E.H.; methodology, investigation, validation, visualization, and supervision, M.L-M., F.E.H., V.G.A.C., and R.M.M.N.; software, R.M.M.N., and M.L-M.; writing—original draft preparation, M.L-M.; writing—review and editing, M.L-M., F.E.H., and V.G.A.C.; project administration M.L-M., and F.E.H; funding acquisition, F.E.H.

Data Availability Statement: Complete presentation of Nutriecology® is shown in Supplementary Material.

Acknowledgments: We thank the National Council for Science and Technology (CONACYT), for scholarship number 717186 (CVU 934420). Also, we would like to thank the SNI-SNCA Permanence Scholarship Program (PROSNI), for the financial support for the development of Nutriecology®.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. FAO (2018) Dietary assessment: a resource guide to method selection and application in low resource settings. .

2. Eldridge AL, Piernas C, Illner A-K, et al. (2018) Evaluation of New Technology-Based Tools for Dietary Intake Assessment—An ILSI Europe Dietary Intake and Exposure Task Force Evaluation. Nutrients **11**, 55.

3. Carter MC, Albar SA, Morris MA, et al. (2015) Development of a UK Online 24-h Dietary Assessment Tool: myfood24. Nutrients **7**, 4016–4032. Multidisciplinary Digital Publishing Institute.

4. Dao MC, Subar AF, Warthon-Medina M, et al. (2019) Dietary Assessment Toolkits: An Overview. Public Health Nutr **22**, 404–418.

5. Lares-Michel M, Housni FE & Aguilera Cervantes VG (2021) A quantitative estimation of the water footprint of the Mexican diet, corrected for washing and cooking water. Food Sec. **13**, 849–874.

6. Lares-Michel M, Housni FE, Aguilera Cervantes VG, et al. (2021) Eat well to fight obesity… and save water: The water footprint of different diets and caloric intake and its relationship with adiposity. Front. Nutr. **8**. Frontiers.

7. Ghammachi N, Dharmayani PNA, Mihrshahi S, et al. (2022) Investigating Web-Based Nutrition Education Interventions for Promoting Sustainable and Healthy Diets in Young Adults: A Systematic Literature Review. International Journal of Environmental Research and Public Health **19**, 1691. Multidisciplinary Digital Publishing Institute.

8. Rosi A, Mena P, Pellegrini N, et al. (2017) Environmental impact of omnivorous, ovo-lacto-vegetarian, and vegan diet. Scientific Reports **7**, 6105. Nature Publishing Group.

9. myfood24® | Quick and easy to use nutritional analysis software. https://www.myfood24.org/ (accessed February 2022).

10. nutricloud. https://www.nutricloud.mx/ (accessed February 2022).

11. Nutrimind Software de Nutrición. https://www.nutrimind.net/ (accessed March 2022).

12. Software Nutricion. AZNUTRITION. https://www.aznutrition-oficial.com (accessed July 2022).

13. Aleksandrowicz L, Green R, Joy EJM, et al. (2016) The Impacts of Dietary Change on Greenhouse Gas Emissions, Land Use, Water Use, and Health: A Systematic Review. PLOS ONE **11**, e0165797. Public Library of Science.

14. Harris F, Moss C, Joy EJM, et al. (2020) The Water Footprint of Diets: A Global Systematic Review and Meta-analysis. Advances in Nutrition **11**, 375–386.

15. Macedo-Ojeda G, Vizmanos-Lamotte B, Márquez-Sandoval YF, et al. (2013) Validation of a semi-quantitative food frequency questionnaire to assess food groups and nutrient intake. Nutr Hosp **28**, 2212–2220.

16. Denova-Gutiérrez E, Tucker KL, Salmerón J, et al. (2016) Relative validity of a food frequency questionnaire to identify dietary patterns in an adult Mexican population. Salud Pública de México **58**, 608–616.

17. Diet quality concept - ClinicalKey. https://www.clinicalkey.com/#!/content/playContent/1-s2.0-S0899900713004462?returnurl=https:%2F%2Flinkinghub.elsevier.com%2Fretrieve%2Fpii%2FS0899900713004462%3Fshowall%3Dtrue&referrer= (accessed February 2022).

18. Ridoutt BG, Baird D, Anastasiou K, et al. (2019) Diet Quality and Water Scarcity: Evidence from a Large Australian Population Health Survey. Nutrients **11**, 1846. Multidisciplinary Digital Publishing Institute.

19. Macedo-Ojeda G, Márquez-Sandoval F, Fernández-Ballart J, et al. (2016) The Reproducibility and Relative Validity of a Mexican Diet Quality Index (ICDMx) for the Assessment of the Habitual Diet of Adults. Nutrients **8**.

20. Pérez Rodrigo C, Aranceta J, Salvador G, et al. (2015) Food frequency questionnaires. Nutr Hosp **31 Suppl 3**, 49–56.

21. Salvador Castell G, Serra-Majem L & Ribas-Barba L (2015) What and how much do we eat? 24-hour dietary recall method. Nutr Hosp **31 Suppl 3**, 46–48.

22. Hu FB (2002) Dietary pattern analysis: a new direction in nutritional epidemiology. Current Opinion in Lipidology **13**, 3–9.

23. Lares-Michel M, Housni FE, Aguilera Cervantes VG, et al. (2022) The water footprint and nutritional implications of diet change in Mexico: a principal component analysis. Eur J Nutr.

24. Bourges Rodríguez H (2001) La alimentación y la nutrición en México. Comercio exterior **51**, 897–904.

25. Drewnowski A, Henderson SA, Shore A, et al. (1996) Diet Quality and Dietary Diversity in France: Implications for the French Paradox. Journal of the American Dietetic Association **96**, 663–669.

26. Patterson RE, Haines PS & Popkin BM (1994) Diet quality index: Capturing a multidimensional behavior. Journal of the American Dietetic Association **94**, 57–64.

27. Fransen HP & Ocké MC (2008) Indices of diet quality. Curr Opin Clin Nutr Metab Care **11**, 559–565.

28. Grasso AC, Olthof MR, van Dooren C, et al. (2020) Effect of food-related behavioral activation therapy on food intake and the environmental impact of the diet: results from the MooDFOOD prevention trial. Eur J Nutr **59**, 2579–2591.

29. Tello J, Garcillán PP & Ezcurra E (2020) How dietary transition changed land use in Mexico. Ambio **49**, 1676–1684.

30. Hoekstra AY, Chapagain AK, Aldaya MM, et al. (2012) The Water Footprint Assessment Manual: Setting the Global Standard. 1st ed. Routledge.

31. Willett W, Rockström J, Loken B, et al. (2019) Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems. The Lancet **393**, 447–492. Elsevier.

32. Terminel-Zaragoza R, Vega-López S, Ulloa-Mercado G, et al. (2022) Reproducibility and validity of a food frequency questionnaire to assess cardiovascular health-related food intake among Mexican adolescents. Journal of Nutritional Science **11**. Cambridge University Press.

