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Consumer preferences for Camelina oil: impact of sensory perceptions and information disclosure on acceptance of an unfamiliar oil coming from a minor crop

Anne Saint-Eve [a,*], Jean-Denis Faure [b], Alexandra Jullien [c], Christophe Martin [d], Stéphan Marette [e]

[a] Université Paris-Saclay, AgroParisTech, INRAE, SayFood, 91120 Palaiseau, France
[b] Université Paris-Saclay, AgroParisTech, INRAE, Institut Jean-Pierre Bourgin for Plant Sciences, 78000 Versailles, France
[c] Université Paris-Saclay, AgroParisTech, INRAE, EcoSys, 91120 Palaiseau, France
[d] Centre des Sciences du Goût et de l'Alimentation, CNRS, INRAE, Institut Agro, Université Bourgogne Europe, F-21000 Dijon, France - CNRS, INRAE, PROBE research infrastructure, ChemoSens facility, F-21000 Dijon, France
[e] Université Paris-Saclay, INRAE, AgroParisTech, Paris-Saclay Applied Economics, 91120 Palaiseau, France

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ABSTRACT

This study aims to assess how French consumers evaluate the traditional but unfamiliar camelina oil, focusing on liking scores and willingness to pay (WTP) through sensory perception and information disclosure. In a controlled lab experiment ($n = 132$, Dijon, France), participants first blind-tasted camelina oil, with half of them evaluating extra virgin olive oil under similar conditions for comparison. After this blind step, stepwise information disclosure on product identity, health and environmental benefits, and possible gene-editing (GE) improvements was proposed.

First, the blind tasting showed that 35 % of consumers disliked the camelina oil, while 45 % liked it. The correlations between liking scores and WTP are positive but relatively weak, particularly for the camelina oil, which had been previously seen in stores by only 12 % of participants.

Second, information disclosure had a significant impact on WTP. (1) The identification of organic camelina oil led to a significant increase in WTP, while a similar disclosure for extra virgin olive oil had no effect. Additional messages about (2) the benefits of the camelina oil for human health and the environment led to significant increases in WTP. Conversely, (3) GE information reduced WTP for 46.2 % of participants, despite being framed with positive outcomes. These findings highlight the importance of targeted messages in promoting novel, sustainable food products and underline the need to address consumer concerns regarding biotechnology.

1. Introduction

Camelina or *Camelina sativa* (L.) (also named False flax, Gold-of-pleasure or Linseed dodders) is an annual plant from the brassica family (mustard, oilseed rape, …) native from Eastern Europe and Western Asia, but widely naturalized in other countries, mainly in Northern America (Zanetti et al., 2021). Despite a recent growing interest in Camelina due to its potential use as a source of jet fuel and as a cover crop, camelina remains an underutilized and largely unknown species—often classified as an "orphan crop" (Berti et al., 2016; Leclère, Jeuffroy, & Loyce, 2021; Leclère, Lorent, et al., 2021). Many reasons contribute to this lack of visibility and market penetration, including lower yields compared to Canola, limited knowledge about the design and management of suitable cropping systems (Leclère, Lorent, et al., 2021), a lack of coordination along the supply chain, and limited consumer awareness (Sims et al., 2010). However, camelina holds significant promise, particularly if agronomic conditions are favorable and consumer demand increases.

From an environmental perspective, camelina offers noteworthy advantages: it can be cultivated on poor soils and demonstrates considerable drought tolerance. Indeed, it is a short-season crop that could be adapted to a wide range of climate and is often grown on marginal land. Camelina oil content and fatty acid profile particularly show some plasticity under environmental constraints (Boutet et al.,

* Corresponding author.
E-mail address: anne.saint-eve@agroparistech.fr (A. Saint-Eve).

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2022 and Codina-Pascual et al., 2025). Moreover, many possible applications make this crop promising (Resurreccion et al., 2021), including food and non-food uses, like jet fuel production. Sydor et al. (2022) underline numerous "potential future applications of camelina: as a pioneer crop in reclaimed areas, as a cover or companion crop in agriculture, and as a source for new chemical additives." In a context of agroecological transition, cameline crop could thus have a leverage effect for crop diversification, as well as an alternative for fossil fuel.

Furthermore, its oil, rich in polyunsaturated fatty acids (ω-6 and ω-3) with a content varying between 51 and 66 % for omega3 α-linolenic acid (C18:3, ALA) that accounts for almost 28–50 % of total fatty acids, and omega6 linoleic acid (C18:2, LA) that accounts for approximately 15–23 % of total fatty acids (Krzyżaniak et al., 2019; Kurasiak-Popowska et al., 2019). Camelina seeds also contain tocopherols, phytosterols, and phenolic compounds with a total of eight flavonoid aglycons, 11 phenolic acids, three carotenoids that were already identified (Mondor & Hernández-Álvarez, 2022).

Despite this precious nutritional potential (Drabińska et al., 2024), this oil remains largely overlooked by consumers. It is available almost exclusively in organic stores and unfamiliar to most consumers. In this sense, camelina oil may be considered as a "new traditional" product: novel in its market presence, yet rooted in natural, sustainable production.

In this context, it is interesting to better understand how consumers arbitrate information about this "new traditional" product with characteristics compatible with sustainability goals. Although camelina oil offers clear environmental and health benefits, sensory factors, particularly its distinctive taste and odor, may hinder consumer acceptance. While the oil's golden colour may appeal visually, its flavor can be surprising for unfamiliar consumers, with the presence of negative descriptors such as bitterness, woody-like flavor, astringency, and persistent mouthfeel (Momot et al., 2023).

The objective of this work was to explore consumer response to this "new traditional" product and the possible impact of new genomic techniques like gene editing (GE). In particular, we wanted to better understand how consumers assimilate and decide based on available information, namely the oil taste and the information concerning the benefits for health and the environment. One way of testing consumer awareness of health and environmental benefits is to associate these criteria with advanced breeding technology like GE, for which we expect the public opinion to be reticent. This raises the question of how consumers assign relative importance to different selection criteria, namely environmental impact, health-related benefits, and production methods, in shaping both their product appreciation and their willingness to pay. Specifically, we examined whether consumers would better accept the use of gene editing for breeding when it is promoting sustainable culture (e.g., enhanced drought tolerance) or product nutritional value (e.g., increased omega-3 content). As noted by Morineau et al. (2017), gene-edited camelina represents a shift from a "new traditional" product to one that could be perceived as "entirely novel," raising critical questions about consumer acceptance and preference.

As a consequence, a protocol involving sensory and economic evaluations of camelina oil was developed and applied to a panel of 132 consumers in December 2024. This study is the first to examine hedonic scores and willingness to pay (WTP) for camelina oil among consumers. To elicit "truthful WTP" under incentive-compatible conditions, we employed the Becker-DeGroot-Marschak (BDM) mechanism, a method widely used in experimental economics for its robustness and ability to reduce hypothetical bias.

A second, more methodological objective of this study was to explore how the unfamiliarity of camelina oil affects its sensory evaluation. Evaluating an unknown product such as camelina oil presents specific challenges, particularly in blind tasting conditions. Unlike widely consumed edible oils such as olive oil, camelina oil is largely unfamiliar to consumers, who often lack any reference for its expected taste, sensory qualities, or typical culinary uses (Weems, 2007). This absence of prior knowledge can make it difficult for participants to meaningfully assess the product when tasting blind, as they have no baseline against which to compare it (Frost and Noble, 2002). Providing contextual information, such as its nutritional and environmental benefits, can help frame the evaluation, but may not fully compensate for this lack of familiarity. In this context, comparing camelina oil to a well-known reference such as olive oil can ease the evaluation, offering consumers a familiar benchmark that facilitates interpretation and preference formation. Olive oil, also used as a salad dressing, was selected as a reference for its relevance and widespread use.

The conclusions drawn from this work provide elements of understanding that can be used in the development of more sustainable food products, which is a major challenge for the coming years.

2. Materials and methods

2.1. Experimental conditions

The experiment was conducted in December 2024 in an air-conditioned room (20 °C), in individual booths, under white light at the INRAE Dijon (National Research Institute for Agriculture, Food and Environment). This experiment complied with all ethical guidelines released at both national and European levels. The current research has received formal approval from the CNRS on the 11th of September 2024 (UMR6265 / 2–24,208).

