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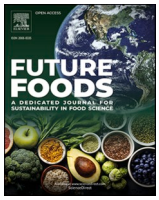

Animal- vs. plant-based origin and degree of processing as determinants of food categorization for omnivores and flexitarians

Jessy Youssef [a,*], Michel Visalli [b], Stéphanie Chambaron [a], Gaëlle Arvisenet [a]

[a] Université Bourgogne Europe, Institut Agro, CNRS, INRAE, UMR CSGA, 21000, Dijon, France
[b] INRAE, PROBE Research Infrastructure, ChemoSens Facility, F-21000, Dijon, France

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ABSTRACT

This study examines how French omnivores and flexitarians spontaneously categorize images of food products available in France. Participants (n = 100) completed a free sorting task to group 25 food product images using their own words to label the resulting categories. Multidimensional scaling and hierarchical cluster analyses were used to identify categorization patterns.

Food origin (animal- vs. plant-based) was the common dimension guiding categorization for participants of the two groups. By contrast, animal-based foods formed a single category for omnivores, whereas flexitarians separated them into two categories. Plant-based foods were separated into two categories by omnivores and flexitarians. Plant-based foods were differentiated by degree of processing and protein content; these dimensions were not applied to differentiate animal-based foods. These findings suggest that consumers use the food origin dimension to establish the primary division between categories, whatever their dietary profile. Omnivores provided a less detailed categorization for animal-based products than flexitarians, but used the same categorization as flexitarians for plant-based products. Categorization strategies appear to draw upon both taxonomic and goal-oriented approaches, sometimes taking visual appearance into account, and perhaps even frequency of consumption. Concepts such as recency negativity and food essentialism are combined to provide a potentially valid theoretical framework to interpret the results obtained.

Understanding these representations could help in developing and communicating more effective public health guidelines and messages.

1. Introduction

To feed a projected global population of around 9.2 billion by 2050, the Food and Agriculture Organization (FAO) calls for region-specific strategies to increase food production while reducing environmental impacts and resource use (Food and Agriculture Organization of the United Nations, 2014). Livestock production is a major source of agricultural greenhouse gas emissions and requires more land and water than plant-based food production (Crippa et al., 2021; Willett et al., 2019). While emphasizing that animal-based products are an "essential source of nutrients" for the global population (Food and Agriculture Organization of the United Nations, 2023), international organizations recommend reducing animal-product production and consumption in developed countries, where protein intake, especially from animal sources, often exceeds nutritional needs and dietary recommendations (Cocking et al., 2020; World Cancer Research Fund, 2018). In response, reducing meat consumption and encouraging a dietary transition toward more plant-based diets has become a pressing call to action for stakeholders in the food industry and consumers alike, in developed countries and particularly in Europe (EAT-Lancet Commission 2019; European Commission, 2020). This encouragement toward dietary change has led to the development and commercialization of plant-based food products with novel functional properties and/or novel uses, and the resulting products often do not fit into traditional food categories (McClements, 2024). Within this evolving food landscape, it is important to understand how consumers incorporate new products into their categorizations of food, and how their representations adapt to this ever-changing food market.

Categorization is a cognitive process that allows consumers to group objects that share salient characteristics or similar functions in order to simplify their understanding of the world (Hoek et al., 2011; Proffitt et al., 2000). Studying food products' categorization provides

* Corresponding author.
E-mail address: jessy.youssef@inrae.fr (J. Youssef).

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information about how consumers mentally structure their knowledge of food. (Rosch and Mervis, 1975). Research has shown that individuals use multiple frameworks to categorize foods, notably taxonomic and goal-oriented categories. Taxonomic categories are based on compositional similarities and intrinsic food properties, such as nutritional composition and origin. In contrast, goal-oriented categories are defined by the roles foods play in fulfilling specific goals and ideals, such as breakfast foods or snacks, regardless of physical similarity (Davis and Love, 2008; Felcher et al., 2001; Ross and Murphy, 1999). These categorization approaches often coexist, even if taxonomic categorization frequently predominates (Ratneshwar et al., 2001; Ross and Murphy, 1999).

Building upon these categorization frameworks, a broad range of criteria may be used by individuals to categorize foods (Foroni and Rumiati, 2017; Sato et al., 2019). Blake et al. (2007) proposed a two-level organization of categorization criteria encompassing all the individual categorization strategies they observed. Twelve category types were grouped into three main criteria based on (i) food properties (e.g. nutrient composition, food group), (ii) personal experience (e.g. preference, routine), and (iii) context (e.g. convenience, location). Rioux et al. (2016) showed that color typicality significantly influenced children's categorizations of vegetables, supporting the importance of physical characteristics in food in categorization processes. Beyond physical characteristics, adult consumers also use additional dimensions, including novelty, origin (animal- vs. plant-based), ingredient composition, and degree of processing to categorize plant-based products (Van Der Meer et al., 2025).