33. Sierra-Ruelas É, Bernal-Orozco MF, Macedo-Ojeda G, et al. (2021) Validation of semiquantitative FFQ administered to adults: a systematic review. Public Health Nutrition **24**, 3399–3418. Cambridge University Press.

34. Bernal-Orozco MF, Badillo-Camacho N, Macedo-Ojeda G, et al. (2018) Design and Reproducibility of a Mini-Survey to Evaluate the Quality of Food Intake (Mini-ECCA) in a Mexican Population. Nutrients **10**, E524.

35. Bernal-Orozco MF, Salmeron-Curiel PB, Prado-Arriaga RJ, et al. (2020) Second Version of a Mini-Survey to Evaluate Food Intake Quality (Mini-ECCA v.2): Reproducibility and Ability to Identify Dietary Patterns in University

Students. Nutrients **12**, 809. Multidisciplinary Digital Publishing Institute.

36. Sequía generalizada en México | Ciencia de la NASA. https://ciencia.nasa.gov/sequia-generalizada-en-mexico?fbclid=IwAR03EyrjUZNenrcgXIsLaF4SKXfPbS4A5RE9Zs82DrWdy_ADZ0itDt5pbfc (accessed January 2022).

37. IUCN (2007) Totoaba macdonaldi: Findley, L.: The IUCN Red List of Threatened Species 2010: e.T22003A9346099. International Union for Conservation of Nature.

38. National Water Commission (CONAGUA). Groundwater Availability by aquifer. 2015. https://sigagis.conagua.gob.mx/gas1/sections/Edos/jalisco/jalisco.html (accessed March 2021).

39. Dietary Assessment Tools - Nutritools. https://www.nutritools.org/tools (accessed July 2022).

40. Gao SK, Beresford SA, Frank LL, et al. See corresponding editorial on page 14. Modifications to the Healthy Eating Index and its ability to predict obesity: the Multi-Ethnic Study of Atherosclerosis1–3. .

41. Kennedy ET, Ohls J, Carlson S, et al. (1995) The Healthy Eating Index: design and applications. J Am Diet Assoc **95**, 1103–1108.

42. Diet quality and major chronic disease risk in men and women: moving toward improved dietary guidance | The American Journal of Clinical Nutrition | Oxford Academic. https://academic.oup.com/ajcn/article/76/6/1261/4689565 (accessed February 2022).

43. Sanjeevi N, Freeland-Graves J & Hersh M (2018) Food insecurity, diet quality and body mass index of women participating in the Supplemental Nutrition Assistance Program: The role of intrapersonal, home environment, community and social factors. Appetite **125**, 109–117.

44. López-Olmedo N, Popkin BM, Gordon-Larsen P, et al. (2020) Cross-sectional association between diet quality and cardiometabolic risk by education level in Mexican adults. Public Health Nutrition **23**, 264–274. Cambridge University Press.

45. López-Olmedo N, Popkin BM, Mendez MA, et al. (2019) The association of overall diet quality with BMI and waist circumference by education level in Mexican men and women. Public Health Nutrition **22**, 2777–2792. Cambridge University Press.

46. NOM-043-2012.pdf. .

47. Pérez-Lizaur AB, Berenice Palacios González, Ana Laura Castro Becerra, et al. (2014) Sistema Mexicano de Alimentos Equivalentes. Ogali.

48. Dinter J, Bechthold A & Boeing H (2016) Fish intake and prevention of selected nutrition-related diseases. Ernahrungs Umschau, 148–154.

49. Jenkins DJA, Kendall CWC, Augustin LSA, et al. (2012) Effect of Legumes as Part of a Low Glycemic Index Diet on Glycemic Control and Cardiovascular Risk Factors in Type 2 Diabetes Mellitus: A Randomized Controlled Trial. Archives of Internal Medicine **172**, 1653–1660.

50. Genkinger JM & Koushik A (2007) Meat Consumption and Cancer Risk. PLOS Medicine **4**, e345. Public Library of Science.

51. Mekonnen MM & Hoekstra AY (2010) The green, blue and grey water footprint of crops and derived crop products. 42. Países Bajos: UNESCO -IHE. Institute for Water Education.

52. Clark MA, Springmann M, Hill J, et al. (2019) Multiple health and environmental impacts of foods. Proceedings of the National Academy of Sciences **116**, 23357–23362. Proceedings of the National Academy of Sciences.

53. Guideline: sugars intake for adults and children. https://www.who.int/publications-detail-redirect/9789241549028 (accessed June 2022).

54. Food and Agriculture Organization of the United Nations & World Health Organization (2019) Sustainable healthy diets: guiding principles. .

55. Blonk Sustainability | Agri-footprint. https://blonksustainability.nl/tools/agri-footprint (accessed March 2022).

56. Blonk Sustainability | Optimeal. https://blonksustainability.nl/tools/optimeal (accessed March 2022).

57. Plan Educativo Nacional. http://www.planeducativonacional.unam.mx/CAP_07/Text/07_03a.html (accessed January 2021).

58. (2015) Instituto Nacional de Estadística y Geografía (INEGI). National Institute of Statistic and Geography. https://iieg.gob.mx/general.php?id=4&idg=45 (accessed March 2021).

59. IPAQ scoring protocol - International Physical Activity Questionnaire. https://sites.google.com/site/theipaq/scoring-protocol (accessed January 2021).

60. INEGI IN de E y G Instituto Nacional de Estadística y Geografía. INEGI. Instituto Nacional de Estadística y Geografía. INEGI; https://www.inegi.org.mx/default.html (accessed January 2021).

61. Lares-Michel M, Housni FE, Cervantes VGA, et al. (2018) The Relationship between Consumption, Socioeconomic Level and Reasons of Tomato Intake in Mexico. Agricultural Sciences **9**, 720–726. Scientific Research Publishing.

62. Denova-Gutiérrez E, Ramírez-Silva I, Rodríguez-Ramírez S, et al. (2016) Validity of a food frequency questionnaire to assess food intake in Mexican adolescent and adult population. Salud pública Méx **58**, 617–628. Instituto Nacional de Salud Pública.

63. López-Espinoza A, Martinez-Moreno AG, Aguilera-Cervantes VG, et al. (2018) Estudio e investigación del comportamiento alimentario: Raíces, desarrollo y retos. Revista mexicana de trastornos alimentarios **9**, 107–118. Universidad Nacional Autónoma de México, Facultad de Estudios Superiores Iztacala.

64. © Photocuisine / Masterfile. https://image1.masterfile.com/getImage/ODI1LTA1ODM2MjIxZW4uMDAwMDAwMDA=AAjGW6/825-05836221en_Masterfile.jpg (accessed July 2022).

65. Miriam Muñoz de Chávez, José Ángel Ledesma Solano, Adolfo Chávez Villasana, et al. Composición de alimentos Miriam Muñoz de Chávez Valor nutritivo de los alimentos de mayor consumo. Second edition. McGraw-Hill.