Individuals received oral and written information about the study and gave written informed consent before participating. They received €18 compensation for their participation: €10 announced during the recruitment, complemented with additional €8 for purchasing one bottle revealed in the lab at the beginning of the session (as explained below). Each session gathering a maximum of 16 participants lasted approximately 50 min.

2.2. Participants

A sample of consumers living in the agglomeration of Dijon (France) was selected for this experiment (Table 1). They were recruited from a database containing around 10,000 volunteers for sensory analysis and consumer testing to ensure diversity in age and gender. Specifically, we selected a sample composed of approximately 50 % women and 50 % men, distributed across three age groups: 20–39 years, 40–59 years, and 60 years and older. This database was authorized by the Commission Nationale de l'Informatique et des Libertés (CNIL, France).

For the purposes of the study, 132 subjects were recruited and randomly divided into two groups differing in tasting of extra virgin olive oil without or with camelina oil, and each of the group differing in the order of the sequential information revealed (see below Fig. 1 for details regarding the design). Groups G1 and G2 only tasted camelina oil, while groups G3 and G4 tasted both olive and camelina oils. Groups G1 and G3 received first the information concerning the environment at steps 3 and 5, and then concerning health at steps 4 and 6. Conversely, groups G2 and G4 received first the information concerning health at steps 3 and 5, and then concerning the environment at steps 4 and 6.

Table 1 shows some characteristics (gender, age, level of education and frequency of seasoning oil consumption) of the panel by distinguishing the group **G1&G2** facing one oil and the group **G3&G4** facing two oils. Note that the two groups were very close (χ^2 tests leading to $p > 0.304$ for gender differences, $p > 0.808$ for education level and $p > 0.25$ for age). The characteristics were relatively similar to those observed for the French population in terms of age, gender, and level of education.

2.3. Products

Two commercially available edible oils, camelina and olive, were selected for the study. Both oils were certified organic and sold with

Table 1
Panel, sociodemographic characteristics and oil consumption (from the exit questionnaire). Groups G1 & G2 only tasted camelina oil, while groups G3 & G4 tasted both olive and camelina oils. The difference between G1 & G2 and between G3 & 4 was only the order of received information concerning the environment and health at steps 3 and 5, and at steps 4 and 6. χ^2 test was performed between Group G1&G2 and Group G3&G4 ($p > 0.05$ for all items).

		GROUP G1&G2	GROUP G2&G3	All	French population
		($n = 58$)	**($n = 74$)**	**(n = 132)**	
Gender	Women (%)	57.55	47.9	51.9	51.6
	Men (%)	42.45	52.1	48.1	48.4
Age (year)	20–39 (%)	31.15	29.15	30.1	31.2
	40–59 (%)	43.85	53.4	49.6	34.4
	60 and over (%)	24.95	17.45	20.3	34.4
Education level	< Baccalaureat (%)	3.7	10.75	7.5	28.4
	Bac and 2 years after bac (%)	49.85	47.9	48.9	40.3
	2 years after bac (%)	46.4	41.35	43.6	31.3
Seasoning [a]	Sunflower oil (%)	55.2	58.7	57.0	
	Olive oil (%)	93.1	98.7	95.9	
	Rapeseed oil (%)	37.9	44	41.0	
	Blended oil (%)	31	32	31.5	
	Soybean oil (%)	1.7	1.3	1.5	
	Flaxseed oil (%)	5.2	6.7	6.0	
	Walnut oil (%)	44.8	36	40.4	
	Grapeseed oil (%)	15.5	17.3	16.4	

From the exit questionnaire, the exact wording of questions was: [a] "In general, what oil(s) do you use in your home? Multiple answers possible."

similar bottles. The cold pressed Camelina Oil, sold under the *Naturalia* brand and with a bottle of 25 centiliters was sourced from the French organic store *Naturalia*. The relatively small bottle size (25 cl) reflected the standard packaging format typically used for camelina oil, which remains a premium product on the edible oil market. The Extra Virgin Olive Oil, sold under *Carrefour* brand and with a similar bottle of 25 centiliters, was coming from the organic shelves of the supermarkets *Carrefour*. From the multiple-choices question about the seasoning, which allowed capturing the possible combinations of oil consumptions, the bottom of Table 1 shows that the olive oil was the "most frequently used" (95.9 %), justifying the choice of this alternative oil for the group G3&G4. The content in omega-3 compared to omega-6, is much higher for Camelina oil than for Olive oil, with a ratio of ω-3/ω-6 equal to 2.5 for Camelina oil and equal to 0.06 for Olive oil (from Table 1 in Gillespie et al., 2025).

Participants in groups G1 and G2 only faced the camelina oil bottle, while groups G3 and G4 faced both the extra virgin olive oil bottle and the camelina oil bottle. Fig. 1 illustrates the bottles used, along with the sequence of steps of information disclosure described in the following sections. "Consequential" means that one bottle was possibly sold at the end of the session based on one of indicated WTP within the BDM (for Becker et al., 1964) mechanism, while "hypothetical" means that no bottle was possibly sold (Fig. 1).

2.4. Sequential experimental steps

This experiment successively combined perception, hedonic questions and WTP elicitation. To elicit participant willingness to pay (WTP), our experiment used the BDM procedure. WTP was provided by each participant for the blind tasting and after every successive step of information disclosure. The exact question was as followed: "What is the maximum price you are willing to pay for the following bottles of oil?" The question was repeated for each product. The details of information provided at each session to the participants for every step of the experiment are now described.

Initial Step.

After entering the room, each session began with general information about the experiment, followed by the reading by each participant of the information sheet detailing the conditions of participation and the reciprocal commitments of experimenters and participants.

More particularly, it was explained that each participant would receive €8 in addition to the initial €10 announced during the

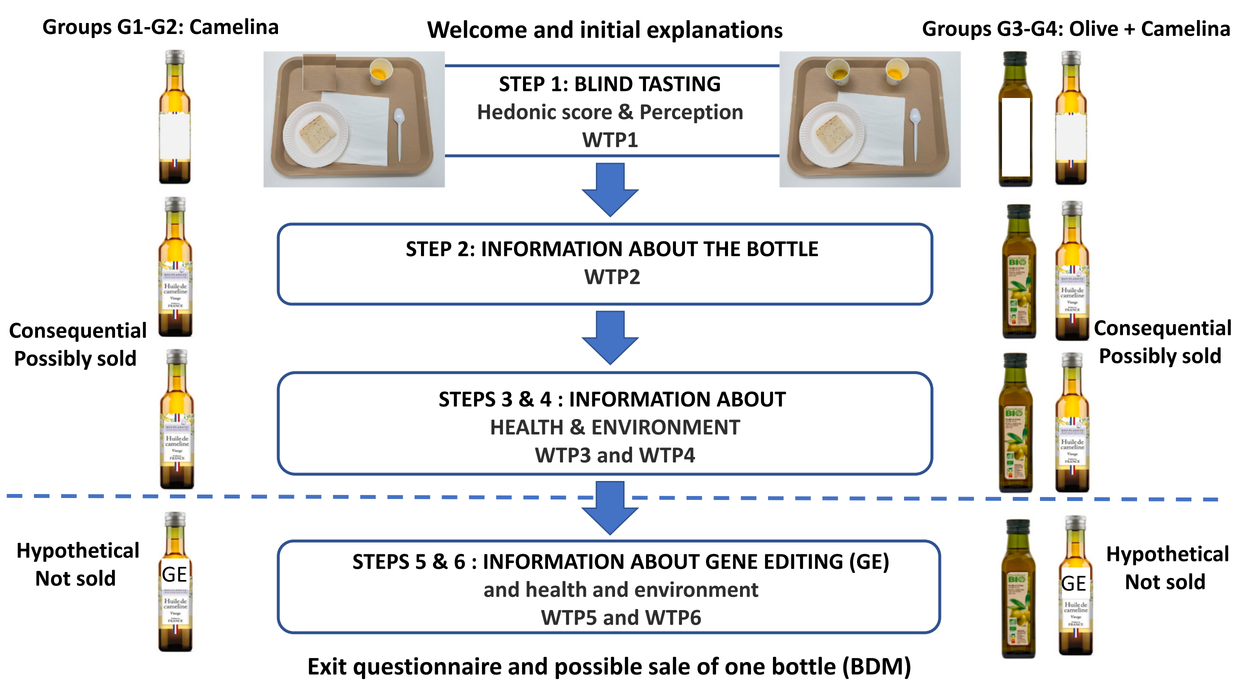

Fig. 1. Bottles and Timeline proposed during the test. Groups G1 and G2 were exposed only to the camelina oil bottle, while groups G3 and G4 were shown both the camelina and olive oil bottles. Participants in G1 and G3 first received information related to health, followed by environmental information. G2 and G4 were first presented with environmental information, followed by health-related content. WTP: willingness to pay, BDM: Becker-DeGroot-Marschak mechanism.