Several recent studies have identified degree of processing or products origin (animal vs. plant-based) as the main criteria used for food categorization. However, findings across studies are not consistent, and may depend on the studied products as well as participants' cultural backgrounds. Degree of processing was the primary factor taken into account by US participants in a categorization experiment using a food triplet task applied to a diversified set of food images (Carrington et al., 2024). In France and Norway, a cross-cultural study using a projective mapping yielded differing results: Norwegian participants relied primarily on product origin (animal or plant-based) to classify images of food products, while French participants took into account both the origin and the degree of processing to distinguish between the proposed images of food products (Varela et al., 2022). Interestingly, in the French participants' categorization, raw and processed plant-based products were clearly differentiated, but this separation was not observed for animal-based products. Processed plant-based foods were positioned closer to animal-based products, in contrast with raw plant-based products, suggesting that this categorization could be at least in part based on a goal-oriented strategy (similarity of use and function). The interpretation proposed for these different categorization profiles was that Norwegian participants based their categories mostly on how to use the food product and how to prepare it (grouping together animal-based products and their plant-based substitutes), while French participants seemed to categorize products according to their taste, healthiness, and novelty. It is possible that the two studied populations had different food consumption habits, but it was not verified whether Norwegians consume more plant-based substitutes than French participants, and all participants from both countries were omnivores. To determine whether specific categorization strategies might result from participants' eating habits, it would be necessary to compare how participants from a similar culture but with different dietary profiles categorize foods.

Building on these insights, the present study aimed to (1) examine how French participants take into account degree of processing and origin (animal- vs. plant-based) when categorizing food products, and (2) determine whether these categorizations vary between consumers that have started or not to engage in a dietary transition towards more sustainable diets (flexitarians and omnivores).

2. Materials and methods

This study received approval from the ethical committee of INSERM (IRB00003888). All participants provided electronic informed consent in accordance with the Declaration of Helsinki.

To explore participants' intuitive representations of the degree of processing of plant- and animal-based products, no pre-set categories were defined, but a free sorting task was proposed. This is a rapid, straightforward method to elicit natural categorizations of food products (Blanchard and Banerji, 2016; Chollet et al., 2022), which is easy for participants to use. The categories formed in such a task provide insights into consumers' mental processes as well as product perceptions and associations (Blake et al., 2007; Hoek et al., 2011; Van Der Meer et al., 2023). These categorizations are presumed to reflect the points of convergence or divergence in representations between subjects or groups of subjects (Chollet et al., 2022). A free sorting task generally yields stable category structures with 20–30 participants (Fastrez et al., 2009; Tullis et al., 2004).

2.1. Participants

We mandated Panelabs (a French agency specializing in panel recruitment) to recruit 100 participants. These participants, aged between 25 and 64, were divided into two equal groups of 50 people each, based on their usual dietary profile: Omnivore and Flexitarian.

For this study, the Omnivore group is composed of participants who regularly consume meat; the participants in the Flexitarian group eat meat only once or twice a week (Pointke et al., 2022).

2.2. Selection of food product images

To investigate which criteria participants would use to categorize foods, 25 food product images were individually selected to represent the broad variety of plant- and animal-based food products available in France. They included examples of meat, poultry, fish, eggs, dairy products, cereals, pulses, and potatoes. Some products were raw (e.g. raw chicken breasts and uncooked lentils), whereas others were ultra-processed (e.g. chicken cordon bleu and duchesse potatoes). Ultra-processed products are industrially manufactured foods that undergo several processing stages and contain ingredients not commonly used in home cooking, such as artificial additives (Monteiro et al., 2019). The ultra-processed plant-based products represented both French and international cuisine, whether traditional (e.g. canned seasoned lentils) or more recently available on the market (e.g. seitan), including innovative "plant-based alternatives" (PBAs), designed to mimic animal-based products in terms of their organoleptic properties (e.g. plant-based alternative to scrambled eggs). The food product images included different types of packaging (e.g. cans, plastic bags, cardboard boxes). Balance between the different options for each criterion was not a pre-requisite (See S.1). Although complete elimination of brand recognition cannot be guaranteed when using real product packaging, brand names and other front-of-pack labels were digitally masked on the images to reduce their potential influence on participants' categorization of these products (see S.1). Each food product image was printed on a 8.5 × 10.5 cm card, and coded with a random 3-digit number. The French name for each product was printed on the reverse side of the card to overcome any difficulties of identification due to the font or color of the product name in the image. The terms (in English) used for the statistical analysis were never shown to the participants.

2.3. Organization of the study

Data were collected online between August and October 2024 using TimeSens v2.2 (Chemosens Platform, Dijon, France). The study consisted of two parts: (1) the free sorting task and (2) a questionnaire.

