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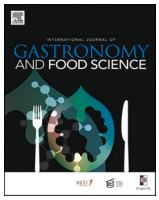

Attitudes and beliefs of French consumers towards innovative food products that mix dairy and plant-based components

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A B S T R A C T

Reducing consumption of animal-based protein in favor of plant-based protein in Western diets could be a way to mitigate the pressure of our diet on the environment. However, consumers may find it challenging to re-balance their diet. In particular, milk substitution seems difficult to some consumers, for nutritional and sensory reasons. New products that mix dairy- and plant-based components could be an opportunity to gradually familiarize consumers with plant-based products characteristics. In the present study, attitudes and expectations of French participants toward such dairy and plant-based mixed products were studied through the implementation of online Check-All-That-Apply (CATA) questionnaires using images of fictional mixed products. Participants responded to a single-item food choice questionnaire (SI-FCQ) and a socio-demographic questionnaire. Three profiles were found according to their criteria of food choice. The attitudes and beliefs of participants toward mixed products depended on both the nature of the plant component of the mixed products, and the profile of participants regarding SI-FCQ answers. Mixed dairy and plant-based products may be considered as more than a combination of both ingredients, and even globally as a new object. This opens new perspectives on eating habit changes.

1. Introduction

It is now accepted that a better balance between proteins from animals and from plants in the western human diet should lead to a substantial decrease in food pressure on the environment. Plant protein requires fewer resources to produce, occupies less land, and emits less greenhouse gas compared to livestock protein (Poore and Nemecek, 2018; Rabès et al., 2020). This change need not necessarily be drastic: at least one study has demonstrated that replacing half the meat and dairy products by plant products would suffice to significantly mitigate the environmental burden of the human diet (Goldstein et al., 2017). This transition can only be achieved through full cooperation among all actors. At the level of production and innovation, there has been a rising offer of plant-based alternatives to animal products over the past few decades, often based on legumes, nuts, and cereals. Alone, however, this evolving offer will not suffice: consumer involvement is the cornerstone of dietary change (de Bakker and Dagevos, 2012).

Several substitution strategies are possible for consumers willing to change their diet in favor of plant products. Protein equivalence can be obtained by changing meal components: i.e. by replacing meat with cereals and pulses, which may be challenging for people with insufficient nutritional knowledge. It has been shown that, for consumers, unprocessed foods of animal origin and those of plant origin belong to distinct categories and do not share many properties. Thus, animal- and plant-based protein foods may be considered uninterchangeable by consumers (Chollet et al., 2022). To circumvent this difficulty, another consumer strategy is to choose "substitutes", i.e. new plant-based products designed to have the same function in a meal as animal products (e.g., plant-based "burgers" or "yogurt"). However, their sensory characteristics are often very different from the animal-based reference food. Unappealing organoleptic properties lead to low acceptance of plant-based products and may represent a barrier to their adoption (Hartmann and Siegrist, 2017; Niva et al., 2017). Several studies have also evidenced that consumers are not ready to replace their favorite products. For example, consumers deeply attached to eating meat may be less willing to adopt a more plant-based diet (Gonera et al., 2021; Graca et al., 2015). Similarly, milk substitution may be hindered by the positive opinion that most consumers have about cow's milk, which is perceived as a good source of protein and calcium, convenient to use, and good-tasting (Haas et al., 2019). Such consumers tend to focus on and dislike the specific attributes of plant-based products that are not present in animal products (Florack et al., 2021). In addition to this lack of sensory appeal, the nutritional properties of plant-based products may also give rise to concern. In the case of dairy products, the protein

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content of milk analogs (apart from soy) is often lower than that of cow's milk, and these products also have lower levels of calcium, and of vitamins D and B12 (Craig and Fresán, 2021). Substitution may therefore demand some effort even for consumers who consider plant-based dairy alternatives as more sustainable than dairy products (Schiano et al., 2020).

To tackle this issue, it is possible to replace only a fraction of animal ingredients by plant ingredients in familiar products. This progressive transition strategy might allow consumers to familiarize themselves with plant-based products and their sensory characteristics, and thus gradually include plant-based products in their diet. Products blending meat and plant-based ingredients have become available in recent years, with increasing consumer acceptance (Profeta et al., 2021). The plant components in these hybrid products favor their perception as being healthier and better for the environment than 100% meat, and their meat content helps to preserve the sensory characteristics to which consumers are attached (Banovic et al., 2022). The development of products that mix dairy and plant-based ingredients is more recent and is still challenging in terms of physico-chemistry and sensory appeal (Alves and Tavares, 2019; Grasberger et al., 2021; Guyomarc'h et al., 2021; Saint-Eve et al., 2021; Sertovic et al., 2019; Yilmaz-Ersan and Topcuoglu, 2022; Yousseef et al., 2016). These studies only addressed the sensory acceptance of 'mixed dairy and plant-based products'. Due to the novelty of these products, however, it is important to explore broader consumer attitudes toward them, to identify which types of consumers might choose mixed products and their motivations, before initiating any form of sensory study.

The aim of this study is therefore to explore French consumers' representations, beliefs, and attitudes toward innovative products that mix dairy and plant-based products, herein called 'mixed products' or 'mixes'. The objectives are (i) to determine how consumers with different dietary attitudes and food-choice criteria react to various mixed products, and (ii) to identify potential differences in acceptance of mixed products in relation to the nature of the dairy or plant-based ingredients. Two product spaces will be considered: one referring to milk and yogurt and related to western animal-based cultural habits, and one referring to tofu and related to plant-based dietary habits. This investigation goes beyond sensory acceptance of mixed products, by considering general attitudes and beliefs of consumers about mixed products.

2. Materials and methods

2.1. Participants

Participants in the online study were recruited via the internet. The link to the survey was shared via social media, and by several institutional and private mailing lists. Respondents were encouraged to forward the message to their own list of contacts, in order to increase the number of respondents and diversify their profile. The link to the test was accompanied by a short text explaining the general objective of the research ("participate in an online questionnaire about food"). Conditions of participation (i.e. age between 20 and 64 years old) and test duration were also indicated. No specific target group was defined for this exploratory study. We deliberately did not mention the type of products under study, so as not to "pre-select" people with a specific interest in this type of product. Participation was strictly anonymous. Data storage conditions were explained in the information form, which also indicated that any data would be used only for scientific purposes. Clicking on the link gave access to a form listing inclusion criteria. Participants had to be at least occasional consumers of milk, yogurt, and plant-based beverages (survey 1) or tofu, and cheese or milk (survey 2). In order to access the first page of the survey, participants had to tick a box to confirm that they had read the information form, that they fell within the inclusion criteria, and that they accepted the conditions of the study. Both surveys in this study were conducted in accordance with the Declaration of Helsinki. Data were collected, stored, and analyzed according to European regulations. Participants received no compensation for their participation.

2.2. Experimental design

Data was collected online, using the 'RedJade' software (RedJade Sensory Solutions, LLC). As different product spaces were being assessed, two separate surveys were designed. The two surveys were conducted sequentially, with different participants. A single survey containing all the products would have taken too long to complete, risking participant fatigue. Both surveys included three independent parts: (i) The Check All That Apply or CATA test (main part), followed by (ii) the single-item Food Choice Questionnaire (SI-FCQ) proposed by Onwezen et al. (2019), (iii) a socio-demographic questionnaire, and finally (iv) questions about their consumption of plant-based beverages and milk (first survey) or tofu (second survey) to verify that participants fell within the inclusion criteria based on frequency of consumption. The only difference between the two surveys was the set of product images presented during the CATA test. The first survey focused on a group of products composed of regular milk, regular yogurt, or mixed dairy and plant-based products, containing either milk or yogurt and one of four different plant-based ingredients. Survey 1 was available online from July to September 2020, with an additional four-week period in November 2020, to reach the desired number of participants. This number was set at 260 complete forms matching all inclusion criteria, in order to reach a suitable size for group segmentation. The second survey focused on a group of products containing regular tofu, or tofu mixed with one of three different dairy products. Survey 2 was available online from mid-January to the end of February 2021. No segmentation was planned for survey 2, which recruited 78 participants.