recruitment, for allowing the possible purchasing of one bottle. The principle of experiment was clearly stated at the beginning of each session: for each participant one of his chosen WTP indicated during the session will be randomly selected at the end of this experiment to determine whether or not participants would buy one bottle at a draw lot price (i.e., performance-based financial incentives). In other words, a purchasing price was drawn at random at the end of the experiment, and purchasing choices were enforced by comparing this purchasing price to one of WTP randomly selected following the BDM procedure initiated by Becker DeGroot and Marschak (see Becker et al., 1964). If the selected WTP was smaller than the randomly drawn price, the participant received the €18 indemnity without purchasing the bottle. If the WTP was higher than the price, the compensation was equal to €18 minus the price randomly drawn, and the participant received the bottle of oil (0.25 l). The purchasing price was randomly selected among "prices" uniformly distributed between €0.10 and €10 with an increment of 10 cents.

An example with a WTP for an apple was given with the initial instructions. We emphasized that, under the BDM procedure, the dominant strategy for a participant really consists in reporting her/his true WTP. It was clearly stated that choosing a WTP equal to €0 would mean that the participant will never buy the oil and leave with the €18 stipend. Finally, the participants signed the consent form before proceeding to the experiment.

Step 1 - Blind tasting and bottle(s) with a cover.

Participants were asked to indicate their overall liking for camelina oil (groups G1 and G2), or for camelina oil and extra virgin olive oil (G3 and G4). 10 bottles of camelina oil (G1&G2), or 10 bottles of camelina oil and 10 bottles of extra virgin olive oil (G3&G4) were displayed on a table at the center of the room. At this stage, their labels were hidden. For groups G3 and G4, the product A (Extra virgin olive oil) was systematically tasted before the product B (camelina) for measuring the impact of a reference oil compared to camelina oil.

The instructions given were as follows: "Observe, smell, and taste the oil, then indicate your overall appreciation below. Take the necessary time to taste the product before providing your answers. To taste the oil, you can use the provided spoon or a piece of bread." The bread used was the unsweetened-sandwich bread. Mineral water was also provided to rinse the mouth. After tasting the sample of oil in the specified order, the participants were asked to indicate their liking on a discrete 7-point scale, ranging from "I don't like it at all" to "I like it a lot" (Lawless & Heymann, 2010).

The participants also evaluated the intensity of eight sensory attributes (colorful, bitter, fruity, sour, pungent, earthy, musty, and rancid), based on a preliminary study and literature (Ellis & Gámbaro, 2024; Momot et al., 2023) on a scale from "not intense at all" to "very intense." The use of this methodology was not to obtain objective, standardized sensory profiles, but rather to capture subjective perceptions of intensity as experienced by consumers, which may influence their liking and willingness to pay. Then, participants had to give their WTP for the corresponding bottle with hidden information (see Fig. 1). Several bottles with a cover were exhibited on a table to observe a 25 cl-bottle.

Step 2 - Presentation of the Camelina oil and bottle without the cover.

The bottle identity was revealed with the oil name, origin of production and organic certification. The message was the following: "Both oils are from the organic sector [for groups G3 and G4] and oil B is from the organic sector [for groups G1 and G2].

Oil B comes from the camelina plant, whose seeds are used to produce this oil. Sold in stores, camelina oil is not intended for frying, but rather for accompanying light cooking or salads. [A picture of the plant during the blossom was shown].

We just removed the cover from the bottles on the table behind you."

After this message, new WTP were elicited for each bottle.

Step 3 to 6 - Additional information in different orders.

The participants successively received messages related to the camelina oil (in different orders as detailed in the next subsection), then had to give their WTP again. At steps 3 and 4, the messages unveiled the advantages of camelina production and consumption for the environment or consumer health, in different orders depending on groups. At steps 5 and 6, the messages concerned gene editing for improving camelina benefits for consumer health or the environment. We made it clear that this was a virtual situation, as such a product does not yet exist or have been authorized for sale, and that the corresponding WTP would therefore not be taken into account in the BDM mechanism (see the bottom of Fig. 1).

Step 7 - End of the experiment.

The participants had to answer a questionnaire intended to collect socio-demographic characteristics and to identify their consumption habits and their attitudes toward new foods. The questions concerned the following variables: age, sex, socio-professional category, income, education level, number of people in the household and number of children, responsibility for household purchases, frequency of oil consumption, beliefs about new foods and the use of camelina for the jet fuel production. We decided to particularly focus on some of them. The exact wording of questions was: "Before coming to this session, had you heard of camelina?", "Before coming to this session, had you seen camelina oil for sale in stores?", "Do you plan to buy camelina oil in the future if it is sold at prices close to those of other oils?", "Do you think that technological innovations in the food sector are compatible with respect for the integrity and naturalness of food?", "If the genetic modifications are low, would you be willing to consider these plants as organic?", "Techniques that aim to introduce a gene from another variety of the same food product (for example, the introduction of a gene from a Gala apple into the genome of a Granny Smith apple) may be authorized", "Techniques that aim to introduce a gene from another food product (for example, the introduction of a gene from cauliflower into the genome of a tomato) may be authorized", "Research on genetic editing of food should be prioritized, but only as an insurance to possibly have plants that can be grown in extreme conditions (drought, diseases)?", "Do you think that public authorities should take a more active position on innovations in biotechnology?", "What is the maximum percentage increase for your plane ticket using sustainable aviation fuel reducing aircrafts CO2 emissions by X%, would you be willing to pay?" with $X = \{20\,\%;50\,\%\}$, "Is it useful to limit the share of crops and plants dedicated to energy and transportation?"

Then the BDM procedure was implemented for determining whether or not the bottle will be purchased, based on an individual random draw for each participant.

2.5. Information revealed to the participants

Health benefits linked to Camelina (at step 3 for groups G1&G3 and step 4 for groups G2&G4): "The camelina oil we offer you is very rich in omega-3, which are polyunsaturated fatty acids with several health benefits. Omega-3 contribute in particular in reducing the risk of cardiovascular disease. They also play a positive role in brain health, helping to reduce certain risks of depression and certain risks of age-related dementia. In France, a large proportion of the population does not consume enough omega-3. Consuming this camelina oil would therefore help increasing your omega-3 intake. Camelina oil oxidizes very slowly, preserving the oil quality."

Regarding the last sentence of this relatively short message, note that camelina oil is rich in omega-3 fatty acids, which are beneficial for health, but also relatively more prone to oxidation compared to oils richer in monounsaturated fats like extra virgin olive oil. However, camelina oil is quite rich in tocopherols and phenolic compounds that were shown to be relatively protective against oxidation observed in other oils rich in omega-3 fatty acids (Maqsood et al., 2014; Tabee et al., 2008).

Environmental benefits linked to Camelina (at step 4 for groups G1&G3 and step 3 for groups G2&G4): "Camelina oil is organic

([G1&G2] or Both oils are organic [G3&G4]). Production of camelina seeds to extract the oil, could be carried out on relatively poor, non-irrigated soils, with few or no pesticides. Camelina is also relatively resistant to drought, provided that its seeds have sufficient moisture to germinate. Camelina grown in summer could attract far more insects like pollinators than other crops thanks to its flowering period from June to August, a period when fewer plants species are in bloom. This makes it a valuable resource for endangered insects, such as wild bees. Furthermore, summer cropping helps in maintaining plant cover between two cash crops. Finally, camelina cultivation contributes to the diversification of cultivated species, which is one of the objectives of the agro-ecological transition."