66. Bonvecchio Arenas A, Fernández-Graxiola AC, Plazas Belausteguigoitia M, et al. (2015) Consumir porciones recomendadas de alimentos según la edad. In Guías alimentarias y de actividad física: en contexto de sobrepeso y obesidad en la población mexicana : documento de postura, pp. 63–75.

67. Ministry of Health of Mexico. 2016. Grupos de alimentos y patrones de alimentación saludables para la prevención de enfermedades adultos y pediátricos 1, 2, 3er Nivel de Atención. México: Centro Nacional de Excelencia Tecnológica en Salud (CENETEC). .

68. Hawkes C, Eckhardt CL, Ruel MT, et al. (2012) Diet quality, poverty and food policy: a new research agenda for obesity prevention in developing countries. .

69. World Health Organization. Regional Office for Europe (2021) Potential for sugar-sweetened beverage taxes in Ukraine: estimated impacts of a sugar-sweetened beverage excise tax on price, consumption and tax revenue. Copenhagen: World Health Organization. Regional Office for Europe.

70. Valerino-Perea S, Lara-Castor L, Armstrong MEG, et al. (2019) Definition of the Traditional Mexican Diet and Its Role in Health: A Systematic Review. Nutrients **11**, 2803. Multidisciplinary Digital Publishing Institute.

71. Almaguer González J, García Ramírez H, Padilla Mirazo M, et al. (2019) Fortalecimiento de la salud con comida, ejercicio y buen humor: La dieta de la milpa. Modelo de alimentación mesoamericana saludable y culturalmente pertinente. Secretaría de Salud. Google Docs. https://drive.google.com/file/d/1n05pSVGY09FlzW91Rt8IZk_6J-KIPRJT/view?usp=sharing&usp=embed_facebook (accessed January 2021).

72. Consejo Nacional para la Cultura y las Artes [CONACULTA]. (2001) La cocina familiar en el estado de Jalisco. 2nd ed. Mexico: Oceano.

73. Gaona-Pineda EB, Martínez-Tapia B, Arango-Angarita A, et al. (2018) Consumo de grupos de alimentos y factores sociodemográficos en población mexicana. Salud Publica Mex **60**, 272.

74. Ortiz-Hernández L (2006) Cambios en factores relacionados con la transición alimentaria y nutricional en México. **142**, 13.

75. Rosas Martín HA (2013) Lo mejor de las carnes y aves en México. Mexico: Dvinni Colombia.

76. Lares-Michel M, Housni FE, Aguilera Cervantes VG, et al. (2022) The water footprint and nutritional implications of diet change in Mexico: a principal component analysis. Eur J Nutr.

77. McCullough ML, Feskanich D, Stampfer MJ, et al. (2002) Diet quality and major chronic disease risk in men and women: moving toward improved dietary guidance. Am J Clin Nutr **76**, 1261–1271.

78. Blas A, Garrido A & Willaarts BA (2016) Evaluating the Water Footprint of the Mediterranean and American Diets. Water **8**, 448. Multidisciplinary Digital Publishing Institute.

79. Widiaty I, Riza L, Gafar Abdullah A, et al. (2019) WEB-BASED DIGITAL LEARNING APPLICATION OF ICONIC BATIK IN BATIK LEARNING AT VOCATIONAL HIGH SCHOOL. .

80. The sustainable Christmas dinner. https://www.sustainabilityexchange.ac.uk/files/christmasfactsheet2014.pdf. .

81. Barnard N, Levin S & Trapp C (2014) Meat Consumption as a Risk Factor for Type 2 Diabetes. Nutrients **6**, 897–910.

82. Briggs MA, Petersen KS & Kris-Etherton PM (2017) Saturated Fatty Acids and Cardiovascular Disease: Replacements for Saturated Fat to Reduce Cardiovascular Risk. Healthcare **5**, 29. Multidisciplinary Digital Publishing Institute.

83. Pesquera S de IA y Rumiantes: los que sí clasifican. gob.mx. http://www.gob.mx/siap/articulos/rumiantes-los-que-si-clasifican (accessed July 2022).

84. Torres VHG, Cruz LH, Gutiérrez JÁR, et al. Dirección General de Educación Tecnológica Agropecuaria y Ciencias del Mar. 78.

85. Mekonnen MM & Hoekstra AY (2012) A Global Assessment of the Water Footprint of Farm Animal Products. Ecosystems **15**, 401–415.

86. Prada M, Saraiva M, Garrido MV, et al. (2022) Perceived Associations between Excessive Sugar Intake and Health Conditions. Nutrients **14**, 640. Multidisciplinary Digital Publishing Institute.

87. Castellanos-Gutiérrez A, Rodríguez-Ramírez S, Bromage S, et al. (2021) Performance of the Global Diet Quality Score with Nutrition and Health Outcomes in Mexico with 24-h Recall and FFQ Data. The Journal of Nutrition **151**, 143S-151S.

88. Valerino-Perea S, Armstrong MEG & Papadaki A (2021) Development of an index to assess adherence to the traditional Mexican diet using a modified Delphi method. Public Health Nutrition **24**, 4387–4396. Cambridge University Press.

Tables

Table 1. Features of Nutriecology® in users' section

Software sections	Features in users' section
Section 1: Registration	Sign up, log in, informed consent, accept / no accept
Section 2: User information	General information (name, last name, phone, email, age, date of birth, sex, place of birth, place of residence, time living there, comments)
	Educational level (to respond according to UNAM [57] according to last level of studies
	Occupational level according to INEGI [58] (type of work, workdays, schedule, monthly income)
	Food purchasing data (monthly money spend in food, principal place of purchasing, days a week user eats out of home, types of food consumed out of home)
	Physical activity (according to IPAQ [59] (type of physical activity, times a week, minutes a day, intensity)
	Presence of disease (open-ended question)
	Anthropometric and body composition data (estimated weight, estimated heigh, body composition): height, weight, body mass index, percentage of body fat, percentage of muscle mass, corporal water, metabolic rate, metabolic age, visceral fat, waist circumference, hips circumference, bone mass)
	Registration button
Section 3: 24-hour recall	Food time, divided by breakfast, morning snack, meal, evening snack, and dinner
	Time (hour) of the eating episode
	Place of consumption
	Menu / Preparation
	Displayable list of foods with images
	Quantity of food consumed in portions
	Water consumed
	Registration button
Section 4: Food Consumption Frequency Questionnaire (FFQ)	Displayable food list with images (248 items with extension, reduction, or edition option)
	Portion of consumption in common food portions of ingestion
	Type of food, branch, flavor, or preparation method
	Average frequency of consumption during the last year (selection of 1 option among the 3 provided frequencies [yearly, monthly and weekly])
	Average frequency of consumption by day of ingestion (selection of 1 option per day)
	Number of portions eaten (selection of how many servings are consumed each time the food is eaten)
Section 5: IACDMx	Internal calculation of the IACDMx
Section 6: Environmental impact assessment (WF)	Total dietary water footprint (WF) assessment (sum of green, blue, and grey WF). All calculations applying correction factors for cooked and peeled food (for the detailed calculation method and correction factors list see Lares-Michel et al. [5]).
	Green dietary WF assessment, which corresponds to the water used during the evapotranspiration process in agriculture (rainwater stored in the soil as moisture)
	Blue dietary WF assessment, which accounts for water involved in agricultural irrigation
	Grey dietary WF assessment, which estimates the water needed to assimilate pollutants, such as water used in food industries, processing, cooking, and food washing