2.3.1. Free sorting task

Due to the impossibility of simultaneously presenting all 25 images on screen in a clear manner, and to reduce participant fatigue, the food product images were sent to participants along with a personal Timesens link. Instructions were provided through Timesens and a tutorial video was used to familiarize the participants with the task (Blanchard and Banerji, 2016).

Participants were advised to spread out all the cards on a large table before forming their categories. They were instructed to categorize the 25 food images into as many categories as they considered relevant, grouping together images that they felt belonged in the same category. They were free to create as many categories as they wished, but were instructed to create more than one group and fewer than 25 groups. Subsequently, they had to assign a name to each group that they had formed, using up to five words of their choice per group. Only after this step did the participants input the product codes into the software program to record the groups that they had formed, along with the name chosen for each group.

2.3.2. Questionnaire

The questionnaire was divided into two main parts: (1) the selection of the most and least consumed foods (from the 25 products), and (2) sociodemographic questions.

In the first part, participants were shown the 25 food product images used in the free sorting task. They had to select the five products that they consumed the most and the five products that they consumed the least. This question served as a validity check to verify whether participants who declared themselves flexitarian did indeed reduce their consumption of meat products. In the second part, participants answered sociodemographic questions (Table 1) covering age, gender, education level, occupation, and area of residence.

Table 1
Comparison of sociodemographic characteristics of the two participant groups. values in bold indicate observed values significantly different from theoretical values (chi-square tests of independence, $p < 0.05$). observed values above the theoretical values are indicated by (+), while those below the theoretical values are indicated by (-).

		Omnivores (n = 50)	Flexitarians (n = 50)
Characteristics	Categories	Number (%) of participants	Number (%) of participants
Gender	Male	**22 (44%)**$^{+}$	**22 (44%)**$^{+}$
	Female	**28 (56%)** $^{-}$	**28 (56%)** $^{-}$
Age	25–44	25 (50%)	30 (60%)
	45–64	25 (50%)	20 (40%)
Education	Baccalaureate and below	16 (32%)	22 (44%)
	Above baccalaureate	34 (68%)	28 (56%)
Occupation	Farmer*	1 (2%)	0 (0%)
	Executive and higher intellectual profession	12 (24%)	13 (26%)
	White-collar worker	17 (34%)	18 (36%)
	Student*	2 (4%)	1 (2%)
	Craftsperson, merchant, or entrepreneur	5 (10%)	3 (6%)
	Intermediate profession	6 (12%)	10 (20%)
	Blue-collar worker	2 (4%)	3 (6%)
	Retired	5 (10%)	2 (4%)
Area of residence	Urban	17 (34%)	23 (46%)
	Periurban	12 (24%)	11 (22%)
	Rural	21 (42%)	16 (32%)

* Excluded from Chi2 calculation because $n < 5$.

2.4. Statistical analysis

2.4.1. Analysis of the free-sorting task

For each assessor, a table was built where the products categorized in the same group shared the same group affiliation number. The categorization data were explored through multidimensional scaling (MDS) using the "FactoMineR" and "Factoextra" packages in Rstudio (version 4.4.0). The MDS determines the configuration of products in a multidimensional space and evaluates their proximities, thereby capturing the similarities and dissimilarities between them (Wish and Carroll, 1982).

To check the number of groups produced by participants of each dietary profile (Omnivores and Flexitarians), a hierarchical cluster analysis (HCA) was performed, on the coordinates of products on the first two dimensions of the MDS. The Euclidean distance metric and Ward.D linkage method were applied to group the products.

The optimal number of clusters was identified using the silhouette index, which quantified how similar the objects within the same cluster are to each other while being distinctly dissimilar from the objects in other clusters.

2.4.2. Analysis of participants' descriptions of each product category

The verbatims used by participants to describe the groups formed during the free sorting task were manually cleaned prior to analysis (i.e., spelling correction, lemmatization, synonym grouping by triangulation). The frequency of use of each term on the final list was recorded for each group of participants. Terms cited by under 5% of participants in each group were excluded from further analysis.

Participants' sorting descriptions were used to interpret the clusters. Two contingency tables were constructed for this analysis, one for each dietary group. To assess the association between the clusters formed and the descriptors provided by each group of participants, a chi-square cell-by-cell independence test (McHugh, 2013) was performed (alpha=5%) using XLSTAT (Addinsoft, version 2023.1.5).

The test determined whether the observed frequencies of terms used by the participants to describe clusters were significantly higher than, equal to, or lower than the theoretical frequencies, enabling the identification of terms that were specifically associated with each cluster of products.