Gene editing in relationship with health benefits linked to Camelina (at step 5 for groups G1&G3 and step 6 for groups G2&G4): "Extra virgin olive oil A is the same as before [only for G3&G4]. We are interested in an innovation concerning camelina oil. Research is underway to improve plants, such as camelina, using an innovative breeding method called genome editing. This technique allows precise modification of camelina genomic DNA to modify its genes in a targeted manner and thus increase the genetic diversity of the species. This method, also called CRISPR-Cas9, makes this modification faster and more precise than before. This technology was applied to the quality of the seeds, notably to increase the concentration of omega-3 fatty acids in camelina oil. Beside the omega-3 modification, the gene-edited camelina oil was equivalent to oils from conventional breeding that have not undergone this innovation. This oil is not authorized for sale and cannot be sold after this session.

The two oils will therefore not be included in the random draw that determines whether or not you will purchase the product. You are simply asked to indicate your values as if you were in a real-life purchasing situation."

Gene editing in relationship with environmental benefits linked to Camelina (at step 5 for groups G2&G4 and step 6 for groups G1&G3): "The aforementioned genome editing technique (namely, CRISPR-Cas9) also makes it possible to improve the camelina agronomic traits, notably by increasing its drought tolerance and its flowering precocity while preserving all the other plant natural characteristics. These traits are favorable to camelina's adaptation to constrained climatic conditions as well as to practices in agroecology.

Beside from these changes, gene-edited camelina oil was equivalent to camelina oils from conventional breeding, which have not undergone this innovation, particularly in terms of nutritional benefits. This oil is not authorized for sale and cannot be sold after this session.

It will therefore not be included in the random draw that determines whether or not you purchase the product. You are asked to indicate your values as if you were in a real-life purchasing situation."

2.6. Data analysis

For the liking scores, the choices resulted in discrete values ranging from −3 to +3, where −3 corresponded to "I don't like at all," −2 to "I don't like," −1 to "I slightly disliked," 0 to "neither like nor dislike" (indifference), +1 to "I slightly like," +2 to "I like," and + 3 to "I like a lot". Liking scores after the blind tasting were analyzed using two-way Analysis of Variance (ANOVA) with products and consumers as main effects, followed by Mann-Whitney U test ($p < 0.05$) to determine differences between oils. Each of the eight sensory characteristics (colorful, bitter, fruity, acid, pungent, earthy, musty and rancid) was mapped as follows: 1 for "not intense at all", 2 for "not intense" 3 for "moderately intense", 4 for "intense", and 5 for "very intense". These data were submitted to an ANOVA for each attribute, with products and participants as main effects. Post-hoc multiple comparison tests were performed to interpret pairwise differences between oils (Tukey HSD test, $p < 0.05$). For each oil, the links between the liking and the perceived characteristics were analyzed using linear regressions. Analyses of variance and linear regressions were performed using XLSTAT (Addinsoft, 2017, Paris, France).

The links between liking scores and willingness to pay were studied using the Pearson correlation coefficient.

For the WTP, average values were presented for different products and for the different steps at which WTP were elicited. Wilcoxon tests were conducted for comparing paired sample WTP values and measuring the statistical significance of differences between WTP elicited for different products and different steps.

Eventually, the impacts of messages on WTP for camelina only were analyzed with several regressions (random effects Tobit model) to obtain some additional details captured by dummy variables equal to 1 for a corresponding characteristic or zero otherwise. Given that each participant i wrote six WTP values for camelina, errors related to these WTP are potentially correlated for each participant. The random effect imposes constraints on the structure of the variance-covariance matrix. Furthermore, a WTP cannot be negative and is left-censored at zero, which is why we use the random effects Tobit estimator. We used the *R* package *pglm* that approximates the likelihood function via a Gauss–Hermite quadrature (Croissant, 2017). The model takes into account, for camelina oil, the global effect of the information concerning the benefits for health and the environment, the two messages about the GE, the liking scores given during the blind tasting, and the effect of a few socio-demographic variables (only keeping the variables having a significant impact).

3. Results

3.1. Liking related to the blind tasting at step 1

Fig. 2 shows the distribution of appreciation scores for oils depending on the groups G1&G2 with Camelina alone (left chart) and G3&G4 with Camelina and Olive (right charts), and based on their sensory properties alone. The charts underline heterogeneous appreciation scores. The blind tasting showed that 35 % of consumers disliked the camelina oil (with scores below 0), while 45 % liked it (with scores above 0). The remaining consumers were neutral regarding this oil (with a score equal to 0). For extra virgin olive oil, an interesting disparity was observed, with a bimodal distribution of liking scores (chart on the right).

Fig. 3 shows the box plots of appreciation scores for the different oils and different groups. Globally, results show that all the oils were moderately appreciated, with a mean liking score of 0.233 for camelina oil alone, −0.258 for camelina oil presented alongside extra virgin olive oil, and 0.025 for extra virgin olive oil, on a scale ranging from −3 to +3. (Fig. 3). Among the different groups of consumers, the group that tasted both camelina and extra virgin olive oils together, showed a significantly lower liking score for the camelina oil compared to the group with camelina only ($p = 0.046$).

The effect of presenting camelina oil alone versus in comparison with extra virgin olive oil was assessed by comparing the liking scores between groups G1 & G2 (camelina oil only) and G3 & G4 (camelina oil presented with extra virgin olive oil) (Fig. 3). A Mann–Whitney test revealed that the liking scores for camelina oil were significantly higher when it was evaluated alone than when it was assessed following the tasting of olive oil. This suggests that the presence of a familiar reference product, such as olive oil, may negatively influence the hedonic evaluation of camelina oil. However, this effect should be interpreted with caution, as the distribution of liking scores for olive oil was bimodal—indicating a strong polarization in preferences, with approximately half of the participants appreciating it and the other half disliking it. Such variability may have introduced contrast effects or expectation biases that differentially affected the evaluation of camelina oil across participants.

The results of perceived intensities for the 8 sensory characteristics are represented in Fig. 4. Some differences between the oils were revealed. Extra virgin olive oil was perceived as more bitter, fruity, acid

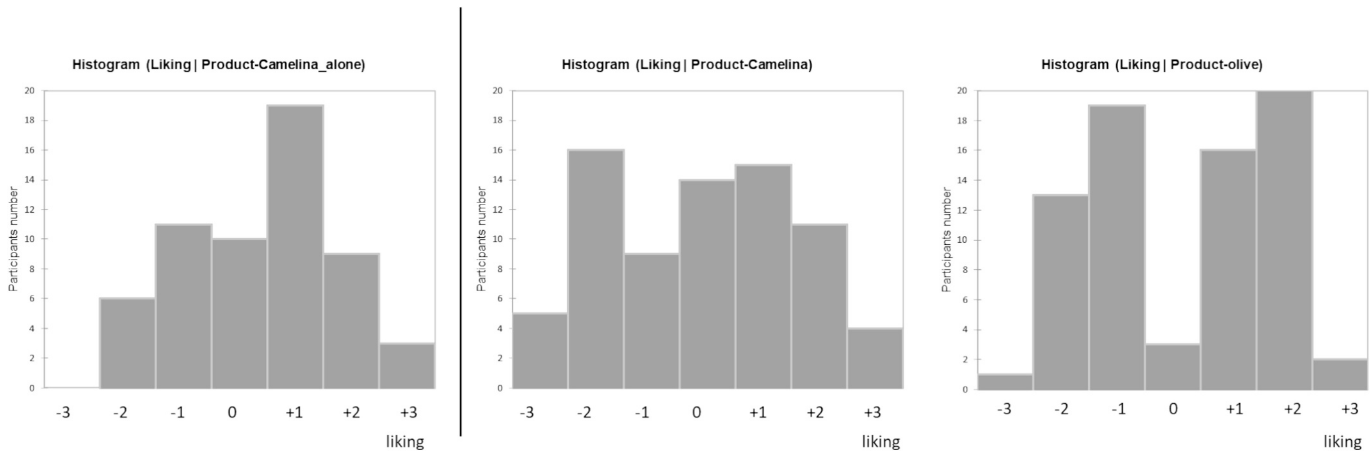

Fig. 2. Number of participants having scored the liking of the three oils (camelina tested alone, camelina tested with olive oil and olive oil) on a 7-point scale ranging from "dislike a lot" (-3) to "like it very much" (+3).