Note: UNAM: National Autonomous University of Mexico; INEGI: National Institute of Statistics and Geography; IPAQ: International Physical Activity Questionnaire; FFQ: Food Consumption Frequency Questionnaire; WF: Water footprint; IACDMx: Alternate Quality Index of the Mexican Diet

Table 2. Calculation and components of the Alternate Quality Index of the Mexican Diet (IACDMx)

Dietary recommendations for a correct diet	IACDMx component (maximum 100 points)	Scoring Criteria
Component 1: Sufficient (20 points)		
It satisfies all nutritional needs, so the adult subject has good nutrition and a healthy weight.	The diet covers 100% of the energy requirements.[1]	>90% o <110% = 8
		>80% – 90% or 110% – <120% = 7
		>70% – 80% or 120% – <130% = 6
		>60% – 70% or 130% – <140% = 5
		>50% – 60% or 140% – <150% = 4
		>40% – 50% or 150% – <160% = 3
		>30% – 40% or 160% – <170% = 2
		>20% – 30% or 170% – <180% = 1
		20 o 180% = 0
	Iron intake is at least 21 mg for women or 15 mg for men.[1]	100% = 3
		50% – <100% = 1.5
		<50% = 0
	Calcium intake is at least 1 g.[1]	100% = 3
		50% – <100% = 1.5
		<50% = 0
	Fiber intake is at least 30 g for women or 35 g for men.[1]	100% = 3
		50% – <100% = 1.5
		<50% = 0
	Water consumption is at least 1500 mL.[1]	1500 = 3
		1000 – <1500 = 1.5
		<1000 = 0
Component 2. Balanced (20 points)		
Nutrients are consumed in balanced proportions with respect to total energy intake.	Proteins, 12% - 15% of energy intake.[1]	12% – 15% = 7
		10 – <12% o >15% – 19% = 3.5
		<10 o >19% = 0
	Lipids, 25% - <30% of energy intake.[1]	25% – <30% = 7
		21% – <25% o 30% – 33% = 3.5
		<21% o >33% = 0
	Carbohydrates, 55%-63% of energy intake.[1]	55% – 63% = 6
		51% – <55% o >63% – 67% = 3
		<51% o >67% = 0
Component 3: Complete (20 points)		
Contains all the nutrients. It is recommended to include foods from the groups evaluated in each meal.	Include at least 400 g from the vegetable and fruit group.[1]	400 = 4
		300 – <400 = 3
		200 – <300 = 2
		<200 = 0
	Include at least 200 g from the fat-free cereal group.[1]	200 = 2
		150 – <200 = 1.5
		100 – <150 = 1
		<100 = 0
	Includes at least 60 g from the legume group.[1]	60 = 2
		45 – <60 = 1.5
		30 – <45 = 1
		<30 = 0
	Includes less than 71 g of the subgroups, red meats and processed meats.[2]	£71 = 4
		72 – 107 = 3
		108 – 142 = 1
		>142 = 0
	Includes less than 56 g of the chicken and eggs subgroup.[3]	£56 = 2
		57 – 84 = 1.5
		85 – 112 = 1
		>112 = 0
	Includes less than 240 ml of the foods whole milk, low-fat milk, low-fat milk, full-fat yogurt, and low-fat yogurt.[3]	£240 = 2
		241 – 360 = 1.5

		361 – 480 = 1
		> 480 = 0
	Includes less than 40g from the cheese group.[3]	£40 = 2
		41 – 60 = 1.5
		61 – 80 = 1
		>80 = 0
	Includes at least 26 g from the fish and shellfish subgroup.[3]	26 = 2
		25 – 13 = 1.5
		12 – 6 = 1
		<6 = 0

Note: Own elaboration. [1]Macedo-Ojeda et al. (19); [2]Rivera et al. (66); [3]Health Ministry of Health of Mexico (67).

Table 2. Cont. Calculation and components of the Alternate Quality Index of the Mexican Diet (IACDMx)

Dietary recommendations for a correct diet	ICDMx component (maximum 100 points)	Scoring Criteria			
Component 4: Varied (20 points)					
Different foods from each group are consumed. This implies a variety of textures, colors, flavors, etc.	Include at least four of five subgroups (red, blue-purple, yellow-orange, green, and white) from the vegetable and fruit group.[1]	4 o 5 = 8			
		3 = 6			
		2 = 3			
		<2 = 0			
	Includes at least three of eight subgroups from the nonfat grain group (wheat, rice, corn, whole grains, tubers, oats, quinoa, and amaranth).[1]	3 – 8 = 6			
		2 = 3			
		<2 = 0			
	Includes at least three of six subgroups (beans, poultry, red meat, fish and shellfish, unsweetened milk, and low-fat cheese).[1]	3 – 6 = 6			
		2 = 3			
		<2 = 0			
Component 5: Innocuous (20 points)					
Its regular consumption does not imply health risks because it is consumed in moderation.	Saturated fatty acids, £7% of energy intake.[1]	£7% = 4			
		>7%–12% = 2			
		>12% = 0			
	Polyunsaturated fatty acids, 6% - 10% of energy.[1]	6% – 10% = 4			
		>10%–15% o <6% = 2			
		>15% = 0			
	Sodium intake, 1600 mg.[1]	£1600 = 4			
		>1600 – 2600 = 2			
		>2600 = 0			
	Intake of alcoholic beverages, £14.4 g of ethanol (equivalent to 1 alcoholic beverage).[1]	£14.4 = 4			
		>14.4–21.6 = 2			
		>21.6 = 0			
	Sugar intake less than 10% of total energy intake.[4]	£10% = 4			
		>10%–15% = 2			
		>15% = 0			
Component 6: Adequate					
		Category	Grade according to consumption tertiles ($g\ p^{-1}d^{-1}$)*		
Regularly consume foods that adhere to the Mexican food culture and are inexpensive	Consume less than 30 grams of Mexican food per day.[5,6,7,8]	Inadequate a	≤ 33.60 - 461.58	461.59 - 754.85	754.86
	Consume less than 180 grams of Mexican recipes per week. This equates to less than 26 grams a day. [5,6,7,8]	Inadequate b	0 - 89.30	89.31 - 180.88	180.89
	Eat more than 30 grams of Western foods a day.[5,6]	Inadequate c	0 - 248.93	248.94 - 533.29	533.29
	Consume more than 180 grams of western recipes a week. This equates to 26 grams or more per day. [5,6,7,8]	Inadequate d	0 - 41.97	41.98 - 85.82	85.83
	Eat 30 grams or more of Mexican foods per day.[5,6]	Adequate a	≤ 33.60 - 461.58	461.59 - 754.85	754.86
	Consume 180 grams or more of Mexican recipes per week. This equates to 26 grams or more per day.[5,6,7,8]	Adequate b	0 - 89.30	89.31 - 180.88	180.89
	Eat less than 30 grams of Western foods per day. [5,6,7,8]	Adequate c	0 - 248.93	248.94 - 533.29	533.29
	Consume less than 180 grams of Western recipes per week. This equates to less than 26 grams a day. [5,6,7,8]	Adequate d	0 - 41.97	41.98 - 85.82	85.83

