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Article information

Article title

Development and validation of a web application to collect food supply data associated with their nutritional composition and environmental impacts

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Keywords

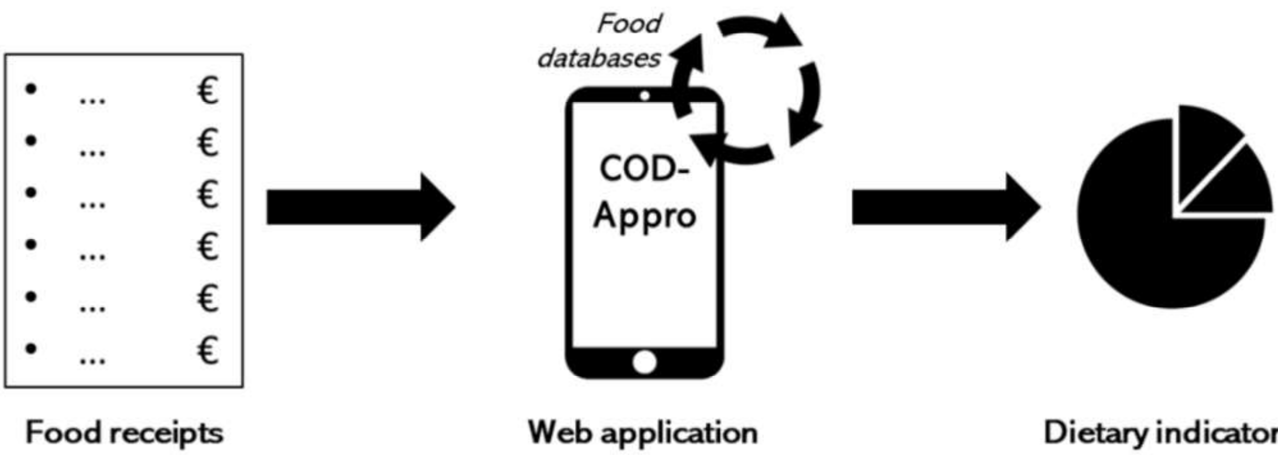
Food purchases; dietary indicators; sustainability; food database

Abstract

Measuring what people eat is a major methodological challenge. We developed and validated a new web-based method to record actual food supply data that would be less time consuming than the original method (i.e., food supply diary). Through the COD-Appro web application, participants can enter their food supplies by selecting a food item from a list based on items included in French food databases; thus automatically associated with nutrient composition and environmental impacts data. We recruited 102 participants who used COD-Appro during one month, among which 30 also used a classical paper-based food supply diary to be able to compare the two methods. A feedback questionnaire was completed by all the participants. The two methods showed no difference between the price and the quantity of food purchases when compared by food groups (n=10) which confirms that the new method was robust compared to the original method. In addition, participants reported good usability of the COD-Appro web application and its use saved a considerable amount of time to the experimenters by integrating data entry and pairing with food databases (nutrient composition and environmental impacts) into the data collection step performed by the participants themselves.

- Web-based food supply data collection
- Association with nutrient composition and environmental impacts
- External validity compared to original method (i.e., food supply diary)

Graphical abstract



Specifications table

Subject area	Food Science
More specific subject area	Households' food supply
Name of your method	Food supply web application (COD-Appro)
Name and reference of original method	Food supply diary Marty, L., Dubois, C., Gaubard, M. S., Maidon, A., Lesturgeon, A., Gaigi, H., & Darmon, N. (2015). Higher nutritional quality at no additional cost among low-income households : insights from food purchases of "positive deviants." *American Journal of Clinical Nutrition*, *102*, 190–198. https://doi.org/10.3945/ajcn.114.104380
Resource availability	https://github.com/ChemoSens/ChemoSensTools/tree/master/ChemosensTools/codappro2

Background

In the fields of nutrition and food sciences, measuring what people eat is a major methodological challenge. Recording actual dietary intakes through direct observation is extremely time consuming and commonly used measures are based on individual reports of consumed foods (e.g., food records, food frequency questionnaire, 24-hour recalls) subject to desirability and recall bias. The diet composition of an individual or an household, in terms of both quality and quantity, can also be assessed by recording food purchases, a method less sensitive to desirability bias and recall bias (information is written on food receipts) [1–4]. Food supply data also provide additional information compared to food consumption data such as price or labels.