2.3. Images of products

The images used for the two CATA tests were specifically designed for the study, using neutral packaging of milk, yogurt, and tofu. Brands, labels, and any identifying information were erased from the packaging. Fictional images and product names were added to the packaging. Our goal was to obtain neutral, uniform images. For milk or yogurt product images, the only difference was the nature of the plant ingredient, or its absence. For the tofu product images, the only difference was the nature of the dairy ingredient, or its absence.

For the CATA test on regular or mixed dairy products (yogurt or milk), a set of ten images was presented to participants (Fig. 1): five images of milk and five images of yogurt. The dairy ingredient was always present, either alone (regular yogurt or regular milk), or associated with a plant ingredient: pea ('milk + pea' or 'yogurt + pea'), lupine ('milk + lupine' or 'yogurt + lupine'), soy ('milk + soy' or 'yogurt + soy'), and almond ('milk + almond' or 'yogurt + almond').

For the CATA test on regular or mixed tofu, a set of four images was presented to the participants (Fig. 2): one of regular tofu, and three images of tofu containing either milk ('tofu + milk'), feta ('tofu + feta'), or emmental cheese ('tofu + emmental').

2.4. Attributes

The statements used as attributes in the CATA tests were generated from the verbatims that emerged during semi-directive interviews with 20 volunteers, aged 18 to 60. These volunteers were recruited by social media, in the same conditions as the participants in the CATA tests. All were habitual consumers of dairy products. Ten of them were omnivorous (6 females and 4 males, mean age 36.5 years old, median: 39.5, min: 18, max: 58) and ten were engaged in transitioning toward a more sustainable diet (nine females and one male, mean age: 32.5 years old, median: 33.5, min: 19, max: 54). Participants were invited to comment on their consumption of dairy products and plant-based substitutes for dairy products, to imagine how they would react if they could no longer

Fig. 1. Product images presented in the CATA test on regular or mixed dairy products: (A) milk *(lait)* and (B) yogurt *(yaourt); From left to right: regular products without plant-based ingredients; mixed products containing pea (pois), lupine (lupin), soy (soja), or almond (amande).*

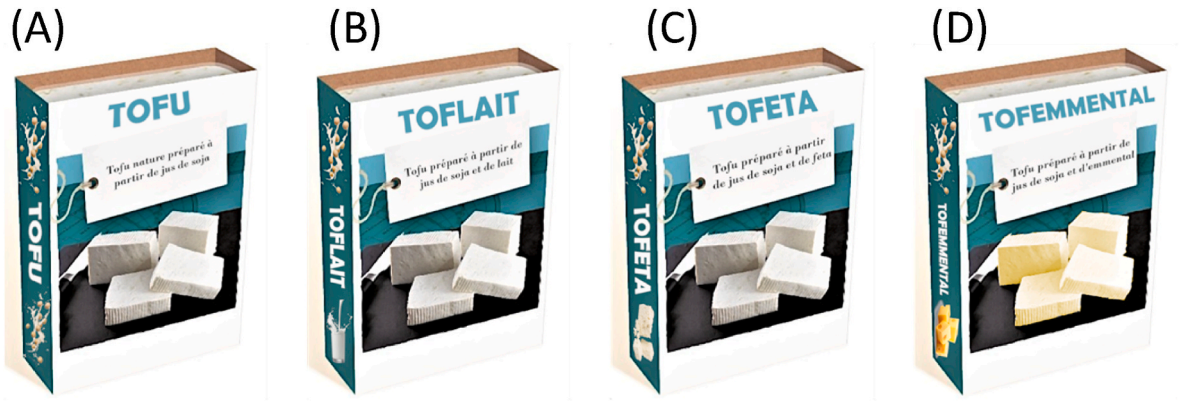

Fig. 2. Product images presented in the CATA test on regular or mixed tofu. *(A) regular tofu, mixed tofu containing (B) milk, (C) feta, or (D) Emmental cheese. The sentence on the front of the package can be translated as follows "Tofu prepared from: (A) soymilk, (B) soymilk and milk, (C) soymilk and feta, and (D)soymilk and Emmental".*

eat dairy products, and finally to comment on fictional images of 9 mixed dairy and plant-based products (Supplementary material). Table 1 (columns 1 & 2) lists the 28 attributes used for the CATA tests. They are related to three distinct themes: nutritional, health, and environmental properties of the products (seven attributes); their sensory properties and liking (seven attributes); and consumer attitudes toward mixed products, possible occasions for use, and (un)willingness to taste (fourteen attributes).

2.5. CATA test procedure

After a welcome message, the images of the products were presented in a sequential monadic design. Each product image appeared at the top of the computer screen and the attributes were listed below. Participants were invited to check all the attributes that corresponded to features they ascribed to the product presented, or to their feelings about this product. The order of presentation for images and list of attributes was randomized between participants. For a given participant, the order of the attributes was the same for all images (Meyners and Castura, 2016). There was no limit to the number of attributes that participants could select.

2.6. Single item food choice questionnaire (SI-FCQ)

In the SI-FCQ that followed the CATA test, eleven sentences were proposed to assess the importance of eleven food-choice criteria. Each sentence began thus "It is important for me that the food I eat on a typical day …", and ended with one of the following criteria: "is healthy"; "is a way of monitoring my mood"; "is convenient"; "provides me with pleasurable sensations"; "is natural"; "is affordable"; "helps me control my weight"; "is familiar"; "is environmentally friendly"; "is animal friendly"; "is fairly traded" (Onwezen et al., 2019). Participants had to indicate the level of importance for each of these food-choice motives, using a scale from 1 to 7 (1: not at all important; 7: very important).

2.7. Demographic and consumption questionnaires

After the CATA test and the SI-FCQ, participants completed a socio-

Table 1
List of the 28 attributes used in the CATA tests (left column), and results of the Cochran tests for each experiment (the 5 columns to the right). Abbreviations used in Figs. 3 and Figs. 5–8 are given in the second column of the table.