Note: Own elaboration. [1]Macedo-Ojeda et al. (19); [4]World Health Organization (53); [5]Mexican System of Equivalent Foods (SAME) (47); [6]Valerino-Perea et al. (70); [7]Almaguer-González et al. (71); [8]Ortiz-Hernández et al. (74). * For classifying the "adequate" aspect of the IACDMx, consumption tertiles were calculated based on the dietary data reported in Lares-Michel et al. (76), full description of this analysis is shown in Supplementary Material 5.

Table 3. Features of Nutriecology® in the administrator section

Software sections	Feature in administrator section
Section 1:	Log in of administrator
	Menu for viewing, editing, adding, or deleting foods, food groups, foods sub-groups, and adequate food sub-group. Also, a section for visualization of the sociodemographic, and nutritional evaluation, 24-hour recall, and FFQ is available. A section for import and export data in excel sheets format is also presented.
Section 2	Exportable excel sheet with registration, sociodemographic, and anthropometric and body composition data
Section 3	Exportable excel sheet with total nutritional composition and water footprint from 24-hour
	Exportable excel sheet with the nutritional composition and water footprint (WF) by food registered from 24-hour
Section 4	Exportable excel sheet with the total nutritional composition of FFQ
	Exportable excel sheet with nutritional composition of FFQ by food registered
	Exportable excel sheet with the nutritional composition of food groups classification (see Supplementary Material 2)
	Exportable excel sheet with the food sub-groups classification
Section 5	Diet quality assessment (IACDMx)
	Food group “adequate” classification, exportable to excel sheets
	Diet quality by components, exportable to excel sheet

Note: FFQ: Food Consumption Frequency Questionnaire; WF: Water footprint; IACDMx: Alternate Quality Index of the Mexican Diet.

Table 4. Nutritional composition and environmental impact aspects incorporated in Nutriecology®

Data calculated by Nutriecology®
Dietary data
Grams consumed (g)
Energy intake (kcal)
Macronutrients
Carbohydrates (g)
Sugar (g)
Fiber (g)
Protein (g)
Lipids (g)
Saturated fatty acids (g)
Monounsaturated fatty acids (g)
Polyunsaturated fatty acids (g)
Cholesterol (mg)
Ethanol (g)
Micronutrients
Minerals
Calcium (mg)
Phosphorus (mg)
Iron (mg)
Magnesium (mg)
Sodium (mg)
Potassium (mg)
Zinc (mg)
Selenium (mg)
Vitamins
Vitamin A (µg RE)
Ascorbic acid (mg)
Thiamine (mg)
Riboflavin (mg)
Niacin (mg)
Pyridoxine (mg)
Folic acid (µg)
Cobalamin (mg)
Environmental indicators
Total WF (calculated with correction factors from [5]
Green WF (calculated with correction factors from [5]
Blue WF (calculated with correction factors from [5]
Water needed for cooking
Water needed for food washing

Note: WF = Water footprint; g = grams; kcal = calories; mg = milligrams; µg RE = microgram.

Figures

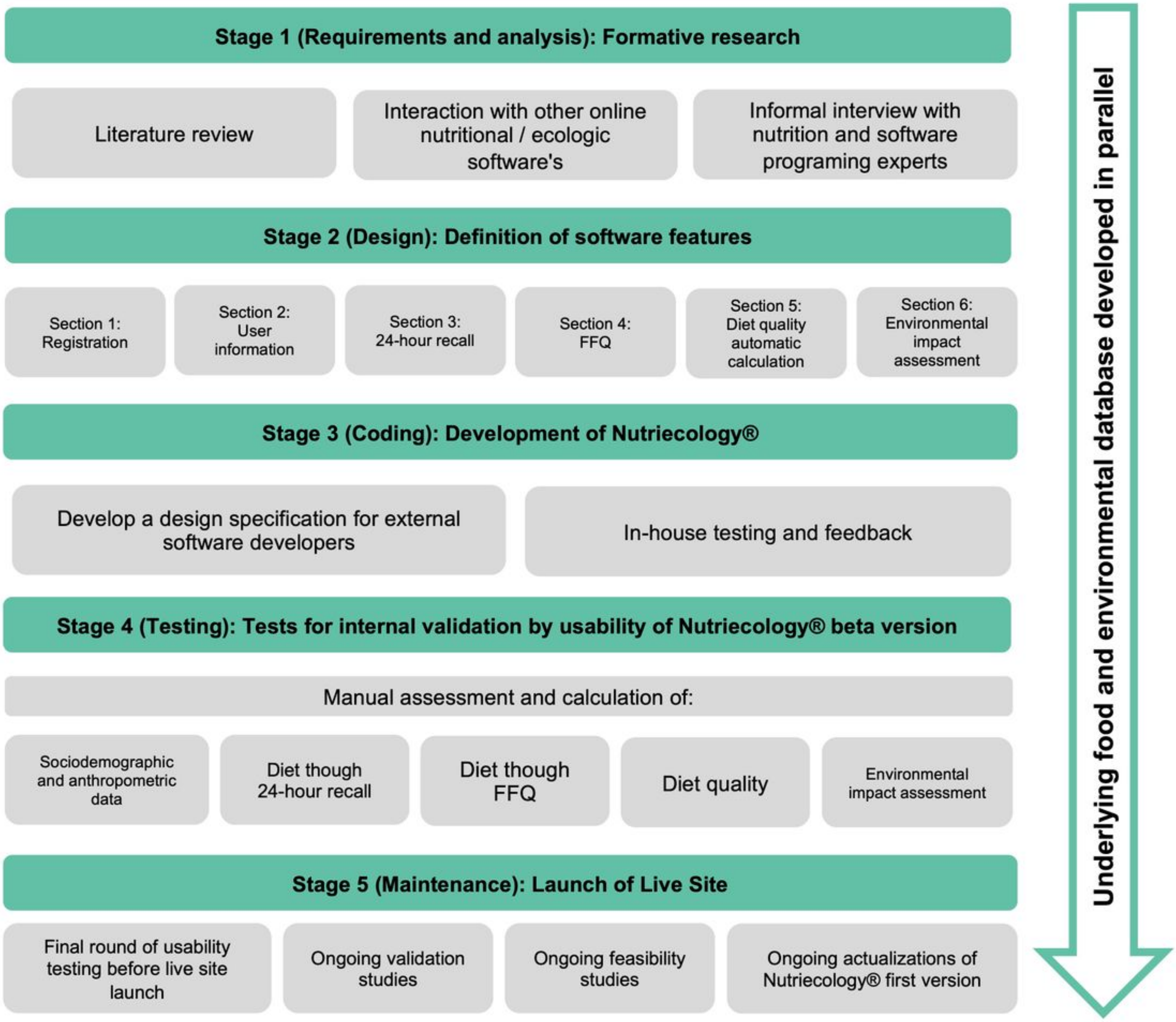

Figure 1

Process followed for the development of the nutritional ecologic software Nutriecology®. Note: FFQ = Food Consumption Frequency Questionnaire.