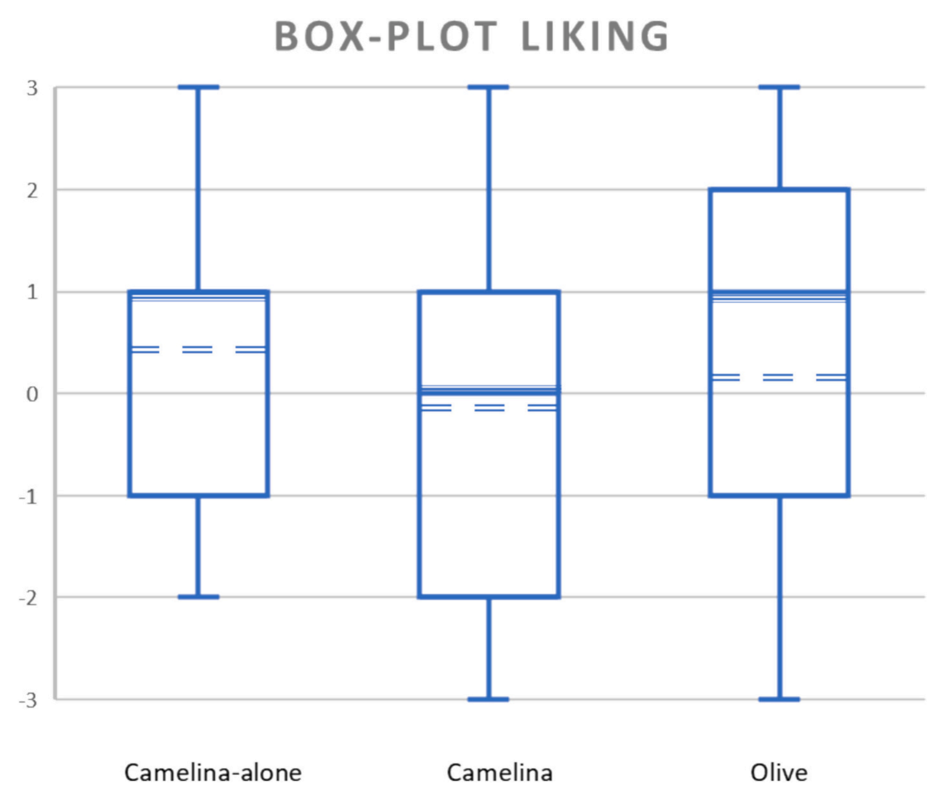

Fig. 3. Box plots of liking for camelina oil alone (evaluated by groups G1&G2), and camelina and olive oils (evaluated by groups G3&G4) on a 7-point hedonic scale (-3 = strong dislike, 0 = neutral, $+3$ = strong like). Dashed lines indicate mean liking scores; double solid lines represent the medians.

and pungent, and less earthy, musty and rancid compared to camelina oil. These significant differences suggest a potential for a product differentiation in the context of salad dressing.

Moreover, to get a clearer view of differences between oils, we separately regressed the liking with the perceived intensities of eight attributes for each oil (Fig. 5). While the liking scores of camelina oil was mainly and positively related to fruity notes, the liking of extra virgin olive oil was negatively related to its bitterness.

3.2. *Correlation between Liking and Willingness to Pay (WTP)*

The correlations between liking scores and WTP are positive but relatively weak, particularly for the camelina oil, which had been previously seen in stores by only 12 % of participants (as stated in the exit questionnaire). For all the participants, the Pearson correlation coefficient between the liking scores and the WTP values at step 1 is equal to 0.181 (with a p-value equal to 0.009). This low correlation may reflect the difficulty participants had in estimating their willingness to pay for an unfamiliar product such as camelina oil. In groups G3 & G4, the correlation between liking and WTP was higher for extra virgin olive oil than for camelina oil, with a Pearson coefficient of 0.382 ($p = 0.006$). However, the relatively weak correlations observed, particularly for camelina oil, may not only be due to unfamiliarity, but could also be partially explained by the bottle format used in the study. Vegetable oils are typically sold in 1-l bottles or larger, and the smaller 0.25-l format used here may have made price extrapolation more difficult for participants, potentially blurring the link between sensory appreciation and economic valuation.

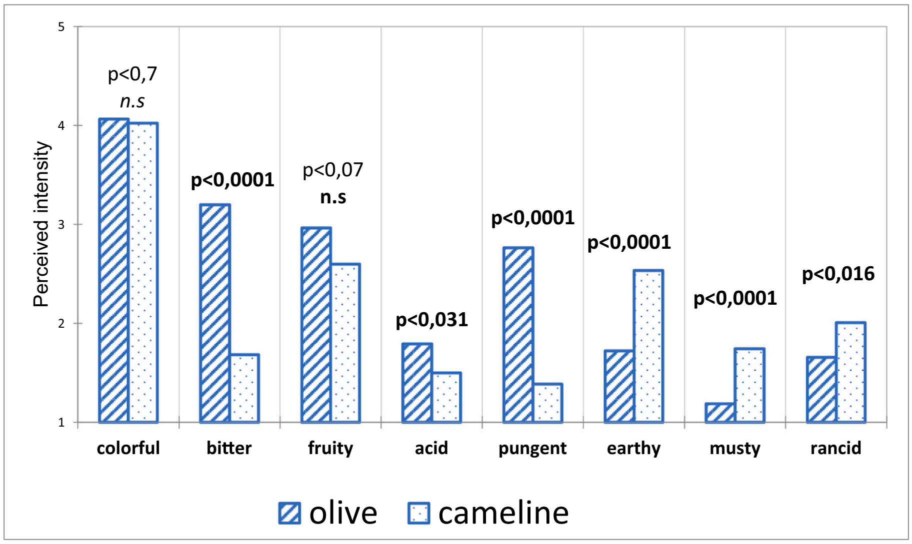

Fig. 4. Perceived intensities for the 8 sensory characteristics for olive and camelina oils for participants of groups G3&G4 facing both bottles. Comparison between oil perceptions was performed with ANOVA.

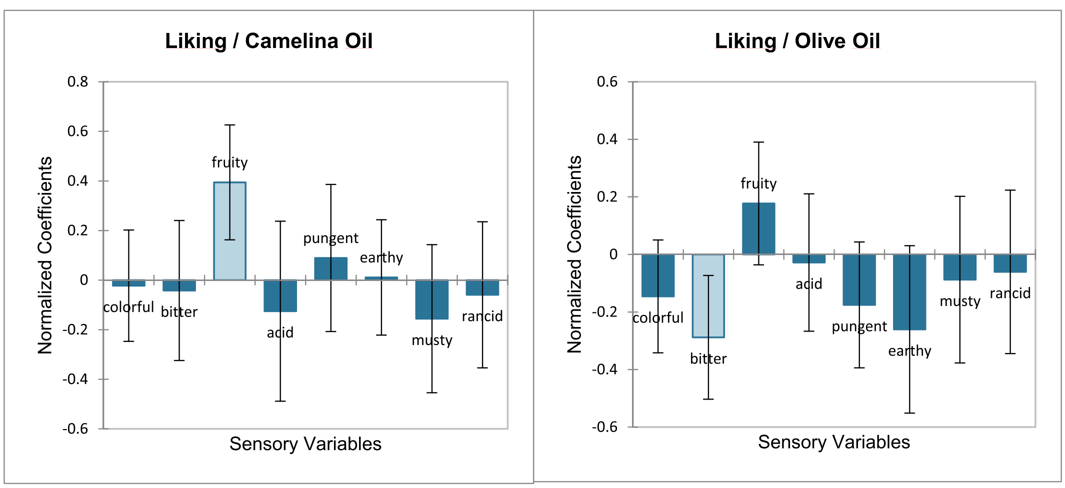

Fig. 5. Linear regressions between the liking and the 8 variables regarding the perceived intensities for camelina and olive oils for the participants of groups G3&G4. The light blue represents statistically significant differences, while the dark blue indicates non-significant differences. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

3.3. WTP for one oil bottle

The descriptive statistics regarding the WTP for the different bottles of oil are presented in Fig. 6, with averages over all the subjects of G1&G2 (blue curve) and all the participants of G3&G4 (black curve) at the 4 different steps. The X-axis represents the step 1, after the blind tasting; step 2, after the appearance of packaging revealing the camelina; step 4, after the revelation of both information (health and environment) for the conventional oil; and step 6, after the revelation of both information (health and environment) for the GE oil (see also Fig. 1 for details).

The average WTP for camelina oil presented with extra virgin olive oil (plain black curve) was not significantly different from the WTP for camelina oil only (plain curve in blue). The small differences in liking (see previous section) were erased when the subjects had to provide a WTP. Both plain curves (in dark and blue) reveal a similar evolution across the four steps.