Attributes in English and (original text in French)	Abbreviations used in this paper, for clarity	Pval Cochran tests				
		Dairy products				Tofu
		all participants	Cluster A	Cluster B	Cluster C	
- It is healthy (c'est bon pour la santé)	healthy	**<0.0001**	0.187	**<0.0001**	**0.002**	**0.028**
- It is unhealthy (ce n'est pas bon pour la santé)	unhealthy	**<0.0001**	0.213	**<0.0001**	**<0.0001**	0.232
- It contains calcium (ça contient du calcium)	calcium	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**
- It contains protein (ça contient des protéines)	protein	**<0.001**	0.433	0.249	**0.001**	0.884
- I am concerned about being allergic (je crains d'être allergique)	concerns about allergies	0.430	0.399	0.947	0.397	0.261
- It is good for the environment (c'est bon pour l'environnement)	good for environment	**<0.0001**	0.253	**0.006**	**0.018**	**0.048**
- It is bad for the environment (c'est mauvais pour l'environnement)	bad for environment	**<0.0001**	**0.001**	**<0.0001**	**0.0001**	0.748
- It is a pleasant product (c'est un produit "plaisir")	pleasant product	**<0.0001**	**0.0001**	**<0.0001**	**<0.0001**	0.615
- I would like flavor (le goût me plairait)	would like flavor	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	0.485
- I would not like flavor (le gout ne me plairait pas)	would not like flavor	**<0.0001**	**0.002**	**<0.0001**	**0.006**	0.145
- It is fresh (c'est très frais)	fresh	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	0.056
- I would like the texture (la texture me plairait)	would like texture	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	0.417
- I would not like the texture (la texture ne me plairait pas)	would not like texture	**<0.0001**	0.084	**0.043**	0.075	0.152
- I do not like these types of products (je n'aime pas ce type de produits)	do not like type of products	**<0.0001**	**0.005**	**<0.0001**	**<0.0001**	0.801
- I would prefer a product exclusively plant-based (je préférerais un produit uniquement à base d'ingrédients végétaux)	prefer plant-based	**<0.0001**	**0.024**	0.112	**<0.0001**	**0.006**
- I could adopt this product for my everyday consumption (Je pourrais adopter ce produit pour ma consommation courante)	could adopt	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**0.011**
- It's a product for dietary transition (C'est un produit de transition)	for transition	**<0.0001**	**0.013**	**0.001**	**<0.0001**	0.784
- It shakes-up tradition (ça bouscule les traditions)	shakes-up tradition	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**0.001**
- I would be curious to taste (Je serais curieux.se de goûter)	curious	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**
- It is for vegetarian people (c'est pour les végétarien.ne.s)	for vegetarian	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**
- It would be expensive (ça risque d'être cher)	expensive	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	0.841
- I don't see the point (je n'en comprends pas l'intérêt)	do not see the point	**<0.0001**	**0.024**	**<0.0001**	**<0.0001**	**<0.0001**
- It is nonsense (c'est aberrant)	nonsense	**<0.0001**	0.087	**0.003**	**0.035**	**0.003**
- I would like to find it in my usual shop (j'aimerais trouver ce produit dans mon magasin habituel)	would like to find	**<0.0001**	**0.083**	**0.0001**	0.199	0.050
- I do not know these ingredients (je ne connais pas ces ingredients)	ingredients unknown	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	0.753
- It is original (c'est original)	original	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**	**<0.0001**

demographic questionnaire (age, gender, profession, rural vs urban domicile), and indicated their frequency of consumption for milk and yogurt (survey 1), or tofu, cheese, and milk (survey 2). The questions were presented with 7-point scales ("never"; "once to several times a year"; "once a month"; "several times a month"; "once a week", "several times a week"; "at least daily"). The questions about frequency of consumption simply aimed to verify that participants fulfilled this inclusion criterion.

2.8. Preparation of data

Only completed forms were considered for analysis. Forms completed by people who did not correspond to the inclusion criteria were discarded, i.e. who do not consume milk or plant-based substitutes for dairy products, or are allergic to any component of the products shown in the CATA tests. These inclusion criteria were decided before the test but, except for age, were not disclosed to participants prior to participation, in order not to reveal the type of products that were studied. Answers from food industry professionals were also discarded to avoid any conflict of interest or over-selection of people with a high level of knowledge about food.

2.9. Statistical analysis

The XLSTAT software program for Windows (Addinsoft, version 2021–1) was used for all statistical analyses. The confidence interval was set at 95%.

2.9.1. Analysis of CATA tests

A Cochran Q test was performed on data obtained by the two CATA tests. The Cochran test indicates whether the products represented by the images significantly differ for each attribute. For all the attributes showing a difference between images, multiple pairwise comparisons were performed using the Sheskin test. For each CATA test, a Factorial Correspondence Analysis (FCA), was created from a contingency table with significant attributes identified by the Cochran Q test as columns and products as rows.

2.9.2. Characterization of different participant profiles, according to their answers to the SI-FCQ

Different attitudes and levels of acceptance for plant-based beverages used as milk substitutes are attested in the literature (Haas et al., 2019; Pointke et al., 2022). We wanted to investigate whether participants' motivations for food choice could influence their beliefs and attitudes toward mixed or regular milk and yogurt. We therefore divided participants in the study on regular and mixed milk and yogurt into clusters, according to their answers to the SI-FCQ. We carried out a Principal Components Analysis (PCA) on the covariance matrix obtained from a table with participants (rows) and items of the SI-FCQ (columns). These data are quantitative (scores on a scale from 1 to 7). Participants were grouped by Hierarchical Clustering on Principal Components (HCPC) performed on the coordinates of the participants on the first six principal components of the PCA (representing 82.8% of the variability). The HCPC was based on the calculation of the Euclidian distance between participants, followed by a stepwise clustering of the most similar variables, by the Ward method. The Ward criterion is used in hierarchical clustering because, like PCA, it is based on multidimensional variance. The answers to the SI-FCQ given by the participants in each of the clusters obtained by this method were then compared by ANOVAs, with clusters as independent variable and criteria of choice as dependent variable. Participants' diet, demographic characteristics, and frequency of consumption of dairy products were compared for each cluster using Chi-square cell-by-cell analysis.

2.9.3. Impact of participants' motivations for food choice on their answers to the CATA test

From the clusters obtained, the CATA test dataset was divided and each group was analyzed separately. Finally, Multiple Factorial Analyses (MFA) were carried out to compare the CATA results of the three clusters of participants obtained with HCPC. To examine participants' consensus, we computed pairwise RV coefficients between clusters. RV coefficient has values between 0 and 1, with numbers closer to 1 indicating greater similarity.

3. Results

3.1. CATA test on regular or mixed yogurts and milk

The characteristics of the 261 participants are shown in Table 2.

3.1.1. Characterization of the images of mixed and regular dairy products by all participants

All attributes but one – *I am concerned about being allergic* – significantly distinguished the product images (Table 2). The FCA presented in Fig. 3 shows the attributes that best apply to each product. The first two axes of the FCA explain 84.8% of the total variance. Products are grouped as a function of the presence and nature of the plant-based ingredient: axis 1 opposes regular milk and regular yogurt to mixed milk + pea. Regular milk and regular yogurt are associated with descriptors related to pleasantness and sensory characteristics usually appreciated by consumers: *would like texture*, *would like flavor,* and *fresh*. Mixed milk + almond and yogurt + almond are not well represented on the FCA, nor well described by the attributes. Participants considered that they 'could adopt' regular dairy products more often than mixed products containing lupine, pea, or soy. Participants expressed their misunderstanding of mixed products containing lupine or pea: these products elicited *shakes up traditions*, *I don't see the point,* and *ingredients unknown* more often than for regular dairy products. Axis 2 distinguishes mixed milk + soy or yogurt + soy, but also regular milk from other products: all three are considered worse for the environment and less healthy. Finally, participants were less curious to taste mixed products containing soy than the other mixed products.

3.1.2. How the characterization of mixed or regular dairy products is impacted by participants' motivations for food choice

In order to determine if participants' attitudes, representations, and beliefs about mixed products differed according to their criteria of food choice, we sorted respondents according to their estimated level of importance of the eleven dimensions of the SI-FCQ (Fig. 4). The large number of participants allowed us to do this, and the number of participants in each of the three resulting groups is coherent with the number of participants recommended by Ares et al. (2014). Table 2 synthesizes the characteristics of the participants within the three clusters - demographic criteria and frequency of consumption of dairy products and/or plant-based alternatives to dairy products.