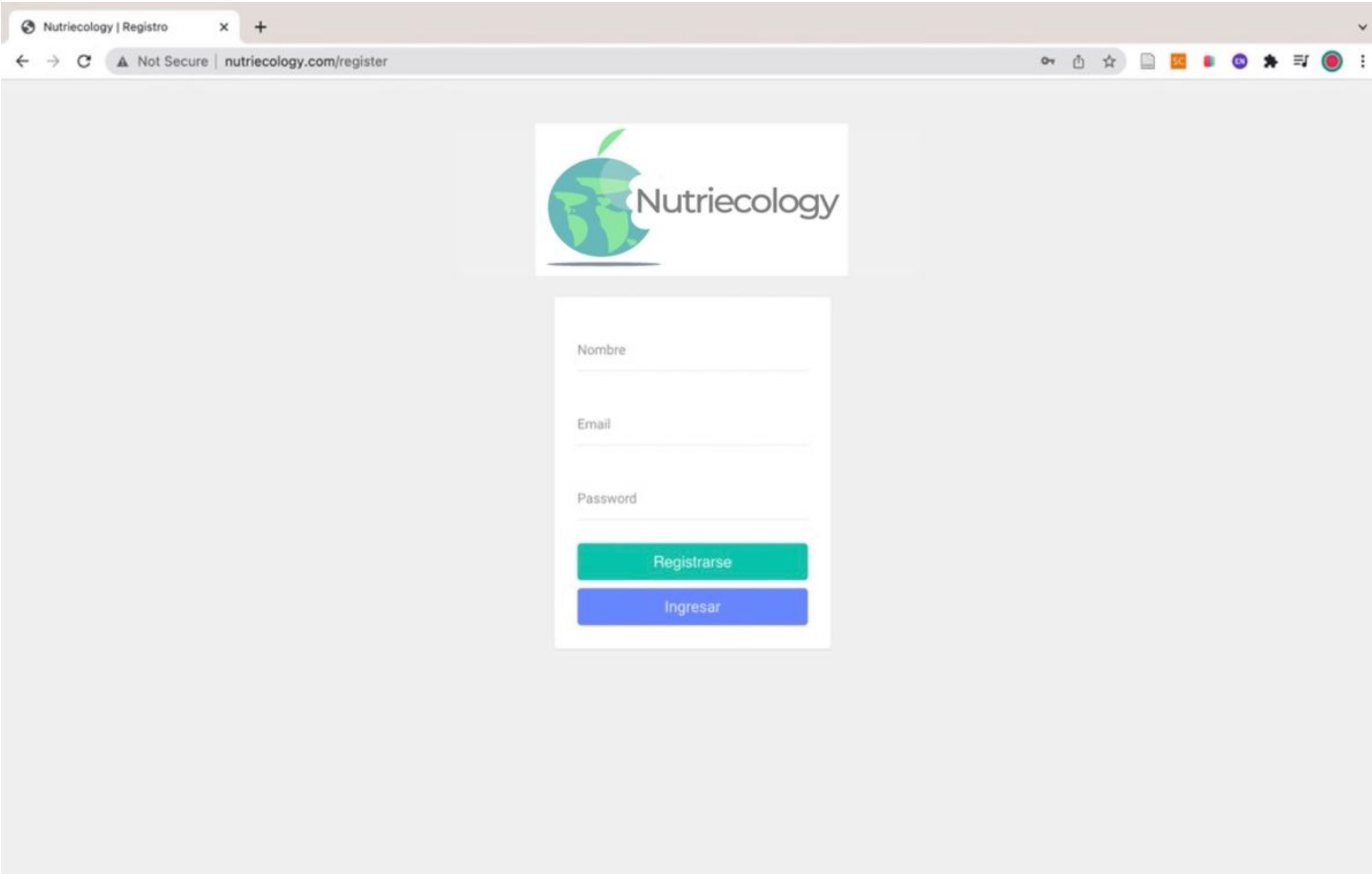

Figure 2

Users' registration in the users' section of Nutriecology®. The complete interface of Nutriecology® is presented in Supplementary Materials 6.