Fig. 6 clearly shows the importance of shared information for the subject WTP for camelina oil. The identification of camelina oil at step 2 led to a significant increase in WTP, whereas a similar disclosure for extra virgin olive oil had no effect. This asymmetry may be attributed to a "novelty effect", camelina being a relatively unfamiliar product, rather than to the organic label itself, since organic extra virgin olive oil (already well-known) did not generate a significant change in WTP, as illustrated by the dashed curve. Additional information about the benefits of the camelina oil for human health and the environment led to significant increases in WTP (step 4). At this stage, the WTP for camelina oil exceeded that for extra virgin olive oil, suggesting a potential competitive advantage and possible market share gain for camelina. However, the introduction of the gene-edited (GE) improvement at step 6 caused a decline in WTP for camelina. On average, WTP at this stage (WTP6) aligned more closely with that of extra virgin olive oil, which was not associated with any GE-related information in the study.

Importantly, while WTP for camelina fluctuated throughout the steps depending on the information disclosed, WTP for extra virgin olive oil remained relatively stable across all steps (dashed curve in Fig. 6). The information focused on camelina, while being neutral regarding extra virgin olive oil. This suggests that highlighting the advantages of camelina oil did not generate negative spillover effects on extra virgin olive oil, likely due to the strong familiarity and established reputation of the

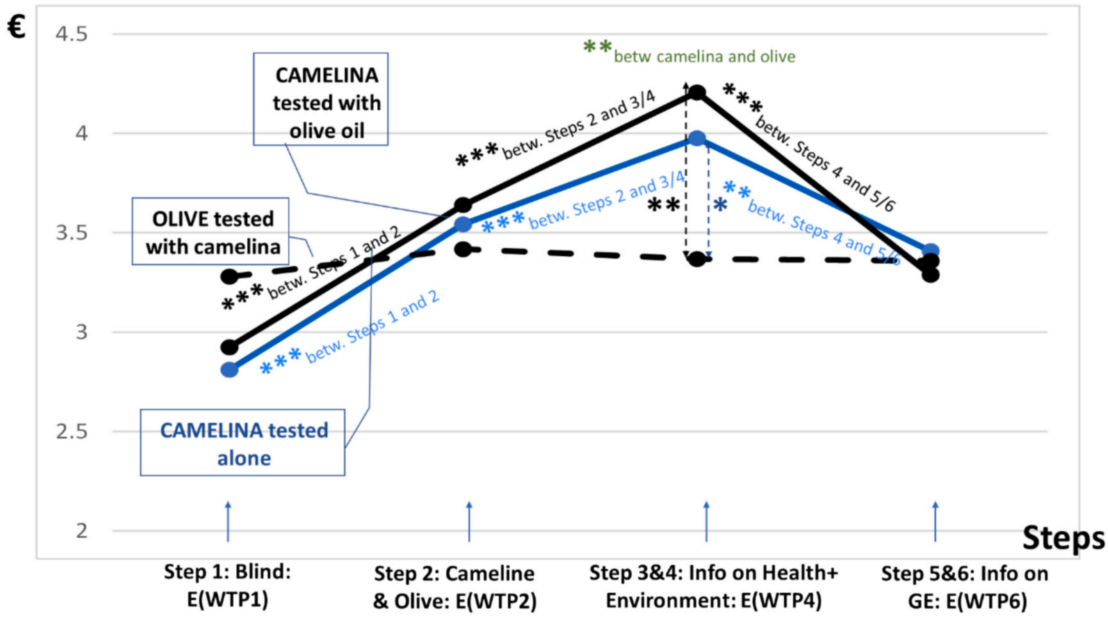

Fig. 6. Average WTP for one bottle of camelina oil only over all the subjects of G1&G2 (blue curve) and over all the participants of G3&G4 (black curve) for one bottle of camelina oil and one bottle of olive oil. The presence of stars (*, ** or ***) indicates a significant change between two steps characterized by the revelation of additional information or between products for the same step. All two-by-two comparisons were made and only significant comparisons are shown. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

latter, which contributes to its valuation stability. We then investigated whether the sequential order of provided information could modify the subjects' WTP for camelina oil.

3.4. The order of messages

Table 2 reports the results of the regressions (random effect Tobit model) assessing the impact of informational messages concerning the health and environmental benefits on the subject WTP. The analysis used a set of dummy variables (1/0), coded as 1 when a specific message was presented (at Step Z, with Z = {2, …,6}) and 0 otherwise. The table presents the estimated coefficients for each of the variables taken into account in the regression model. For a given variable, the higher the coefficient, the more the corresponding factor had a positive impact on the WTP in response to a message. Conversely, the smaller the coefficient, the more the corresponding variable had a negative impact on the WTP given a message. The p values associated with each coefficient specify whether the impact was significant or not, with a threshold set at 1 % (***), 5 % (**), and 10 % (*). Standard errors in parentheses. The constant and 3 socio-demographic variables represent the baseline WTP at step1 for Camelina when all other variables are zero (the omitted variable is for step 1).

Table 2
Global impact of health and environmental information on WTP for Camelina: estimated coefficients coming from the regression (random effect Tobit model).

Independent variables	WTP for Camelina		
Constant	3.22	***	(0.25)
Liking (score from −3 to +3)	0.35	***	(0.05)
Gender (woman = 1, man = 0)	0.47	***	(0.05)
Income [a]	−0.001	***	(<0.001)
Step2 (1/0) (camelina oil revealed)	0.75	***	(0.18)
Groups G1&G3			
Step3 (1/0) × Environ. First (1/0)	0.71	***	(0.23)
Step4 (1/0) × Health Second (1/0)	0.96	***	(0.22)
Step5 GE (1/0) × Environ. First (1/0)	0.10		(0.23)
Step6 GE (1/0) × Health Second (1/0)	0.29		(0.23)
Groups G2&G4			
Step3 (1/0) × Health First (1/0)	1.38	***	(0.22)
Step4 (1/0) × Environ. Second (1/0)	1.67	***	(0.23)
Step5 GE (1/0) × Health First (1/0)	0.45	**	(0.23)
Step6 GE (1/0) × Environ. Second (1/0)	0.51	**	(0.23)
Stand. devi ε (random effect of the estim.)	1.46	***	(0.04)
Stand. dev. μ (tobit part of the estimator)	1.83	***	(0.06)
Observations	$N = 792$		
Log likelihood	−1509		

Notes: Non-significant socio-demographic variables were not estimated in this table for clarity.
Significant difference is indicated by asterisks (* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$). Standard errors in parentheses.
[a] Average variable indicating monthly household revenue with 750 for rev. < 1000 €, 1500 for rev. ∈[1000–2000€[, …, 5500 for rev. ∈[5000–6000€[, 6500 for rev. > 6000€.

The results of Table 2 confirm that information significantly influences WTP as shown in Fig. 6. The 4 variables (*Constant*, *Liking*, *Sex*, and *Income)* explain the WTP at step 1 when the other dummy variables are equal to zero. The coefficient linked to each step measures the impact of this step (and the previous one) on the WTP compared to the step 1. The presence of extra virgin olive oil (coded 1/0) was not considered in the regression of table 2, since this variable did not have any statistical significance in alternative regressions, confirming the results of Fig. 6 showing very close curves for Camelina WTP across different groups. The revelation of the nature of the oil, namely Camelina at Step 2, led to an average increase of WTP equal to 0.75. The value of the coefficients associated with the successive steps respects the positive trend for steps 3 and 4 and a declining trend for steps 5 and 6, corresponding to the GE messages at stages 5 and 6. For these last steps 5 and 6, coefficients are not statistically significant for groups G1&G3, meaning that final WTP returned to step 1 WTP. For the groups G2&G4 the coefficients (0.45 and 0.51) are statistically significant, but lower than those in earlier steps (1.38 and 1.67 for Info3 and Info 4), probably because of the reluctance of some subjects to GE technology lowered their WTP. The coefficient obtained at step 3 suggests that the effect of the message was greater for the health information (coef. = 1.38 for groups G2&G4) than for the environmental message (coef. = 0.71 for groups G1&G3).