Women were over-represented in all clusters, but more particularly in cluster A (n = 62; women 80.6%). More than two-thirds of the participants within this cluster declared themselves omnivorous, 23% flexitarian, and 5% vegetarian, which is very close to the diet distribution of the entire set of participants. Participants in cluster A had extended food-choice criteria. Their main concerns were health, natural content, sensory appeal, animal welfare, environmental protection, mood, and weight control (Fig. 4). The latter two dimensions were significantly higher than in the other clusters.

Men were under-represented in all clusters, but the proportion of men in cluster B (n = 69) was significantly higher than in other clusters, as was the proportion of people aged from 20 to 29 years (Table 2). Omnivores were more numerous than in other clusters (>80%), while flexitarians and vegetarians were less numerous. A significantly lower proportion of members in cluster B consumed plant-based alternatives to dairy products weekly (4.4%). Participants in cluster B could be described as having self-centered food-choice criteria. Their main concern was sensory appeal, and most of the other dimensions of the SI-FCQ were rated of lower importance, except health. In particular, dimensions related to animal welfare, environmental protection, fair-trade, health, and natural content were significantly lower in comparison with the two other clusters (Fig. 4).

People under 29 years old were significantly under-represented in cluster C (n = 78) compared to the other two clusters. The proportion of omnivores was significantly lower, and the proportion of self-declared flexitarians and vegetarians significantly higher than in the other clusters. About one-third of participants consumed plant-based alternatives

Table 2
Gender, age, type of diet, and consumption habits with respect to various dairy products and plant-based alternatives for the participants in the CATA tests dealing with regular and mixed milk and yogurt. Values in bold with the symbol a are significantly different from the theoretical values (Chi-square cell per-cell analysis; p-value <.05). (+) indicates an observed value higher than the theoretical value, and (−) a lower observed value.

		all (209)	cluster A (n = 62)	cluster B (n = 69)	cluster C (n = 78)
Gender	women	145 (69.4%)	**50 (80.6%)** $^{a\,(+)}$	**38 (55.1%)** $^{a(-)}$	57 (73.1%)
	men	62 (29.7%)	**12 (19.4%)** $^{a(-)}$	**30 (43.5%)** $^{a(+)}$	20 (25.6%)
	preferred not to answer	2 (1.0%)	**0** $^{a(-)}$	1 (1.4%)	1 (1.3%)
Age	20–29	64 (30.6%)	15 (24.2%)	**31 (44.9%)** $^{a(+)}$	**18 (23.1%)** $^{a(-)}$
	30–39	26 (12.4%)	7 (11.3%)	7 (10.1%)	12 (15.4%)
	40–49	54 (25.8%)	19 (30.6%)	15 (21.7%)	20 (25.6%)
	50–65	65 (31.1%)	21 (33.9%)	16 (23.2%)	28 (35.9%)
	median	42	45	35	44
	mean	41	42	37	43
Diet	omnivorous	147 (70.0%)	45 (72.6%)	**57 (82,6%)** $^{a(+)}$	**45 (57.7%)** $^{a(-)}$
	flexitarian	49 (23.4%)	14 (22.6%)	**11 (15.9%)** $^{a(-)}$	**24 (30.8%)** $^{a(+)}$
	vegetarian	13 (6.2%)	3 (4.8%)	**1 (1.4%)** $^{a(-)}$	**9 (11.5%)** $^{a(+)}$
Milk consumption	less than once a week	115 (55.0%)	30 (48.4%)	37 (53.6%)	48 (61.5%)
	more than once a week	94 (45.0%)	32 (51.6%)	32 (46.4%)	30 (38.5%)
Yogurt consumption	less than once a week	60 (28.7%)	15 (24.2%)	16 (23/ 2%)	29 (37.2%)
	more than once a week	149 (71.3%)	47 (75.8%)	53 (76.8%)	**49 (62.8%)** $^{a(-)}$
Consumption of other dairy products	less than once a week	31 (14.8%)	10 (16.1%)	10 (14.5%)	11 (14.1%)
	more than once a week	178 (85.2%)	52 (83.9%)	59 (85.5%)	67 (85.9%)
Consumption of plant-based dairy alternatives	less than once a week	163 (78.0%)	44 (71.0%)	**66 (95.7%)** $^{a(+)}$	**53 (67.9%)** $^{a(-)}$
	more than once a week	46 (22.0%)	18 (29.0%)	**3 (4.3%)** $^{a(-)}$	**25 (32.1%)** $^{a(+)}$

Values in bold with the symbol [a] are significantly different from the theoretical values (Chi-square cell per-cell analysis; p-value <.05). (+) indicates an observed value higher than the theoretical value, and (−) a lower observed value.

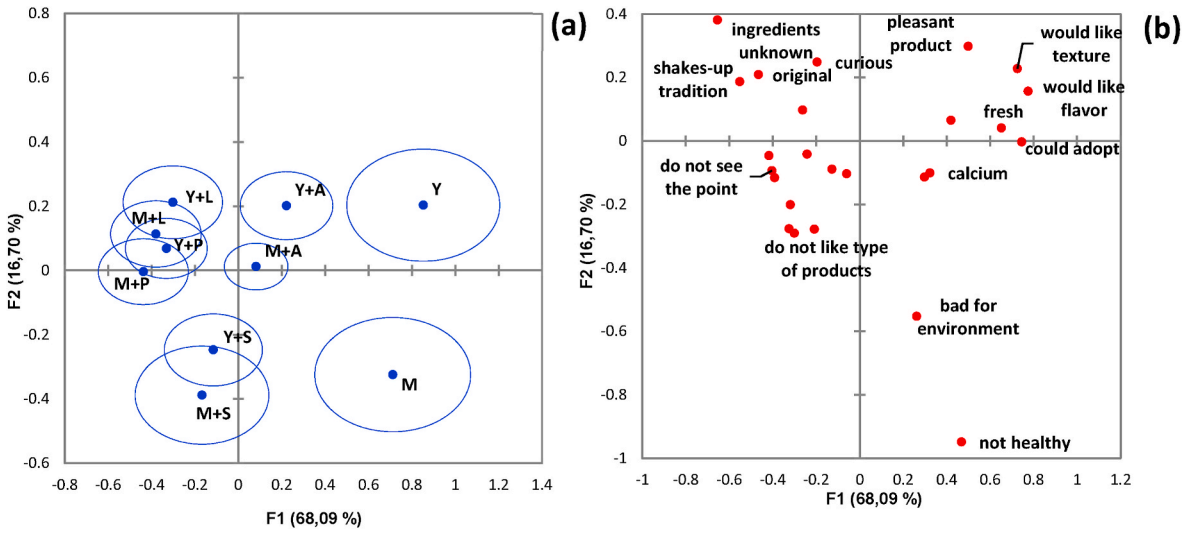

Fig. 3. Representation of samples (a) and attributes (b) in the first two dimensions of the Factorial Correspondence Analysis performed on the results of the CATA test on regular or mixed milk and yogurt, obtained for all participants. *(codes of the products: M: Milk; M + A: Milk + Almond; M + S: Milk + Soy; M + L: Milk + Lupine; M + P: Milk + Pea; Y: Yogurt; Y + A: Yogurt + Almond; Y + S: Yogurt + Soy; Y + L: Yogurt + Lupine; Y + P: Yogurt + Pea). Ellipses represent confidence areas. To simplify the MFA spaces, we represented only the attributes that contributed the most to the components (contribution values higher than the average contribution).*