3. Results

3.1. Characterization of the participants

The objective was to recruit an equal number of participants (n = 50), balanced in terms of age and gender, for each of the two dietary profiles (Omnivores and Flexitarians). The sociodemographic characteristics of the participants recruited are presented in Table 1.

3.2. Categorization of the 25 food product images by the two groups of participants

The following sections present the results of the MDS and the HCA for the two groups: Omnivores (Fig. 1) and Flexitarians (Fig. 2). The items in Cluster 1 and Cluster 2 are the same in the two figures; the items in Cluster 3 in Fig. 1 are allocated either to Cluster 3a or to Cluster 3b in Fig. 2. Table 2 presents the terms used by each group of participants to describe their clusters, together with citation frequency. The results of the chi-square test applied to each group of participants identified the terms used significantly more often by each of the two dietary profiles to describe each cluster.

3.2.1. Categorization by the omnivore group

Applying MDS and HCA to the categorization of the set of 25 food product images by Omnivores resulted in three clusters (Fig. 1). The first dimension contrasts plant-based products (Clusters 1 and 2) with

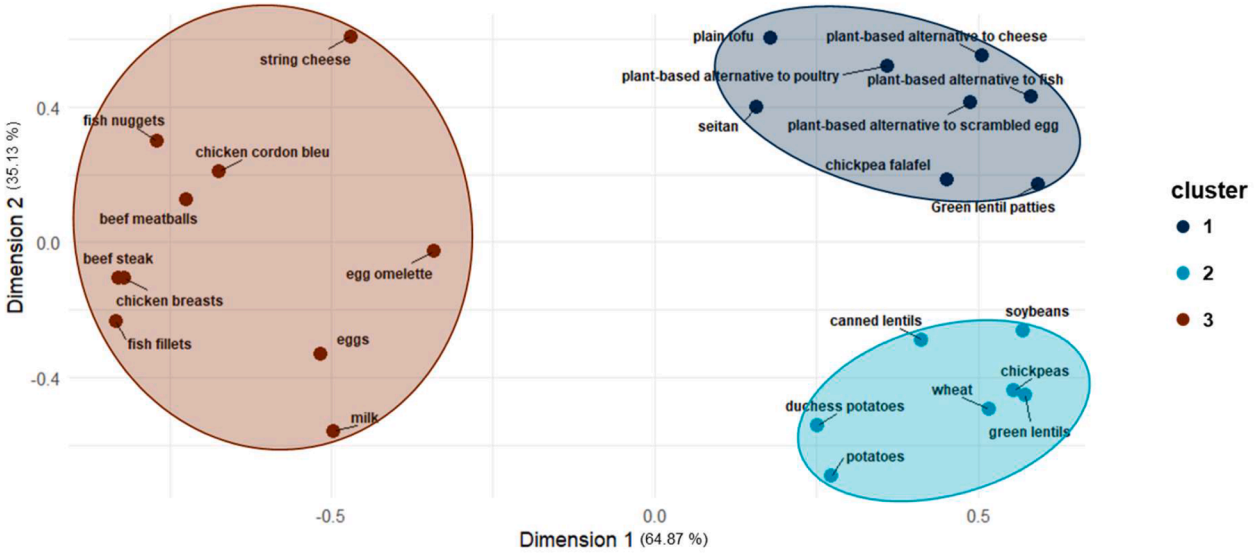

Fig. 1. Map representing the first two axes of the MDS, showing categorization by the Omnivore group (n = 50). Ellipses represent the clusters formed by the HCA.