The most up-to-date method to collect food supply data has been described in a paper investigating food cost and nutritional quality in low income households [1]. In order to assess the food supply of their households, participants were asked to complete a food supply diary, in which they had to list all foods and drinks purchased, harvested, or received for at-home consumption, over a one-month period. For each food purchase made, participants were asked to collect grocery cash register receipts. When receipts were not available, participants were asked to provide details of foods purchased, received or harvested by writing their name, quantity and price in the food supply diary. Then, the experimenters entered manually each food purchase made into a database to be able to perform data analyses.

This method presents limitations. First, the quantity of work for both the participants and the experimenters is substantial. The participants have to keep all their food receipts during one month (i.e., remember to ask for it, keep it in the food supply diary, give it back to the experimenter) and to write manually all the information when no receipt is available (*data collection step*). The experimenters have to copy from paper to computer all the food supply data which represents a considerable amount of time (*data entry step*). These two demanding steps are thus prone to human errors (e.g., omissions, typos) which will require double checking by the experimenters (*data validation step*). Second, the raw food supply data do not provide useful information *per se* for nutrition and food scientists. An additional step is needed to associate the food supply database with relevant information (e.g., food groups, nutritional composition, environmental impacts). This step requires from the experimenters to manually classify food supply into an appropriate category and/or to match food supply with items in existing food databases (e.g., French food nutrient composition databases: CIQUAL 2020 and CALNUT 2020 [5], French food environmental impacts database: AGRIBALYSE v3.0 [6]) (*food item classification step*). On the one hand, the experimenters may not have sufficient information from the receipts to perform the best association. On the other hand, this repetitive task on large datasets is prone to human errors.

We aimed to develop and validate a new method to record food supply data which would be less time consuming, would provide a finer description of food items and would limit human errors. We developed a web application where the participants can enter food supply by selecting a food item from a list based on items included in French food databases and includes warnings when price or weight values are unlikely. Four steps are thus combined and performed by the participants themselves: data collection, food item classification, data entry, and data validation.

Method details

Web application development (COD-Appro)