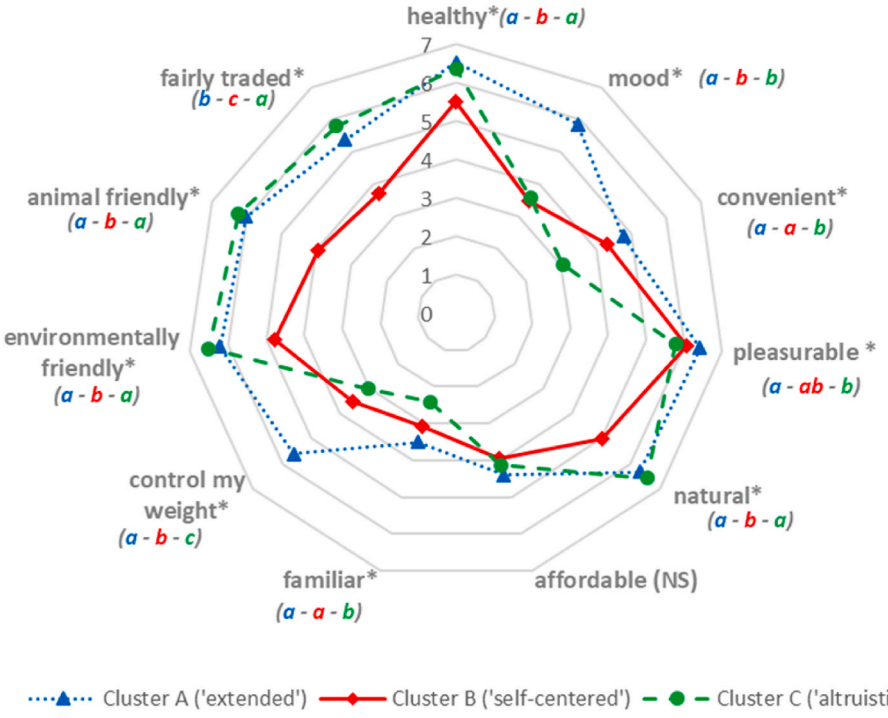

Fig. 4. Radar plot illustrating the results of the ANOVA on the results of the SI-FCQ, followed by tests of multiple comparisons of means (NK) for the different clusters. *For each dimension, the star * indicates significant difference ($p < .05$), and two clusters with the same small letter obtained similar scores of importance (pairwise comparison by a Newman Keuls test).*

to dairy products weekly, which is significantly higher than in the other clusters. Participants in cluster C had more altruistic food-choice criteria. Their main concerns were animal welfare, environmental protection, fair-trade, health, and natural content. Familiarity and convenience are significantly less important for them than for participants in the other clusters. Sensory appeal is significantly less important for them than for cluster A.

Participants' answers obtained in the CATA test were compared for the three clusters. In each group, several attributes were not discriminant. Eight attributes were non-discriminant for cluster A: *It is nonsense, I would not like the texture, It is healthy, It is unhealthy, It is good for the environment, It contains proteins, I am concerned about being allergic*, and *I would like to find it in my usual shop*. Three attributes were not discriminant between the products in cluster B: *I would prefer exclusively plant-based, It contains proteins* and *I am concerned about being allergic* and in cluster C: *I would not like texture, I am concerned about being allergic*, and *I would like to find it in my usual shop*. We carried out Multiple Factorial Analyses on the data obtained from the three clusters, by dividing significant descriptors into three groups according to meaning i) sensory properties and liking; ii) nutritional and environmental properties; and

iii) attitudes, uses, and willingness to taste. All MFA interpretations were double-checked with the results of pairwise comparisons.

Fig. 5 compares the participants of the three clusters regarding their opinion about the sensory properties and liking of the products. The first factorial map represents 89.4% of the variance. Participants of the three clusters had quite similar opinions about the sensory properties, as shown by the short distance between partial points relating to the same product and average points (Fig. 5a), and the high RV coefficients (from 0.874 to 0.934). On axis 1 (80% of variance), regular yogurt and mixed yogurt + almond are opposed to mixed milk + pea and milk + soy, for participants in all three clusters. Regular yogurt was expected to be pleasant, and participants mentioned they would like the flavor. For all three clusters, participants imagined they would dislike the flavor of mixed products based on soy or pea. The only difference between clusters can be seen on axis 2, where regular milk is opposed to mixed yogurt + almond. Cluster A is the only one contributing significantly to axis 2. For participants in cluster A, milk was not a pleasant product, while mixed yogurt + almond was expected to be pleasant (Fig. 5b). Participants in clusters B and C did not really oppose regular milk to other products, for any sensory characteristic.

Fig. 6 shows participants' representations and beliefs about the nutritional and environmental properties of products. The first factorial map represents 84.5% of the variance. Participants considered the nutritional and environmental characteristics of products differently depending on the cluster to which they belong (values of RV coefficients vary from 0.273 between cluster A and C, to 0.800 between clusters A and B). Cluster A contributes mainly to axis 1, cluster B to both axes 1 and 2, and cluster C to axis 2. For participants in clusters A and B, mixed products containing soy are opposed to mixed milk + lupine on axis 1 (54.4% of the variance). They considered that mixed products containing soy were bad for the environment, while participants in cluster B also considered these products as unhealthy. For participants in cluster C, regular milk and yogurt were opposed to mixed milk + pea on axis 2. The only descriptors that contribute to this axis for cluster C are '*contains calcium*', used to describe regular milk and yogurt, and '*contains protein*', associated with mixed milk + pea. The attribute '*good for the environment*' used by participants in cluster B, contributes significantly to axis 2. Mixed milk + pea products were considered better for the environment than the other products by participants in cluster B. Multiple pairwise comparisons showed that all participants considered that regular milk and yogurt contained more calcium than mixed products. Participants in cluster B also considered milk healthier than other products (significant results, not shown).

The opinion of the participants in the three clusters regarding possible usage occasions, product positioning, and willingness to taste are quite similar, as shown in Fig. 7, by the short distance between partial points and average points relating to a same product, and the RV coefficients between 0.864 and 0.928. For all participants, regular milk and yogurt are the only products well represented on axis 1 (65% of the variance). All participants could adopt regular milk and yogurt. Axis 2 (15% of the variance) opposes products containing lupine to mixed products containing soy and mixed milk + almond. Mixed products containing soy were more often considered to be for a vegetarian diet than other mixed products, for all clusters. In cluster C, participants would prefer products exclusively plant-based to the mixed products milk + soy and yogurt + soy. In cluster B, participants consider mixed products containing soy more expensive than the other products. In all three groups, people did not know the ingredients when products contained lupine, and they less frequently considered these products to be for vegetarians than mixed products containing soy or almond. In cluster A, mixes containing lupine were considered to shake up tradition and to be original.

3.2. CATA test on regular and mixed tofu

The characteristics of the 78 participants are shown in Table 3. Here again, most of the participants were women. The main diet represented was omnivorus and only 5% of the participants said they consumed tofu once a week or more. Most of the descriptors that discriminated the products referred to attitudes and possible use (Fig. 8). Only three descriptors related to healthiness, and nutritional and environmental properties were discriminant. None of the descriptors relative to organoleptic characteristics was discriminant. The FCA in Fig. 8 shows that regular tofu was opposed to mixed products on axis 1 (85% of the variance). Regular tofu was considered healthier and better for the environment than tofu mixed with dairy products, but was also considered to contain less calcium. Participants considered they could adopt regular tofu for usual consumption more often than mixed products. Axis 2 (10% of the variance) opposes the mixed product tofu + milk to other mixed products. The tofu + milk was considered nonsense more often than other mixed products.