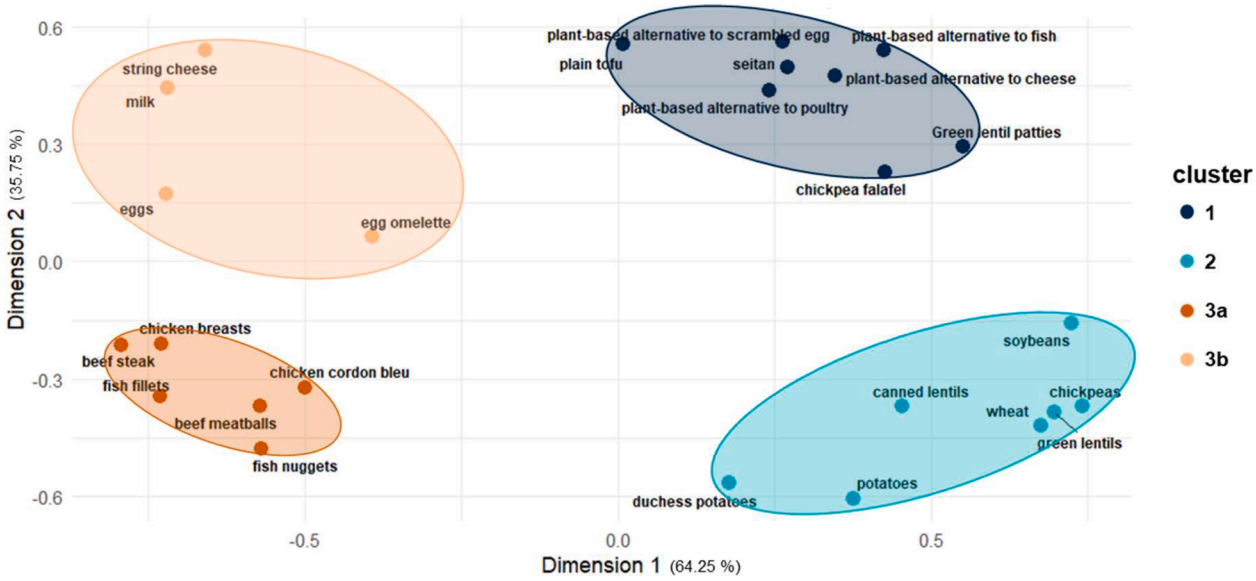

Fig. 2. Map representing the first two axes of the MDS, showing categorization by the Flexitarian group (n = 50). Ellipses represent the clusters formed by the HCA.

animal-based products (Cluster 3). The second dimension differentiates between the two plant-based clusters: Cluster 1, comprising all four plant-based alternatives, together with tofu, seitan, chickpea falafel, and green lentil patties; Cluster 2, comprising all four raw plant-based products, together with canned lentils and duchesse potatoes.

As shown in Table 2, the chi-square test demonstrated the significance of some specific terms used by Omnivores to describe each of the three clusters. In order of citation frequency, Cluster 1 was significantly characterized by: *plant-based, alternative, processed, vegetarian, vegan,* and *plant protein*; Cluster 2 was significantly characterized by: *legumes, starch, vegetables, potato, cereals,* and *side-dish*; Cluster 3 was significantly characterized by: *meat+poultry, fish, dairy, egg, protein, animal-based,* and *animal protein.*

3.2.2. *Categorization by the flexitarian group*

Applying MDS and HCA to the categorization of the set of 25 food product images by Flexitarians resulted in four clusters (Fig. 2). The first dimension contrasts plant-based products (Clusters 1 and 2) with animal-based products (Clusters 3a and 3b). The second dimension for the Flexitarian group differentiates the plant-based products in the same way as the Omnivore group (see Section 3.2.1). It also sub-divides the animal-based products into two: Cluster 3a, comprising all the meat, poultry, and fish products; Cluster 3b, comprising all the egg and dairy products. Thus, the second dimension opposes Cluster 1 and Cluster 3b to Cluster 2 and Cluster 3a.

As shown in Table 2, the chi-square test demonstrated the significance of some specific terms used by Flexitarians to describe each of the four clusters. In order of citation frequency, Cluster 1 was significantly characterized by: *plant-based, alternative, plant protein, vegetarian, processed*, and *healthy*; Cluster 2 was significantly characterized by: *legumes, starch, vegetables, potato, pulses, cereals,* and *dry*; Cluster 3a was significantly characterized by: *meat+poultry, fish, animal protein,* and *animal-based*; Cluster 3b was significantly characterized by: *dairy, egg, animal protein,* and *animal-based*.

Table 2
citation frequency of terms used by each group of participants to describe food product clusters. Terms significantly more cited, as determined by chi-square test, are shown in bold. Underlined terms in bold are significant for only one group of participants.

	Omnivores (n = 50)			*Flexitarians (n = 50)*			
Items	*Cluster 1*	*Cluster 2*	*Cluster 3*	*Cluster 1*	*Cluster2*	*Cluster 3a*	*Cluster 3b*
alternative	**59**	1	0	**74**	9	0	0
animal-based	0	5	**35**	1	0	**20**	**16**
animal protein	1	0	**31**	2	2	**48**	**19**
cereals	5	**21**	0	7	**29**	0	0
dairy	33	0	**99**	32	2	6	**102**
dry	0	0	0	0	**18**	0	0
egg	10	4	**74**	7	0	6	**48**
fish	9	0	**114**	13	2	**102**	9
grains	2	13	0	0	12	0	0
healthy	0	0	0	**15**	12	2	2
imitation	0	0	**0**	0	0	0	0
legumes	18	**99**	2	12	**84**	0	0
lentils	3	9	0	0	0	0	0
meat+poultry	8	7	**169**	15	3	**166**	15
natural	0	0	0	0	0	0	0
plant-based	**167**	48	8	**158**	33	7	5
plant protein	**22**	1	0	**29**	8	0	1
potato	1	**31**	0	1	**34**	0	0
prepared	15	16	16	36	20	27	10
processed	**44**	20	37	**22**	7	14	6
protein	7	0	**52**	0	0	0	0
pulses	6	8	0	0	**31**	0	0
raw	2	12	19	1	13	11	5
side-dish	3	**19**	0	0	0	0	0
starch	6	**65**	3	6	**48**	0	0
unprocessed	0	0	0	1	11	9	3
vegan	**35**	1	0	0	0	0	0
vegetables	2	**50**	3	15	**45**	0	1
vegetarian	**41**	6	1	**23**	1	0	1
wheat	0	0	0	1	7	0	0