Interface and content

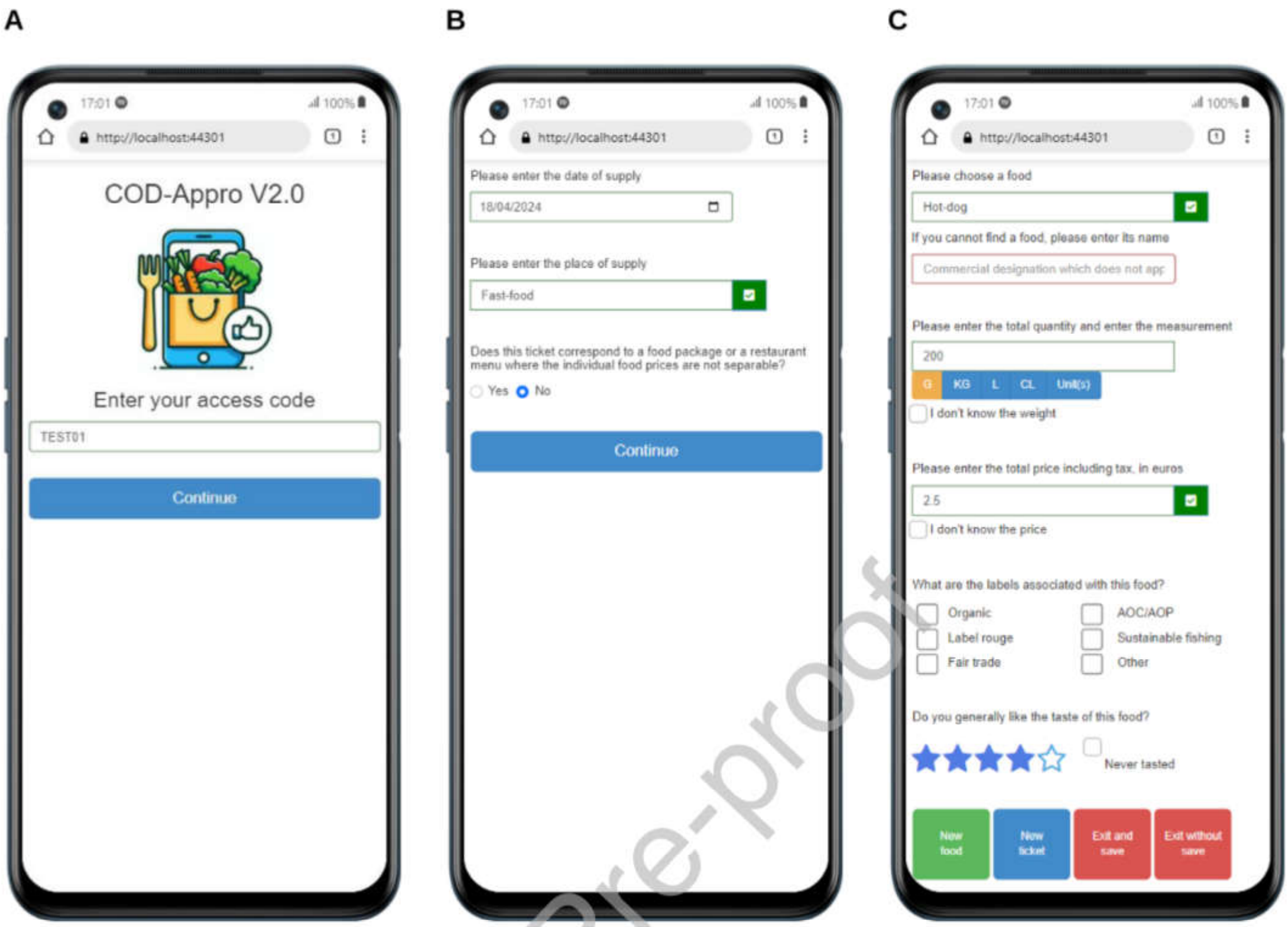


Figure 1. Screenshots of the user interface

From a participant perspective, the COD-Appro application is available through a web link. On the first screen (**Figure 1.A**), the participants are asked to enter a 6-letter personal code (ID). On the second screen (**Figure 2.A**), the participants select a date and a place for a food supply episode (e.g., supermarket, farmer market, restaurant, take-away, gifts, food aid) among a list pre-defined by the experimenter. The participants are additionally asked if the food and drinks are part of a menu or bundle (e.g., restaurant menu, food baskets) and if yes to enter the total price (they will not be asked about the price of each individual item on the next screen)[1]. On the third screen (**Figure 3.A**), the participants enter food supply data by selecting a food item within the pre-defined list then entering its weight and price. The entry is facilitated by a dynamic restriction of the food items based on a set of letters entered by the participant (e.g., "yog" for "Yoghurt with fruits"). Additional questions can be included depending on the purpose of the data collection (e.g., presence of food labels, liking rating). The participants repeat the third screen for each item bought on the same day at the same place then go back to second screen to enter a new food purchase episode. All the lists can be customised by the experimenters to adapt to different contexts.

For the food items, we used a pre-defined list of 2,119 food items declared as consumed by a representative sample of 3,157 adults participating in the 2013–2014 national dietary survey INCA3 (*Etude Individuelle Nationale des Consommations Alimentaires 3*, in French) [7] and for which the composition in 62 nutrients is available without missing values (CALNUT 2020 [5]). After a careful check of this initial list, we removed some duplicates and some ambiguous items to avoid any confusion from the participants (n=50). Since food consumption behaviours have evolved during the last decade, notably towards more ready-to-eat meals and plant-based alternatives, we added food items retrieved from a bigger nutritional

[1] This option is only possible for food supply episodes where a menu or bundle is possible (e.g., restaurants, food aid, etc. but not supermarkets).