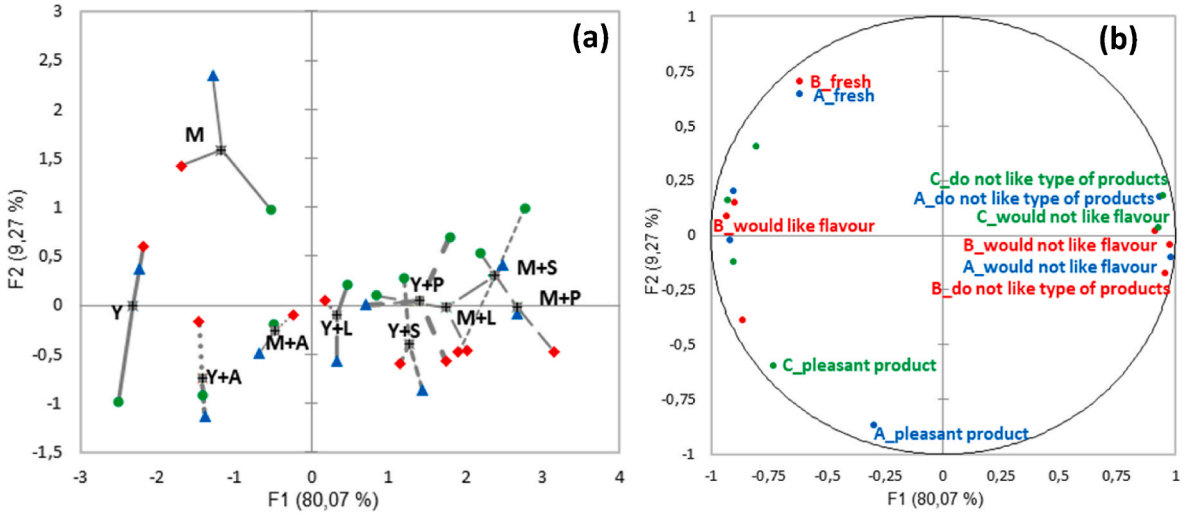

Fig. 5. Multiple Factorial Analysis applied on the descriptors related to sensory properties and liking, by the three clusters of participants, in the CATA test on regular and mixed dairy products *(cluster A -extended- in blue; cluster B -self-centered- in red; cluster C -altruistic- in green), showing a product map (figure a) and correlation circle (figure b) in the first two dimensions. Only attributes with contribution values higher than average on factorial maps 1–2 are represented in figure b.* (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

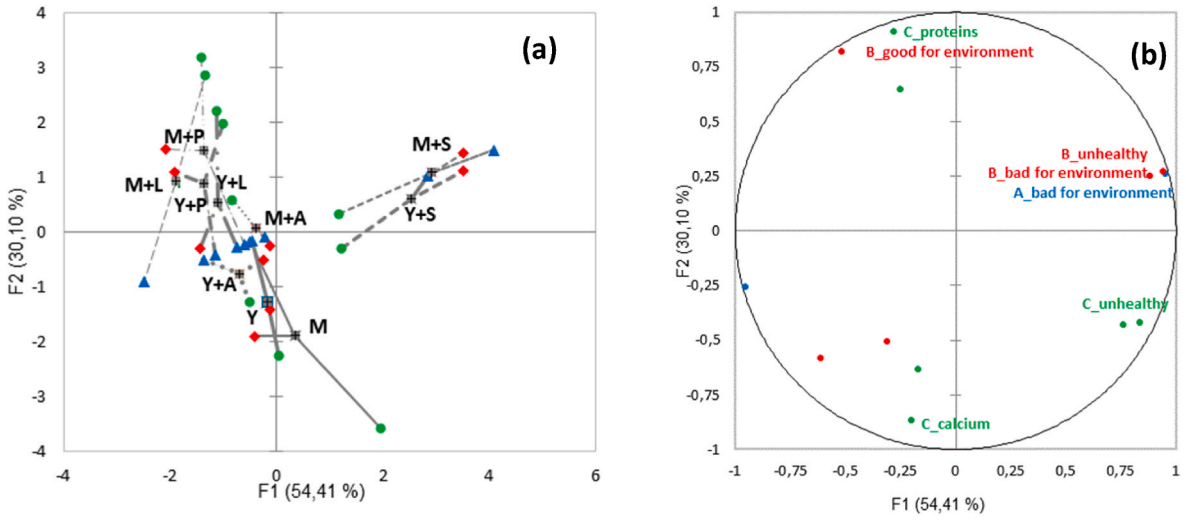

Fig. 6. Multiple Factorial Analysis applied on the descriptors related to health and environment, by the three clusters of participants in the CATA test on regular and mixed dairy products *(cluster A -extended- in blue; cluster B -self-centered- in red; cluster C -altruistic- in green),* showing a product map *(figure a)* and correlation circle *(figure b)* in the first two dimensions. *Only attributes with contribution values higher than average on factorial maps 1–2 are represented in figure b.* (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

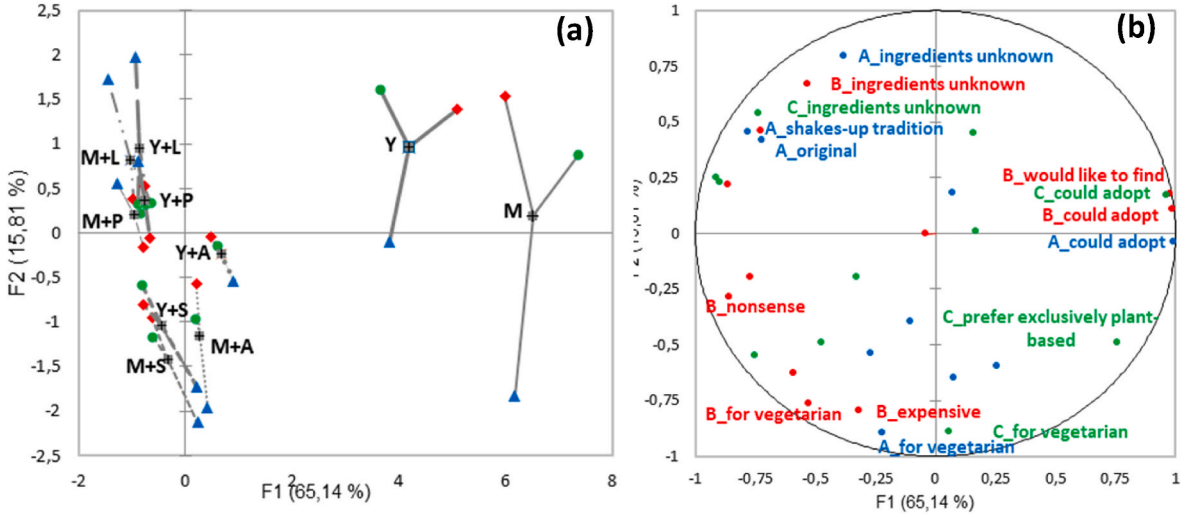

Fig. 7. Multiple Factorial Analysis applied on the descriptors related to possible usage occasions, product positioning, and willingness to taste, by the three clusters of participants in the CATA test on regular and mixed dairy products *(cluster A -extended- in blue; cluster B -self-centered- in red; cluster C -altruistic- in green),* showing a product map *(figure a)* and correlation circle *(figure b)* in the first two dimensions. *Only attributes with contribution values higher than average on factorial maps 1–2 are represented in figure b.* (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