3.2.3. Comparison of term use across dietary profiles

Examining term usage (Table 2) reveals that the following lexicon (alternative, animal-based, animal protein, cereals, dairy, egg, fish, legumes, meat+poultry, plant-based, plant protein, potato, processed, starch, vegetables, and vegetarian) was common to both dietary profiles.

Other terms used in the description of product clusters bring to light differences in the reasons motivating the formation of specific clusters by each dietary profile. The term "vegan" was significantly associated to Cluster 1 by Omnivores, but was not used by Flexitarians. The terms "protein" to describe Cluster 3 and "side-dish" to describe Cluster 2 were used only by Omnivores, and were absent from the Flexitarian profile. Flexitarians alone described Cluster 2 using the term "dry". They also used the term "healthy" more specifically for Cluster 1. Even though the term "pulses" was present across both dietary profiles, it was applied significantly more often to Cluster 2 by Flexitarians.

4. Discussion

Our objectives were to examine to what extent French consumers take degree of processing and food origin into account when categorizing food products and to explore whether such categorizations differ across dietary profiles (Omnivore and Flexitarian).

4.1. Food origin (animal- vs. plant-based) is a salient dimension for both dietary profiles

Our results showed that both groups of participants consistently separated animal- and plant-based products, thus highlighting the major role of food origin as a categorization criterion in this study. This criterion was much less important in a multi-national study by Rozin and Holtermann (2021), where the French participants ranked animal- vs. plant-based origin last among a set of five dichotomic criteria to categorize what they imagine people might eat and drink. However, the task in that study did not rely on food images, and the range of products, including unlimited food and beverages, was potentially much broader. Our study aligns more closely with a study by Chollet et al. (2022), investigating how French participants categorize protein-containing foods using food images. Their findings showed that food origin was the main criterion used to separate slightly processed and processed foods, but that this criterion was not salient in the case of highly processed products (ready-to-eat meals). These highly processed products could obviously not be separated by food origin as the animal-based ready-to-eat meal in that study also contained plant-based ingredients.

Despite the consistent differentiation between animal- and plant-based products across participants, our results also show that categorization strategies differed slightly in relation to dietary profile. Omnivores organized the 25 food product images into three clusters and Flexitarians into four.

4.2. Differences in categorization of food products among the two dietary profiles

4.2.1. Categorization of animal-based products for each dietary profile

Omnivores placed all the animal-based products together in a single cluster. In contrast, Flexitarians separated products produced by animals (eggs and dairy) from edible parts of animal carcasses (meat, poultry, and fish). By definition, flexitarians are meat reducers. In our study, verified by the inclusion questionnaire, this dietary profile consumes both dairy and eggs. Their categorizations may therefore separate products that they consume regularly from products that they consume rarely or never. This difference in frequency of consumption, in general, may explain the difference in categorization of animal-based products for Flexitarians compared to Omnivores.

Our results differ from those of Van Der Meer et al. (2023), who investigated how Dutch consumers categorize protein-based foods (particularly plant-based proteins), and what strategies they use to do so. In that study, omnivores and flexitarians distinguished between animal-derived meat products and animal-derived dairy products and

eggs. This systematic distinction by both dietary profiles may be related to the inclusion in the study of sweet dairy products (together with savory dairy and meat-based products). The set of 25 food product images in our study was designed to cover a broad variety of protein-rich foods available in France, including both plant- and animal-based products, with varying degrees of processing. We therefore focused on savory products that are typically consumed in France as part of a main meal, thus excluding other food categories such as sweet dairy products, nuts, fruits, and vegetables, and hybrid products, in contrast with the study by Van Der Meer et al. (2023). Including a broader range of products may affect the dimensions used by participants in their categorizations.

The term "animal protein" was significantly more cited to describe all animal-based clusters, whatever the dietary profile of the participants. This result probably reflects the long-lasting impact of previous guidelines that emphasized the superior quality of animal proteins, because of their higher content in essential amino acids, with greater bioavailability (The French Agency for Food, Environmental and Occupational Health and Safety, 2013).