composition database CIQUAL 2020 (n=73) [8] to better represent this category (e.g., vegetarian burger, tacos). Finally, some food items were duplicated to reflect the different forms under which they can be bought (e.g., dry/cooked cereals, raw/cooked meat or fish) (n=199). For each item in the final list (n=2,341), we associated a yield factor and a consumption factor [9] to take into account changes in weight from purchase to consumption associated with preparation and waste (e.g., from dry to cooked pasta, from unpeeled to peeled banana); this allows to calculate an edible weight for each food item that matches nutritional composition data (usually given in g/100g of edible portion). As the French food nutrient composition databases CIQUAL 2020 and CALNUT 2020 [5] are connected to the French food environmental impacts database AGRIBALYSE v3.0, we are able to match data on the environmental impacts of each food item in the list (e.g., greenhouse gas emissions, land use, water use calculated through life cycle analysis). The final list is available in French on the OSF page of the project (https://osf.io/zvbjk/). For each food item entered by a participant, we thus automatically retrieve both its nutritional composition (62 nutrients) and environmental impacts (16 indicators). If the participants cannot find an item in the list, they are instructed to enter the closest they can find. If they cannot find a similar item, they also have the option to enter the name of the product manually which will be handled by an experimenter at data management step. The weight of each item can be entered in grams, kilograms, litres, centilitres or units. The unit option is only available for fruit and vegetables for which we were able to retrieve mean weight per unit [9]. When the participants enter the price, a warning is displayed if the ratio price/weight is unlikely (<5th or >95th percentile for each food category, based on preliminary data) and they are asked to double check the weight and price of the food item in order to limit human errors. The participants also have the option to tick a box “I don’t know the weight/price of this product”. In a later implementation of the method [10], an additional validation on the weekly amount of purchases was added: participants whose weekly supplies are below one fourth or above four times their own initial estimate also receive a warning requesting them to explain this unlikely behaviour.

We developed a user guide where 1/ we defined what “food supply” means and which food items should be entered in the app (i.e., food items that are purchased, gifted, harvested) or not (i.e., invitations for meals); 2/ we explained step-by-step how to connect to the app at how to enter the data; 3/ we gave contact details for assistance (email, phone number). The user guide is available in French on the OSF page of the project (https://osf.io/zvbjk/).

Technical development

The software was developed as a Progressive Web Application (PWA). A PWA is a cross-platform app designed for the web with a mobile app-like experience. It can be installed as a native application on mobile or tablet without submission to an App Store. Once installed, the PWA gets an app icon on the device. A PWA is also a web application, similar to a website. Search engines can therefore index it, and users can access it from an URL with any browser. The code was implemented using Microsoft Visual Studio Community 2022. TypeScript, HTML5 and CSS languages (with bootstrap framework for responsive design) were used for the front-end. Windows Communication Foundation (WCF) and C# https SOAP-based services were used for the back-end, and hosted on an IIS web server. Each study is hosted in a different directory and parameterized with a configuration file. The configuration file (excel file) enables the experimenter to select options for inputs, enter the codes for participants, the list of foods, supply places and labels to be displayed, and to internationalize the app for different languages. Data are saved as encrypted json files (one file per participant), no identifying data is stored. Each study has a unique URL. The experimenter can download data from another URL (authentication with ID/password required). The application can be tested (in French) here: https://www.chemosenstools.com/codappro2/index.html?sn=test (with the ID='TEST01').

Data management procedure

Dataset description

The final dataset (excel file) includes one row for each food item and 10 columns: 6-letter personal code, date of food supply, place of food supply, name of the food item selected from the pre-defined list, name of the food item typed by the participant (if not in the pre-defined list), quantity, quantity unit (grams, kilograms, litres, centilitres or unit), price, menu (yes, no), menu price. When the name of the food item from the list is present then the name of the food item typed by the participant is missing and vice versa. When the box “I don’t know the weight/price of this product” is ticked then quantity and quantity unit or price are missing data. When menu is ‘yes’ then price is missing and menu price is present. If additional questions are added to the web application, then additional columns are added to the dataset (e.g., presence of food labels, liking rating).

Classification of manually entered food items

All manually entered food items have to be paired with one of the items in the pre-defined list (n=2,341) by an experimenter to retrieve their nutrient composition and environmental impacts. When the experimenter did not find an exact match, we defined the following rules in order of priority: 1/ paired with a similar food (e.g., carrots instead of baby carrots, vegetable patty instead of spinach patty), 2/ paired with a food from the same food group (e.g., carrots instead of parsnip, beef burger instead of beef and bacon burger), 3/ paired with the average food item (e.g., ice cream instead of caramel Sunday, fruit juice instead of guava juice).