4. Discussion

4.1. The opinion of participants on mixed products depends on the nature of both the plant-based and the dairy ingredients

The expected sensory characteristics and liking accounted for the largest differences between products evidenced by the CATA tests. The taste and texture of mixed products were expected to be less appreciated than those of regular dairy products or tofu. It is likely that participants had never tested mixes like those presented, because none of these products was yet available on the French market at the time of our study. So it was obviously difficult for participants to predict the sensory perception of such ingredient mixing. This uncertainty may have contributed to the difference in expected liking between mixed products (all unknown) and regular yogurt, milk, or tofu (more familiar). Participants considered that the sensory properties of the mixes would differ according to their ingredients, and they anticipated that their appreciation of the mixes would also depend on the ingredients. These differences were certainly based on memories of other associations of ingredients, and the recall of the sensory properties of these ingredients alone or in mixes. It has been shown that the association of flavors that are usually perceived separately can result in a novel sensory experience, which can be considered successful or not (Spence, 2020). The appropriateness of a pairing depends on the chemical characteristics of both ingredients, but also on other consumer-related factors, such as culture, tradition, and physiology (Galmarini, 2020). These factors can be perceptual (e.g., the balance of intensity of the two components, the enhancement of some flavors and masking of others, the qualitative similarity between the components in the mixture, or the harmony between them). They can also be cognitive (i.e. linked to properties stocked in memory such as norms, geographic origin, etc.). In that sense, "traditional" associations of products belonging to the same food culture

Table 3
Gender, age, diet, and consumption habits with respect to various dairy products and to tofu for the participants in the CATA test in Survey 2 dealing with regular and mixed tofu.

gender	women	55 (70.5%)
	men	21 (26.7%)
	preferred not to answer	2 (2.6%)
age	20–34	35 (44.8%)
	35–49	18 (23.1%)
	50–65	25 (32.1%)
	median	40
	mean	39
diet	omnivorous	54 (69.2%)
	flexitarian	20 (26.6%)
	vegetarian	4 (5.1%)
milk consumption	less than once a week	42 (53.8%)
	more than once a week	36 (46.2%)
cheese consumption	less than once a week	12 (15.4%)
	more than once a week	66 (84.6%)
consumption of other dairy products	less than once a week	21 (26.9%)
	more than once a week	57 (73.1%)
consumption of tofu	Less than once a month	66 (84.6%)
	At least once a month and less than once a week	8 (10.2%)
	once a week and more	4 (5.1%)

may be more cognitively acceptable than new mixes based on products from a different origin or cultural background (Eschevins et al., 2018; Spence 2020). The level of familiarity toward the individual components could also be involved. In our study based on images, several cognitive factors could explain why some mixed products were imagined to be more acceptable than others for their sensory characteristics. The expected sensory properties of mixed products appear to depend mostly on the appreciation of the plant-based component. Mixes containing almond were the most positively considered, and those containing soy were rejected. This is consistent with the gradient of acceptability observed for plant-based beverages in the literature (Jaeger and Giacalone, 2021; Sertovic et al., 2019). Some ingredients could be considered incongruent, such as soy and milk, which traditionally belong to different cultures. Soy and tofu are strongly associated with Asian culture and are not much consumed in Europe, while dairy products are among the pillars of the French diet. These strong cultural identities may have been translated into incompatibility in participants' minds, and thus detrimental to the acceptance of mixed products containing soy. Another principle of the acceptance of an association is that both components are similarly appreciated as a stand-alone experience, which is probably not the case for soy products and dairy products, as shown by Sertovic et al. (2019).

The perceived environmental impact of the mixes also varied according to their composition and seemed to depend on the plant-based component. Products containing pea and lupine were perceived as more environmentally-friendly than regular dairy products, but mixes containing soy were considered comparable to milk for this criterion. This is aligned with the scientific evidence about the differences in the environmental impact of these plants. The perceived environmental impact of a mixed product might therefore be a combination of the perceived environmental impact of each of its ingredients. Regarding the healthiness of the products, most participants in our study considered the properties of mixed dairy products better than those of regular dairy products, except for the mixes containing soy. This result is aligned with studies in which consumers considered cow milk as healthier and better for bone fortification than plant-based milk substitutes (Haas et al., 2019). Within the different mixes, healthiness was also considered to be different, depending on the plant-based component. In particular, products containing soy were considered unhealthy by most participants. Except for this bad opinion about mixes containg soy, participants did not really distinguish the other mixed products according to healthiness. This result may seem surprising, considering the large variability of nutritional properties observed for plant-based milk substitutes (Craig and Brothers, 2021; Craig and Fresán, 2021). The nature of the plant-based ingredient defines the concentration of proteins, calcium, saturated fat, and the amount of added sugars in these products (Craig and Fresán, 2021). Here, it seems that the representation of the concept of 'healthiness' for participants was not so much related to nutritional properties, and that other properties such as the presence of contaminants (e.g. phytosterols in soy) were considered as primordial. The fact that the products considered richer in calcium are often considered less healthy is coherent with this interpretation. Halo effects might come into play here, e.g. if the soy-containing mixes that participants considered as less sustainable were therefore considered to be less

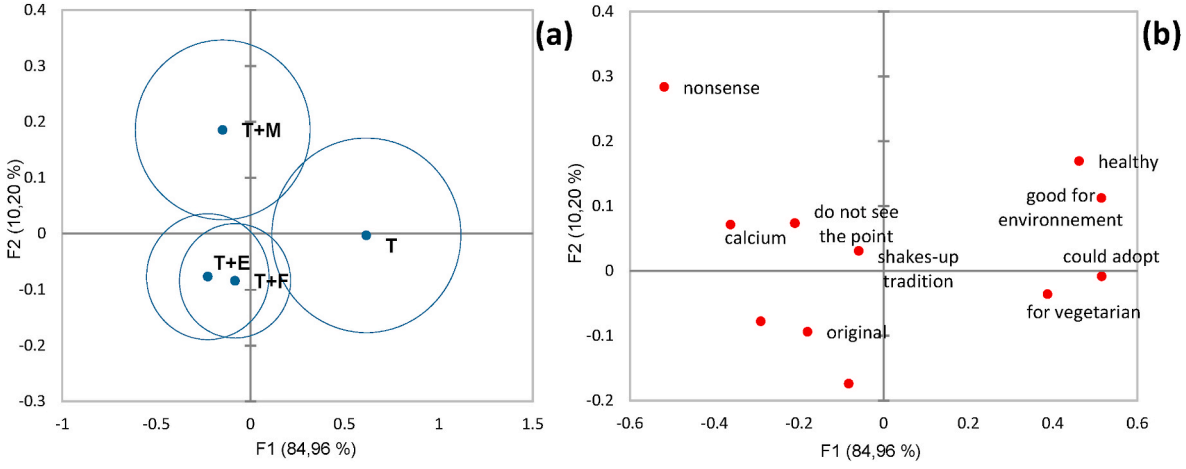

Fig. 8. Representation of samples (a) and attributes (b) in the first two dimensions of the Factorial Correspondence Analysis for the results of the CATA test on regular or mixed tofu, obtained for all participants. *(codes of the products: T: Tofu; T + M: Tofu + Milk; T + E: Tofu + Emmental cheese; T + F: Tofu + Feta cheese). Ellipses represent confidence areas. Only attributes with contribution values higher than average on factorial maps 1–2 are represented in figure b.*

healthy (Berry and Romero, 2021). It is also possible that the perceived healthiness in a mix is not the sum of the healthiness level of its parts. Properties perceived as strengths in one component of the mixed products may compensate the properties perceived as weaknesses in the other component, resulting in a mixed product considered as average overall. It is also possible that a specific property of one ingredient took the lead during the estimation of healthiness, smoothing the effect of other properties.