3.5. The reaction to the messages about GE

Fig. 7 illustrates the individual variations in WTP for a bottle of camelina oil following the disclosure of two successive pieces of information concerning gene-editing (GE), presented at Steps 5 and 6. These variations were measured as the difference between WTP6 (after the GE messages) and WTP4 (prior to any mention of GE), and are plotted on the Y-axis. Each data point on the X-axis corresponds to a single participant, sorted in ascending order of WTP variation—except at the boundary separating participants categorized as "afraid" from those deemed "reluctant," as discussed further below.

A negative change in WTP reflects a negative perception of GE (rejection effect), a value of zero indicates neutrality or indifference, and a positive change suggests a favorable response to the potential benefits of GE presented in the messages. It is important to emphasize that the content at Steps 5 and 6 exclusively highlighted potential advantages of GE, without mentioning any risks or controversies, indicating that the negative responses would originate only from the concept of GE itself, even when presented positively.

Fig. 7 clearly shows a fragmentation of consumers preferences regarding GE, with 4 subgroups represented. Inside each subgroup, we reported the WTP in increasing order. Between steps 4 and 6, 15.9 % of participants can be characterized as afraid participants (also referred to as boycotters), namely with a WTP initially greater than zero and becoming equal to zero after the revelation of insights about GE (with WTP4 > WTP6 = 0). The boundary between afraid and reluctant participants "breaks" the increasing order, since a few reluctant participants with a large decrease in WTP (between steps 4 and 6) still have a positive WTP at step 6, with WTP6 > 0. 30.3 % of them decrease their WTP but still with a positive one for GE (namely, with WTP4 > WTP6 > 0). 34.4 % are indifferent participants, with a similar WTP for the product whatever the presence or the absence of GE (namely, WTP4 = WTP6). Eventually, 19.4 % of them increased their WTP (namely, with WTP4 < WTP6). These figures suggest a relative acceptability of GE by a majority of participants (53.8 % of indifferent and interested consumers), provided that both health and environment benefits related to GE are clearly explained.

3.6. Preferences for characteristics related to food innovation, and jet-fuels made with GE

To better characterize the general opinion about food, camelina and its potential dual uses as food or by-product for energy, post-session questions were provided to all participants. Table 3 summarizes the key issues linked to participant perceptions. First, the top of Table 3 the initial knowledge about Camelina was very low (camelina section). Interestingly, after participating to a session, 69 % of participants declared being interested in purchasing the Camelina Oil, suggesting a persuasive effect of successive messages revealed to participants.

The central section of Table 3 focuses on innovation and possible neophobia regarding new foods. To further interpret participants' attitudes toward food technology innovation, the final questionnaire included specific items on the perceived compatibility between technological advancements and the preservation of food integrity and naturalness. Responses were evenly split: 39 % of participants considered such innovations to be compatible with these values, one-third did not, and the remaining of participants expressed uncertainty. This distribution highlights a clear divide in participant perception. There is, however, a complex and sometimes ambiguous relationship between innovation and the perceived naturalness of food (innovation section). For instance, only 17 % of participants agreed that genome editing (GE) could be compatible with organic production. This suggests a potential

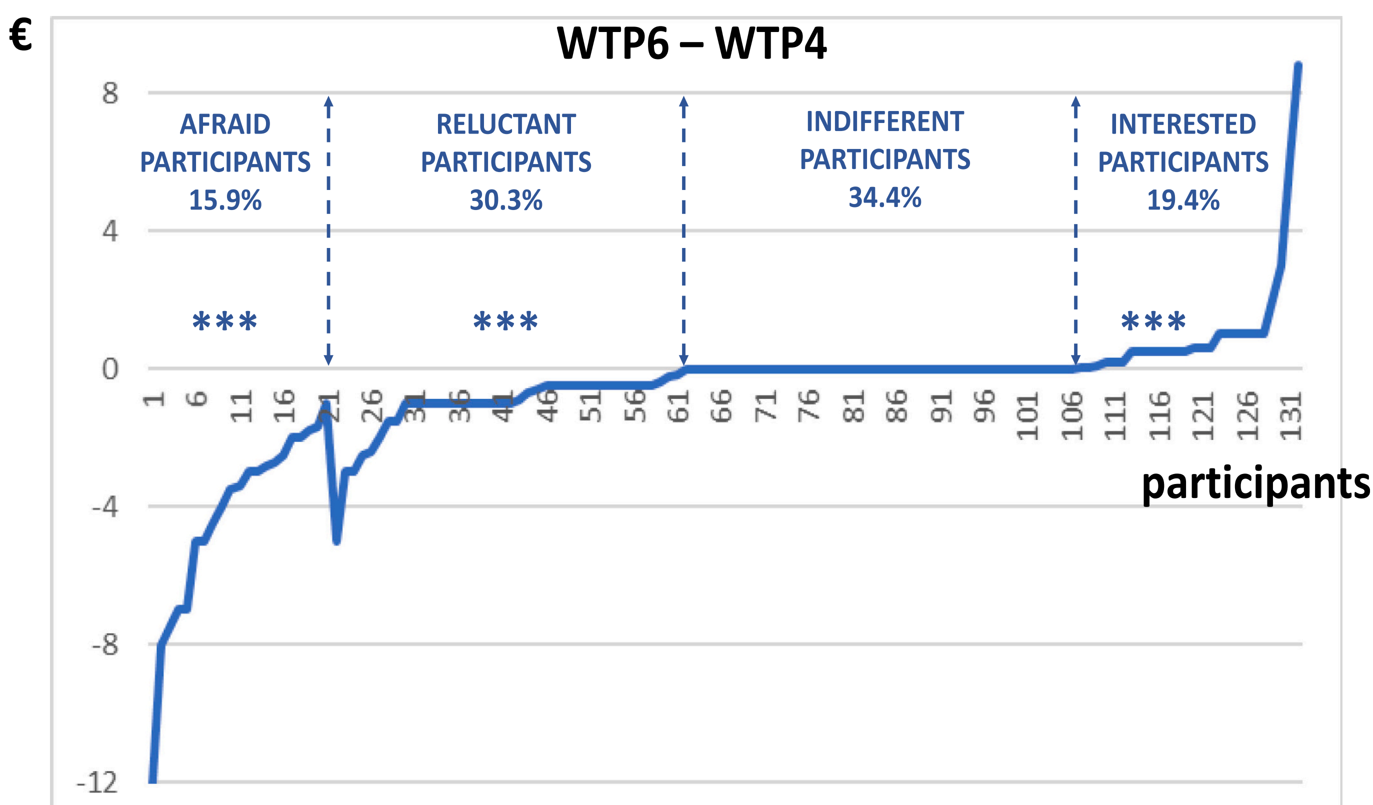

Fig. 7. Variation in WTP for one bottle of camelina oil, following the revelation of two messages about GE. The WTP variations are reported in increasing order for each subgroup, with the subgroup of afraid participants (WTP4 > WTP6 = 0), the subgroup of reluctant participants (WTP4 > WTP6 > 0), the subgroup of indifferent participants (WTP4 = WTP6) and the subgroup of interested participants (WTP4 < WTP6). For a subgroup, *** indicates a significant difference in variation from zero, at 1 % as tested by the Wilcoxon test.

Table 3
Perceptions and views (from the exit questionnaire).

Camelina	
The term camelina already heard before the session (% of Yes)	19 %
Bottle of camelina oil already seen in supermarket (% of Yes)	12 %
Purchase intent of camelina after the session (% of Yes)	69 %
Innovation and acceptability of new foods	
Food innovation is compatible with naturalness of food (% of Yes)	39 %
GE food could be sold as organic food (% of Yes)	17 %
Authorization of GE introducing a gene from another variety of the same food (average support)	−0.46
Authorization of GE introducing a gene from another food (average support)	−1.06
Authorization of GE as an insurance against extreme events with plants that can be grown in extreme conditions (average support [a])	0.80
More public intervention regarding biotechnology (% of replies "Absolutely")	65 %
Jet Fuel coming from plants including Camelina	
Average premium that participants are ready to pay for airplanes tickets using fuel from plant origins and reducing the CO2 emissions by 20 % (% of price) [b]	5.1 %
by 50 % (% of price) [b]	6.5 %
Ave. premium after explanations about negative consequences on the environment from plant growing for energy, the same question: reduction in CO2 by 20 % (%)[b]	3.6 %
by 50 % (%)[b]	5.4 %
Necessity to regulate the crops/biomass for energy & transport (% of Yes)	68.9 %

Notes: From the exit questionnaire, the exact wording of questions is given in the step 7 of section 2.4.
[a] Average support measured by a scale starting with −2 for "not favorable at all" to +2 for "very favorable.
[b] Possible replies ranging from 0 % to 40 % with a 5 % increment.

confusion or lack of clarity among consumers regarding what "organic" entails, and how it differs, or not, from modern biotechnologies. Similarly, the concept of "naturalness" itself remains poorly defined in the minds of many participants, complicating the acceptance of novel food products such as camelina oil.