Missing data

To limit the number of missing data for quantity and price we developed imputation methods separately for out-of-home and at home consumption food supply (because price and weight vary greatly for a same food item in these two different contexts). For at home consumption food supply (i.e., supermarket, farmer market and other food shops excluding gifts and food aid), we calculated the average price per unit of weight for each food item based on observations with no missing data and then calculated the quantity or the price for observations as weight_calculated = price / average_price and price_calculated = weight * average_price. For out-of-home consumption food supply (i.e., restaurants, fast-food, take-away, collective catering), the weight is particularly difficult to obtain from the participants. For collective catering, we used portion sizes recommended by the relevant French authority (GEMRCN) [11]. For commercial catering, we used the larger portion sizes from the SU.VI.MAX portion book (i.e., portion C) [12]. Missing prices could not be imputed for out-of-home consumption food supply because observations were mostly menus.

Method validation

Aims and design

We designed a study with two aims: 1/ to collect food supply data from university students (which is an underexplored population in terms of eating behaviours), 2/ to validate the COD-Appro food supply web application through the comparison with food supply diary (original method). This study was cross-sectional and collected quantitative and qualitative real-life data.

Recruitment and participants

Participants were recruited by emailing individuals from a previous study who agreed to be contacted again by the research team [13], by social media, posters and flyers and finally by emailing individuals from a population registered in the Chemosens Platform’s PanelSens database at Centre des Sciences du Goût et de l’Alimentation (Dijon). This database was declared to the relevant authority (Commission Nationale Informatique et Libertés; CNIL; n◦1,148,039). Eligible participants were university students on Dijon campus aged over 18 and fluent in French with quotas on age, sex and scholarship status to be representative of the French university students. Participants were asked either to use the COD-Appro food supply web application during one month or to use COD-Appro and to complete a food supply diary during one-month. We aimed to recruit 120 participants in total (35 for the comparison with the food supply diary) to reach a minimal sample size of 100 university students (resp. 30) who completed data collection. Participants received a 50€ (resp. 80€) compensation. We organised 30-min inclusion sessions (in-person or online) to present the aims of the study (i.e., examine food supply of university students and validate a new data collection tool), to explain how to use the COD-Appro web application and the food supply diary, to hand the user guide out, and to collect informed consent from the participants. This study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the ethical evaluation committee for research of Inserm (IRB00003888, reference: 22–884, delivered on March 8th, 2022). Data were collected between the 7th of November and the 18th of December 2022.

In total, 464 individuals were emailed and 123 expressed their interest and booked a slot for an inclusion session. In the end, 110 gave their informed consent and 102 completed the one-month data collection (30 with the food supply diary). Among the 102 participants, 56% were female and 44% were male, 49% aged between 18 and 21, 39% between 22 and 25 and 12% over 25, 34% had a scholarship (i.e., lower parental income) and 62% were omnivorous, 30% flexitarian and 8% vegetarian.

Data collection and data management procedure

COD Appro web application

Across one month and 102 participants, we collected data for 8,346 food items through the web application. For at home consumption food supply, we collected data for 4,745 food items with 1,231 missing data on quantity (26%) and 68 missing data on price (1.4%). Following our imputation method, we were able to calculate 645 values for quantity and 52 for price leaving 12.3% of missing values on quantity (mostly from gifts and food aid) and 0.3% missing data on price in the final dataset (when weight was also missing). For out-of-home consumption food supply, we collected data for 3,601 food items with 2,714 missing data on quantity (75%) and 41 missing data on price (1.1%). Following our imputation method, we were able to calculate 2,668 values for quantity leaving 1.3% of missing values on quantity in the final dataset.