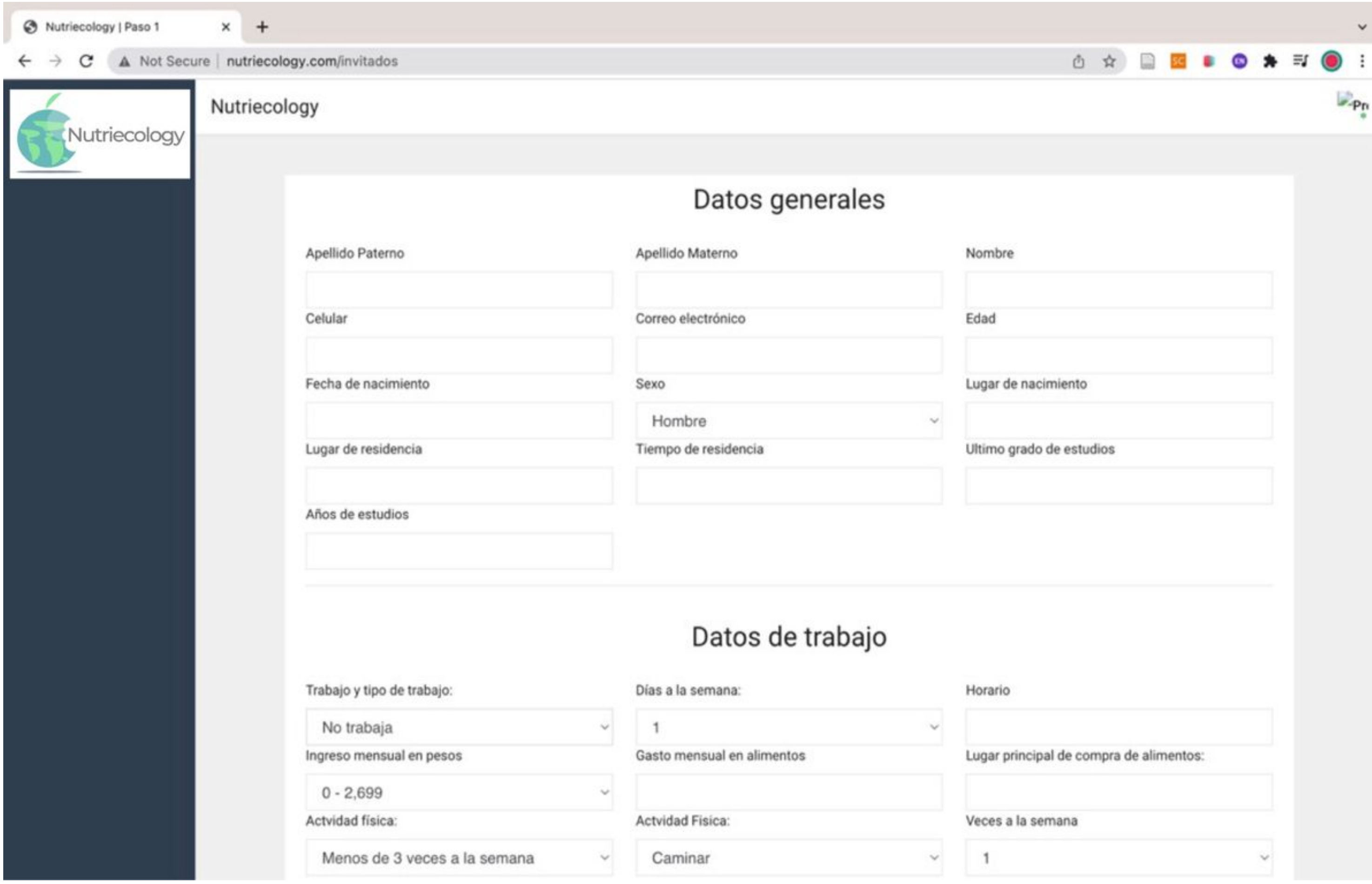

Figure 3

General data of user's section in Nutriecology®. The complete interface of Nutriecology® is presented in Supplementary Materials 6.

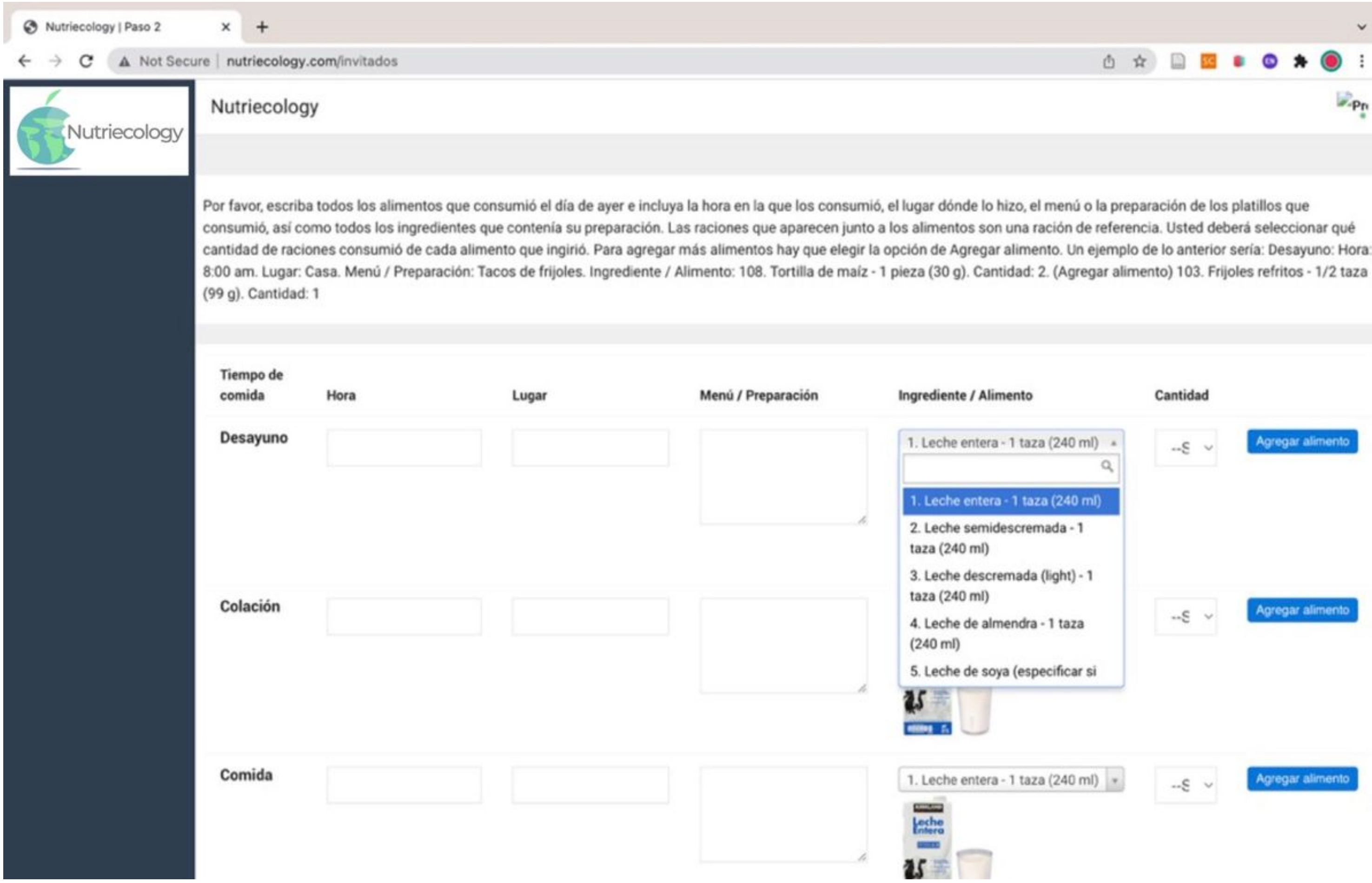

Figure 4

24-hour recall of user’s section in Nutriecology®. The complete interface of Nutriecology® is presented in Supplementary Materials 6.