4.2.2. Categorization of plant-based products for each dietary profile

Omnivores and Flexitarians both placed the same eight plant-based products together to form Cluster 1. They also placed the remaining seven plant-based products in Cluster 2. For both dietary profiles, the terms significantly associated with Cluster 1 were "plant-based," "alternative," "processed", "vegetarian", and "plant protein". Cluster 2 is described by Omnivores and Flexitarians using the terms "legumes", "starch", "vegetables", "potato", and "cereals". Degree of processing is therefore a salient dimension in the categorization of plant-based products for both dietary profiles. A recent study has shown that processing is a salient criterion used by French omnivores to categorize plant-based products (Varela et al., 2022). Our results now extend this observation to flexitarians.

The significantly positive combination of the terms "plant-based", "alternative", "processed", and "plant protein" to describe Cluster 1 aligns with the results from a semi-structured interview study in Norway, where some participants described ultra-processed plant-based products as good sources of protein (Haneberg et al., 2024). It should be noted that the participants in our study did not have access to the actual protein content of the food products in the images and were thus unaware that some processed plant-based products (e.g. plant-based alternative to fish and plant-based alternative to cheese) had a lower protein content than some raw plant-based products (e.g. raw chickpeas and raw lentils). Our participants may therefore have conceptualized plant-based alternatives to be rich in proteins. This interpretation is coherent with an online questionnaire which revealed that Dutch consumers tend to over-estimate the protein content of plant-based alternatives compared to meat products (Ketelings et al., 2023). The term "plant protein", used across both dietary profiles, is applied only to "processed" "plant-based" "alternative" products (Cluster 1), mirroring the term "animal protein" significantly employed to describe the animal-based clusters (Clusters 3, 3a, and 3b). The fact that these plant-based products are often presented as valid alternatives to meat, poultry, fish, eggs, or dairy may lead consumers to suppose that they possess nutritional qualities traditionally associated with animal-based foods (i.e. protein content). The absence of the term "plant protein" from Cluster 2 suggests that the participants in our study did not conceptualize raw plant-based products as a protein source.

4.3. Possible interpretations of differences in categorization between animal- and plant-based products

Our results reveal that the two groups of participants take degree of processing into account, but only for the categorization of plant-based products. The concept of recency negativity (Inbar et al., 2020) suggests that consumers tend to perceive food processing technology more negatively if the technology is recent, while another study (Etale and Siegrist, 2021) showed that traditional foods tend to be perceived as more natural and less processed. Many of the processed animal-based foods in our study (e.g. meatballs) have been present on the French market for over a century, whereas the processed plant-based products have only recently become available to French consumers. The salience of processing for plant-based but not animal-based products may therefore reflect consumer sensitivity to technological novelty, rather than to the degree of processing *per se*.

Omnivores and Flexitarians included canned lentils and duchesse potatoes in the same category as the raw plant-based products. For Omnivores, the term "side-dish" is among the descriptors frequently cited for this category, underlining the more traditional role of these plant-based products in French cuisine. The effect of recency negativity in relation to degree of processing has been shown to diminish over time (Inbar et al., 2020), as culinary familiarity increases. Canned lentils and duchesse potatoes have been present on the French market for several decades, which may have reduced their recency negativity, compared to the other processed plant-based products included in our study. The visual appearance of the products may also play a role in categorization. Duchesse potatoes still resemble potatoes to some extent. Lentils are still visibly the main ingredient in canned lentils, whereas the ingredients in green lentil patties are blended together to form a homogenous texture perceived by all participants as "processed".

Another possible explanation for our results is the concept of food essentialism, the belief that food products have inherent, robust essences that persist even after processing. In a recent study, Cheon et al. (2024) found that a perceived high degree of processing was not systematically associated with a reduction in perceived naturalness and nutritional quality, for animal-based products such as dairy and fish, suggesting that their essences were perceived as robust and retained even after processing. The perceived intrinsic properties of plant-based products were more likely to be affected by a high degree of processing, suggesting that mental representations of plant essences are more fragile. In our study, the plant-based products were categorized either as "processed" or by the type of product (e.g. legumes, starches, pulses, etc.), suggesting that the essences of the "processed" plant-based products were perceived as less robust. The animal-based products were never categorized by degree of processing but were always named by all the participants (i.e. dairy, eggs, fish, meat and poultry) suggesting that the essences of all animal-based products were perceived as robust. The underlying reason why these essences persist despite processing might be related to recency negativity: processed animal-based products have been available in France much longer than most processed plant-based products.