Food supply diary

On top of using the COD-Appro web application during one-month, the 30 participants who completed the food supply diary were asked to collect their grocery cash register receipts and when grocery cash register receipts were not available to provide details of foods purchased, received or harvested manually (date, place, name, quantity and price). Then, an experimenter entered manually each food item into a database that followed the exact same structure as the dataset from the web application to allow the comparison between the two. The experimenter associated each food item with one of the items in the pre-defined list from the web application (n=2,341). When the experimenter did not find an exact match, we defined the following rules in order of priority: 1/ paired with a similar food (e.g., carrots instead of baby carrots, vegetable patty instead of spinach patty), 2/ paired with a food from the same food group (e.g., potatoes instead of sweet potatoes, beef burger instead of beef and bacon burger), 3/ paired with average food item (e.g., ice cream instead of caramel Sunday, fruit juice instead of guava juice).

Across one month and 30 participants, we collected data for 2,596 food items through the food supply diary. For at home consumption food supply, we collected data for 1,538 food items with 354 missing data on quantity (23%) and no missing data on price. Following our imputation method, we were able to calculate 252 values for quantity leaving 6.6% of missing values in the final dataset. For out-of-home consumption food supply, we collected data for 1,058 food items with 933 missing data on quantity (88%) and no missing data on price. Following our imputation method, we were able to calculate 890 values leaving 4.1% of missing values in the final dataset.

User experience questionnaire

After one-month using the COD-Appro web application, the 102 participants answered a short user questionnaire including: the System Usability Scale (SUS) [14] and open-ended questions regarding technical improvements that may be needed and their general feeling after their participation in the study.

The SUS is a 10-item questionnaire scored on a 5-point scale from strongly disagree to strongly agree (range [0-4], including reverse scoring items (R)) and aims to measure the usability of a system. Responses are summed and expressed as a percentage of the maximum score; the SUS score then range from 0 to 100, a higher score indicating a greater usability. A cut-off at 70 is generally used to define *acceptable* usability of a system [15]. For the purpose of the present study we excluded one item that was not relevant (i.e., I think I would like to use this system frequently) and included the 9 other items: 1/ I found COD-Appro unnecessarily complex (R), 2/ I thought COD-Appro was easy to use, 3/ I think I would need the support of a technical person to be able to use COD-Appro (R), 4/ I found the various functions in COD-Appro were well integrated, 5/ I thought there was too much inconsistency in COD-Appro (R), 6/ I would imagine that most people would learn to use COD-Appro very quickly, 7/ I found COD-Appro very cumbersome to use (R), 8/ I felt very confident using COD-Appro, 9/ I needed to learn a lot of things before I could get going with COD-Appro.

Validation

Comparison of the food supply diary and the COD-Appro web application

For the comparison, we only considered the participants who completed both the COD-Appro web application and the food supply diary for one-month (n=30). Across the 30 participants, 2,596 food items were collected through the food supply diary and 2,431 through the web application. We found that 62% of the food items that were present in the food diary were present under the same name in the web application, 90% under the same food group (n=10, i.e., fruit and vegetables, starchy foods, meat, fish and eggs, mixed dishes, dairy products, sweet products, high fat savoury products, water and drinks, added fat, herbs and spices). Discrepancies between the two methods may have several explanations. Participants may have forgotten to enter some of their food purchases in the web application and may have misclassified some food items. Perhaps more likely, the experimenters may have lacked information in the food supply diaries to find the correct food item in the list resulting in higher discrepancies at the food item level than at the food group level (e.g., 60% fat butter vs 82% fat butter, 5° beer vs 8° beer). Thus, the web application data may actually be more trustworthy at the food item level than the food supply diary data entered and classified by experimenters who did not purchase the food themselves.

For the 30 participants, we calculated the total weight and price of the 10 food groups derived from the food supply diary on the one hand, and from the COD-Appro web application on the other hand. Bayesian analyses were performed (JASP Version 0.9.2) to test whether the weight and price for each food group were similar across the two methods (**Table 1**). As opposed to frequentist analyses that can only test whether a null hypothesis can be rejected or not, Bayes factors can determine whether a null hypothesis is actually supported by the data [16]:

$$BF_{01} = \frac{likelihood\ of\ data\ given\ H_0}{likelihood\ of\ data\ given\ H_1}$$

If $BF_{01} > 1$ then the null hypothesis is accepted, i.e., no difference exists between the weight and price for each food group across the two methods. As BF_{01} increases, there is more evidence in support of the null hypothesis.