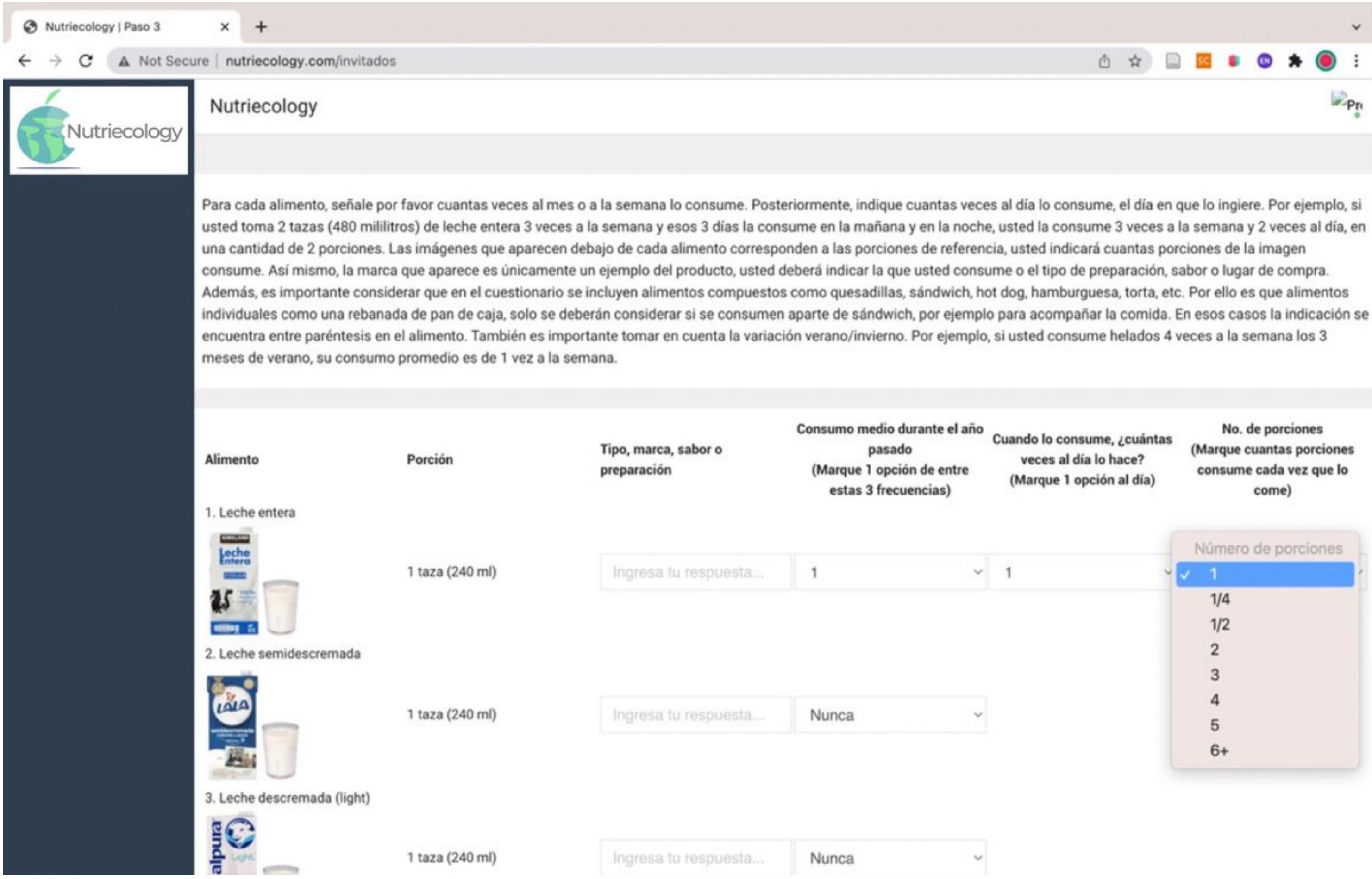

Figure 5

Food Consumption Frequency Questionnaire (FFQ) of user’s section in Nutriecology®. The complete interface of Nutriecology® is presented in Supplementary Materials 6.

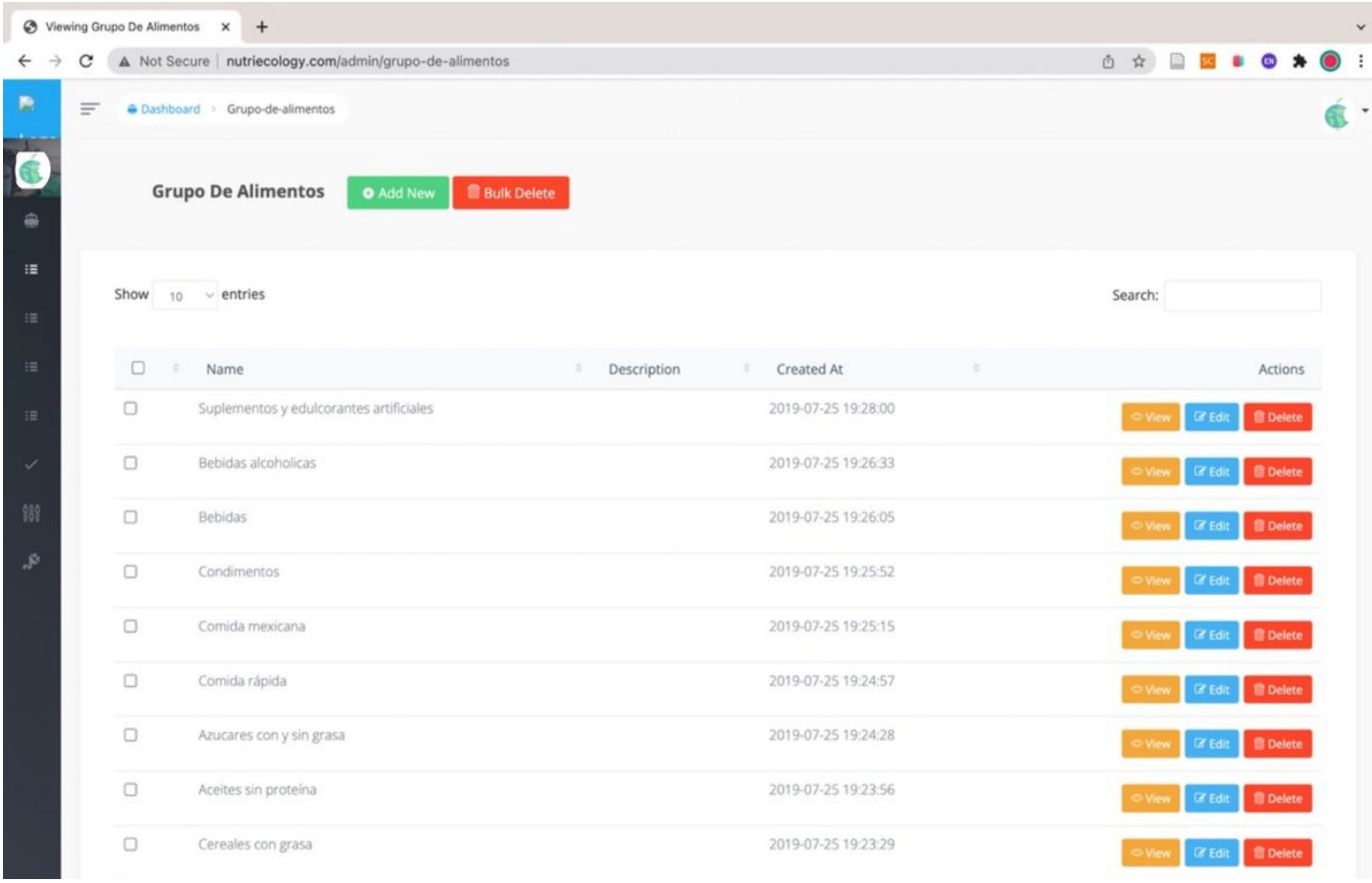

Figure 6

Administrator section in Nutriecology®. The complete interface of Nutriecology® is presented in Supplementary Materials 6.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- SupplementaryMaterialNutriecologyEdit.pdf
- GraphicalAbstract.jpg