4.4. Categorization mechanisms: taxonomic vs. goal-oriented

The taxonomic approach to categorization is based on the inherent, intrinsic properties of items, whereas the goal-oriented approach is based on the use or context of use of the items (Felcher et al., 2001; Ross and Murphy, 1999). In our study, participants apparently used both approaches. The importance of the food origin dimension (animal- vs. plant-based) for both dietary profiles reflects a taxonomic approach to categorization, which is typically dominant in the absence of explicit guidance or contextual cues (Etter et al., 2024; Ross and Murphy, 1999). Participants in our study performed a free sorting task on a set of 25 food product images from which all contextual information had been removed. In our study, the goal-oriented approach is apparent in (a) representations of the use of a specific group of products, either common to both dietary profiles (i.e. the plant-based products in Cluster 1 described as alternatives), or specific to one dietary profile (i.e. Omnivores using the term "side-dish" to describe the plant-based products in Cluster 2); (b) the frequency of consumption of specific products (i.e. Flexitarians separating eggs and dairy from meat, poultry, and fish).

4.5. Strength and weaknesses

The task. In this study, attention was particularly focused on participants' spontaneous categorization of food product images, in the absence of predefined categorization criteria. This methodological approach allowed us to identify the influence of food origin (animal- vs. plant-based) and degree of processing on categorization. The limitations of this method are that verbalizing categorization criteria is cognitively demanding, so participants may rely on the salient properties of one category member and generalize it to the other members of the same category. Another consideration concerns the interpretation of the terms participants used to describe the categories they constructed, such as "protein" and "processed". While these terms were commonly used by participants, it cannot be assumed that the underlying meanings attributed to them were consistent across individuals. The free sorting task did not allow us to directly assess participants' beliefs or definitions regarding these concepts, as descriptions emerged only after the task was completed. Consequently, it remains unclear whether references to terms like "processed" refer to industrial processes, packaging, formulation, or other aspects of food processing. This ambiguity introduces potential variability in how groups were formed and understood, suggesting the need for future studies to directly assess participants' nutritional beliefs and definitions of key terms to better understand their categorization processes.

In addition to that, it remains an open question whether participants would organize actual food items in the same way as food images, and future research should explicitly address this distinction to confirm the generalizability of our findings.

The participants. Our results may be considered robust as the free sorting task in our study was completed by a total of 100 participants representing two balanced dietary profiles: omnivores (n = 50) and flexitarians (n = 50), with comparable age and gender distributions. This sample size exceeds the threshold commonly cited in the literature for free sorting tasks, where robust results have been demonstrated with as few as 20 to 30 participants. However, the results of this study should not be generalized to the entire French population, but rather interpreted within the context of this specific sample. It would also be interesting to replicate the same study with additional dietary profiles (e.g., vegetarians and vegans) in future studies. Further research is also needed to confirm population-level generalizability and, if possible, explore the applicability of the findings across different cultural contexts.

5. Conclusion

5.1. New insights into the relationship between dietary profiles and food categorization

This study confirmed that French participants mentally structure food along two orthogonal dimensions: origin and degree of processing. When participants adopted a taxonomic approach, the resulting categorization reflected grouping patterns common to both dietary profiles (Omnivores and Flexitarians). When participants adopted a goal-oriented approach, the resulting categorizations reflected differences between the dietary profiles. The results obtained with flexitarians suggest that goal-oriented categories may evolve slowly. The flexitarians' categorization of animal-based products does not perfectly align with that of omnivores, but their categorization of plant-based products remains aligned, probably reflecting the ongoing process of dietary transition. Even when goal-oriented categorizations differ between dietary profiles, the fundamental role of intrinsic food properties in taxonomic categorization appears to persist for all participants.

Furthermore, even though participants described the processed plant-based products as "alternatives" to animal-based products, this functional similarity was not strong enough to overcome their difference in origin. This raises the question of whether French consumers are ready to replace animal-based products with processed plant-based products. If structural differences are perceived as more significant than functional differences, it will be difficult to replace one category with the other in the short term. It will be even more complicated to substitute raw or unprocessed plant-based products (not described as alternatives) for animal-based products.

Our results pave the way for actionable recommendations for several stakeholders. Since plant-based meat substitutes did not overlap with meat in French consumers' representations, it may be worth reconsidering whether innovation in the plant-based food sector should continue to focus heavily on products designed to mimic meat. Instead, minimally processed plant-based products could be proposed and prioritized, accompanied by more effective communication strategies and public health guidelines that insist on the potential role of raw plant-based products as valuable protein sources. Achieving this requires better coordination between the various stakeholders, including food manufacturers, marketers, and public health policymakers.

Ethics

We are pleased to inform you that this study received an approval from the INSERM ethics committee (IRB00003888). It is part of the project referenced in the official letter attached below.

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CRediT authorship contribution statement

Jessy Youssef: Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Michel Visalli:** Writing – review & editing, Software, Formal analysis, Data curation. **Stéphanie Chambaron:** Writing – review & editing, Project administration, Methodology, Funding acquisition, Conceptualization. **Gaëlle Arvisenet:** Writing – review & editing, Validation, Supervision, Methodology, Data curation, Conceptualization.

Declaration of competing interest

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.

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Supplementary materials

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Data availability

Data will be made available on request.

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