Across all food groups, Bayesian analyses were in support of no difference in total weight and price either using the food supply dairy or the COD-Appro web application which validates the new method compared to the original method at the food group level (external validation).

Table 1. Comparison of total weight and price of 10 food groups from food supply dairy and COD-Appro web application

	Weight (kg)[1]			Price (€)[2]		
	Dairy	Web	BF_{01}	Dairy	Web	BF_{01}
fruit and vegetables	8.38 (1.14)	8.26 (1.04)	2.44	19.72 (3.12)	18.16 (2.57)	1.91
starchy foods	4.16 (0.58)	3.87 (0.5)	2.54	8.96 (1.01)	8.62 (1.03)	4.56

meat, fish and eggs	2.87 (0.46)	2.70 (0.46)	2.60	25.32 (5.24)	23.69 (5.20)	1.55
mixed dishes	3.15 (0.46)	3.16 (0.42)	5.06	21.73 (2.69)	18.76 (2.82)	1.54
dairy products	4.61 (0.78)	4.24 (0.66)	2.00	18.09 (3.27)	19.45 (4.11)	4.21
sweet products	2.61 (0.59)	2.10 (0.35)	1.85	16.03 (2.52)	14.46 (2.33)	3.04
high fat savoury products	0.83 (0.22)	0.90 (0.20)	3.46	4.80 (0.81)	4.89 (0.81)	3.24
water and drinks	5.33 (1.25)	5.03 (1.34)	4.32	19.40 (4.94)	16.72 (4.73)	1.18
added fat	0.50 (0.11)	0.48 (0.08)	3.66	4.17 (0.73)	4.08 (0.61)	3.67
herbs and spices	0.68 (0.15)	0.70 (0.14)	3.18	6.02 (1.32)	5.30 (1.24)	2.99

Values are means (SD). [1]All items were used. [2]Menus were excluded.

Feedbacks from the participants

Across the 102 participants who used the COD-Appro web application during one month, the SUS score was 78 (SD 14) indicating good usability of the system. In terms of technical improvements, 14 participants mentioned that the application could be more user-friendly when used on smartphone and 24 participants indicated that the list of food items could be easier to navigate if presented by food category, by order of popularity, or including brands – which may be considered for the next versions. Regarding their general feeling after their participation in the study, 44 participants mentioned an “interesting” or “good” experience and only 5 mentioned it was “time-consuming”. In addition, 12 participants highlighted the support from the research team as a key element for motivation.

Limitations

The COD-Appro web application still has several limitations. We used a list of 2,341 food products associated with average nutritional quality and environmental impact in public French databases which does not capture the diversity of all food products available on the market nor the between-brand variability that may exist for a given product in terms of nutritional quality and environmental impact. More precise lists of food products may be uploaded into the COD-Appro application (e.g., Open Food Facts [17]) although it may increase data collection time for the participants. Another limitation is indeed the time required from the participants to enter their food supply into the application. The use of COD-Appro reduced considerably the amount of time for the experimenters, but was still intensive for the participants. Although user experience was positive for university students, it may be perceived as more difficult for larger households. A solution to increase precision while reducing participants’ burden would be to include a barcode scanning tool into the application. Finally, the COD-Appro application reduces but does not eliminate any recall or desirability bias as one may forget to enter one food item or deliberately decide not to.

Ethics statements

Informed consent was obtained from the participants before they start data collection. This study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the ethical evaluation committee for research of Inserm (IRB00003888, reference: 22–884, delivered on March 8th, 2022).

CRediT author statement

Lucile Marty: Conceptualization, Funding acquisition, Methodology, Formal analysis, Data Curation, Writing - Original Draft; **Fanny Teil**: Methodology, Investigation, Formal analysis, Data Curation, Writing - Review & Editing; **Christine Lange**: Conceptualization, Methodology, Writing - Review & Editing; **Valentin Bellassen**: Conceptualization, Funding acquisition, Methodology, Writing - Review & Editing; **Michel Visalli**: Conceptualization, Methodology, Software, Data Curation, Writing - Review & Editing

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Declaration of interests

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐ The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

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