4.2. Opinions about mixed products depend on participant profiles

Our study makes it possible to characterise consumers who could more easily adopt mixed products, according to their food-choice motivations or their demographic specificities. Participants were clustered into three groups (Table 2). Cluster A (extended food-choice criteria) was composed mainly of self-declared omnivores. They were generally women concerned about almost all food characteristics, whose food-choice motivations were both self-centered and altruistic. They did not distinguish products by any of the attributes related to health, contrary to participants in other clusters who found differences between products because of healthiness (cluster B), or because of protein and calcium content (cluster C). Participants in cluster A did not reject mixed products as a whole, and they even considered they could like some of them (yogurt mixed with almond or soy). Of the three clusters, consumers with this profile are the most receptive to mixed products. The importance assigned to well-being and weight control by this group could be an opportunity for mixes, which combine the advantages of containing fewer calories than regular dairy products because of the plant-based ingredient (Bridges, 2018), with an emotional valence because of the dairy ingredient, rooted in food habits and culture.

Cluster B (self-centered food-choice criteria) was mainly composed of millenials, almost equally male and female, omnivorous, consuming milk daily, and not interested in milk substitutes. For these participants, the main food-choice criterion was sensory appeal. They had positive attitudes toward dairy products, which they considered healthy, with pleasant sensory properties. This group used all the terms related to sensory properties in the CATA test to indicate their liking of dairy products and dislike of mixed products. The only interest they found in some mixed products was related to their positive effect on the environment. Yet they did not consider dairy products to be bad for the environment, unlike participants in other clusters. They were not particularly concerned by this property, which they do not consider a priority when choosing foods. It therefore seems very unlikely that these participants would want to reduce dairy product consumption in favor of mixed products. If, despite all these negative signals, mixed products were developed for consumers with self-centered criteria, soy should be avoided. These participants had particularly negative attitudes toward soy-based mixed products, which they considered bad for health and for the environment.

Cluster C (altruistic food-choice criteria) was very different from cluster B. It was composed of a majority of women, and 40% self-declared flexitarians or vegetarians. The main characteristic of these participants was to reject milk: they considered regular milk worse for health and environment than mixed products. Their opinion about the expected sensory properties of mixed products was not particularly good, but it was not as strongly negative as in cluster B. The only characteristic they anticipated to be unpleasant in mixed products was flavor, while the texture of mixed products was not distinguished from that of dairy products. These participants considered that ethical and nutritional characteristics of products are more important than their sensory appeal. Thus, it is likely that they could accept products with a poorer sensory quality if their nutritional and environmental quality was improved. People with this profile would probably reject mixed products based on liquid milk, because of their negative attitudes toward milk. Their more positive opinions and attitudes toward yogurt-based mixed products would probably lead to greater acceptance. Yet mixed products might not be an opportunity for these participants, since one-third of cluster C was composed of people already used to consuming plant-based alternatives to dairy products, and most of them disliked milk and consumed less yogurt than other participants in our study. Participants in cluster C would not consider mixed products as facilitators in "transitioning" toward dairy alternatives as they have already adopted plant-based products.

4.3. Strengths and limits of the study

At the time of our study, mixed products were not yet for sale on the French market. As a consequence, participants had probably not been exposed to mixed products, and could therefore only express their expectations of such products, rather than give feedback on their experience with them. Presenting images of mixed products instead of experimental products gave us the opportunity to propose a broad range of combinations of diverse dairy and non-dairy ingredients. Yet it also had drawbacks: participants rated their expected sensory properties of products instead of perceived sensory properties. Consequently, it is possible that the role of sensory appeal was over-represented in CATA ratings compared to other properties. It would be necessary to confirm our results by testing real mixed products, to know how much, in consumers' minds, sensory properties of mixed products interfere with their nutritional properties, and their impact on the environment.

Participation in the CATA tests was made accessible by a link, sent by mail, and via social networks. All the results provided by participants who fitted the inclusion criteria were used. This methodology does not provide a sample of participants representative of the general population. It resulted in over-representation of females, as in many consumer studies, and under-representation of 30–39 year olds. Nevertheless, segmentation into groups for the CATA test about mixed products containing milk and yogurt highlighted different trends in representations, according to different consumer profiles. Even though the number of people in each cluster was not necessarily representative of the proportion of each profile in the French population, these profiles still bring new insights into the variety of representations toward mixed products.

We distinguished groups of participants for the CATA test on milk and yogurt because the literature shows different consumption patterns and motives for plant-based milk substitutes (Pointke et al., 2022). We did not distinguish profiles for the CATA test on tofu because (1) the number of tofu consumers in France is low, and it would have been difficult to find enough participants who fit the inclusion criteria, and (2) there was no available literature about any divergence of representations and attitudes toward the cheeses associated with tofu in our study.

Finally, in order not to multiply the number of products, we only compared mixed products to one type of component in the CATA tests (regular dairy product or regular tofu). It would be interesting to propose mixed products, regular dairy products, and regular plant-based products in the same test. This would provide insight into how mixed products are categorized, and whether their properties are considered closer to those of plant-based products or those of dairy products.

5. Conclusions

This study demonstrated that French consumers' representations, beliefs, and attitudes toward dairy and plant-based mixed products depend on the nature of the ingredients and on the consumer's profile. Expected taste, but also beliefs about the effects on health, and the consequences for the environment depended on the plant-based component in the mixed products. Surprisingly, unfamiliarity with the plant-based ingredient was not the main barrier toward mixed products: pea- and lupine-based products were unknown to most participants, but less rejected than soy. Regarding participant profiles, people with extended food-choice criteria had more positive attitudes toward mixed products than those with self-centered motivations or those mostly

driven by altruistic criteria. This result suggested that, for some people with a specific profile (who exhibit neither a marked preference for animal or traditional food, nor a habit of already consuming vegan food), mixed products could play the role of a "transitional product" helping them move progressively toward more plant-based diets. From a more theoretical point of view, this pilot study showed that the representations about mixed foods might not result only from the combination of the representations about both ingredients. Mixed products seem to be considered globally as a new object, and this point will need to be confirmed by further research.

Author statement

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Fanny GUYOMARC'H: Funding acquisition, Conceptualization, Methodology, Writing- Reviewing and Editing.

Valérie GAGNAIRE: Funding acquisition, Project administration, Conceptualization, Methodology, Writing- Reviewing and Editing.

Gaëlle ARVISENET: Conceptualization, Methodology, Writing- Original draft preparation, Supervision.

Implications for gastronomy

The gastronomy sector has an important role to play in the transition toward a more sustainable food offer. In particular, the gastronomy sector can contribute to making the path toward plant-based foods easier for consumers, by creating new transitional products for a progressive shift. This paper proposes a strategy based on the use of familiar products as a base, in order to lessen the changes in food habits. More generally, the gastronomy industry could benefit from new insights from research into whether consumers consider an association of ingredients as suitable or not, and how they anticipate their acceptance of the sensory properties of the resulting products. Considering consumers' expectations, rather than just asking them to assess their perception and acceptance of the newly created products at the end of the process, is a promising strategy that can give rise to interesting ideas for chefs and the entire gastronomy industry.

Declaration of competing interest

The authors have no conflict of interest to disclose.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ijgfs.2023.100725.

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