Additionally, some questions regarding the authorization of GE allow to measure the acceptability or reluctance regarding some applications of genomic technology, including classical transgenesis and GE, referred as biotechnology. Based on a scale going from −2 for "not favorable at all" to +2 for "very favorable", the average support for authorization is negative, reflecting an overall reluctance despite some heterogeneity, which is in line with the variations of WTP underscored in Fig. 7. The reluctance for gene transfer from another food (−1.06) is stronger than the reluctance for the transfer of a gene from another variety of the same food (−0.46), being perceived as less manipulated. Interestingly, the authorization of GE for food as a possible insurance against extreme events with plants that can be grown in extreme conditions received significant support (0.80). These findings reflect ambivalent and in some cases resistant, attitudes toward food technology, underscoring the importance of public trust, ethical considerations, and communication in the development and implementation of future innovations. Eventually, the support for more public intervention regarding biotechnology is strong (65 %). The fact that the classification as GMO refers to different genomic technologies ranging from site directed mutation of few nucleotides (GE) to the transfer to one or several genes (transgenesis) does not help public decision-making concerning their acceptance or not of these products.

The bottom of Table 3 focuses on by-product for energy with consequences on land-use. Since camelina is currently considered a potential source of sustainable oil for jet fuel, we investigated whether the participants' knowledge about camelina acquired during the session could impact their willingness to pay for the use of sustainable jet fuel made from plant-based sources. Overall, participants are ready to pay a relatively small average premium for airplane tickets using sustainable jet fuels, namely between 3.6 % and 6.5 %, even when informed of their potential to reduce CO_2 emissions. Moreover, 68.9 % of participants supported regulating the production of plants/biomass for energy and transport, particularly when it competes with food and feed uses.

Table 4 shows that premiums for airplane tickets using jet fuel made from plants/oils and reduces the emissions by 50 % is mainly explained by both the level of education and the importance participants place on the environment in food choices ($R^2 = 0.42$). However, additional regressions (not showed in Table 4) revealed that this premium for jet fuel made from plant sources was not significantly influenced by the premiums for Camelina (WTP4-WTP2) after participants received information about its health and environmental benefits. This suggests that there are "segmented preferences for the environment" when it comes to food versus transport, indicating that people's environmental concerns may differ according to the related sectors, such as food or transport.

4. Discussion

To the best of our knowledge, this study is the first to combine both hedonic scores and WTP for camelina oil, which was directly offered to consumers for tasting. This approach differs from Rokka et al. (2002) who focused on sensory quality of eggs from hens fed with camelina meal, resulting in a high level of omega-3 in eggs. Despite inherent limitations linked to the lab environment (namely, the possible biases regarding WTP and the artificial environment), several important conclusions can be drawn from the study.

4.1. Liking and willingness to pay based on blind tasting

Consumer food preferences are shaped by complex interactions, among which sensory attributes play a major role. Accordingly, the first step of this study involved a blind tasting session, conducted in two distinct contexts: for half of the participants, camelina oil was evaluated in isolation, while for the other half, it was assessed in direct comparison with a well-known reference product, olive oil. This design allowed us to investigate the potential impact of a familiar comparator on the sensory evaluation of a lesser-known product.

Analysis of hedonic scores revealed that 35 % of participants disliked camelina oil, while 45 % expressed a liking for it, with the remainder showing neutral reactions. Similarly, WTP for the unknown oils (WTP1) indicated a promising initial interest in camelina oil (Fig. 6), suggesting a potential for future market interest. At Step 2, the revelation of the bottle contents and elicitation of WTP2 indicated a "surprise effect": identifying the oil as organic camelina significantly increased WTP, whereas disclosing that the extra virgin olive oil was organic had no impact. Given that only 12 % of participants were initially familiar with camelina, this suggests that unfamiliarity can positively influence perception when the product is framed with favorable attributes, reinforcing the potential for camelina's market development. However, while this "surprise effect" demonstrates the potential of positive framing and novelty to enhance perceived value, its long-term persistence remains uncertain. Some studies on food neophobia and repeated exposure (Zandstra et al., 2000) suggest that initial positive shifts in willingness to pay or liking, driven by contextual cues or information, may diminish over time without repeated consumption and

Table 4
Premium for the airplane ticket with jet fuel made with plants reducing the emissions of 50 %: estimated coefficients coming from a linear regression.

Independent variables	Premium for the ticket reduction in CO2 emissions by 50 %		
Education	0.03	***	(0.01)
Importance of environment for food [a]	0.04	***	(0.01)
	$N = 133$, Adjusted $R^2 = 0.42$		

Notes: [a] Yes = 1 for replying to the exact question was "Do you think that food should be produced using environmentally friendly methods even if this increases the cost of production?"

reinforcement. Further research would be needed to determine whether this increased valuation of camelina oil endures beyond the experimental setting, particularly in real-world purchasing contexts.

Regarding product selection, it is important to note that although the two oils used in the study were sourced from commercially available products, their sensory profiles cannot be claimed to fully represent the entire diversity of their respective categories. Nonetheless, the dominant sensory descriptors for olive oil, namely bitterness, pungency, and fruitiness, are well-established in the literature (Aparicio & Luna, 2002; Bendini et al., 2007) and were observed in our blind tasting, supporting the representativeness of the sample.

Similarly, camelina oil has been consistently described in prior research as having earthy, nutty, and slightly bitter notes (Abramovic et al., 2007; Vollmann et al., 2007). These sensory traits were also identified by participants in our study, lending credibility to the selection of this particular commercial sample and supporting the generalizability of the findings within the constraints of a controlled tasting environment.

4.2. Effect of information about the benefits of Camelina for health and the environment

Our results showed that the information concerning the benefits for health and the environment of a new product can improve its acceptability, a result in line with several other works (Loebnitz & Bröring, 2015; Martin et al., 2021; Siegrist, 2008). These positive reactions to messages also come from the liking of camelina oil as revealed by the blind tasting, which appears as a necessary condition for reacting to cues (Martin et al., 2023; Saint-Eve et al., 2021). Under full information, combining sensory experience with information on production impact, omega-3 content, and environmental sustainability, the WTP for conventional camelina oil at Step 4 outdo the ones for olive oil (Fig. 6, Step 4). It means that there is a potential for boosting the demand, with the need of targeted communication to enhance consumer acceptance and awareness of health and environmental benefits. Notably, the health-related message had a stronger positive effect on WTP than the environmental message (Table 2), emphasizing the strategic importance of communicating on camelina oil primarily through its health benefits. Information via advertising could inform about the existence of the product unknown by many consumers (top of Table 3), as well as the positive impacts on health and environment.

However, beyond the weak actual demand by consumers, many hurdles like the poor incentives for farmers, the competition between oils, and the bottleneck related to the supply chain organization hinder the development of camelina.

4.3. GE Acceptability

Almost half of the participants (46.2 %) exhibited clear reluctance toward GE and a notable 53.8 % were either indifferent or favorable when potential health and environmental benefits of GE processes were clearly explained. The percentage of "afraid" participants (also called boycotters) was lower than the one observed in previous studies, which means that for some participants the GE reluctance may decrease when social benefits are clearly visible. It is also possible that application of GE on minor crop and unfamiliar products is less threatening than when applied to crop strongly contributing to the food chain. Recent contributions underlined a significant discount for GE foods compared to conventional foods, even if this discount in absolute value is lower than those observed for Genetically Modified Organisms (GMO) (see Beghin & Gustafson, 2021; Caputo et al., 2020; Marette et al., 2021; Marette et al., 2023). Given the heterogeneity of consumer responses illustrated in Fig. 7, implementing clear labeling of GE food presence or absence could be essential to support informed consumer choice and minimize market tension.

We could conclude that providing information has an essential role, and that some consumers tend to be more open when they understand the breeding objectives and the impact of the modified traits.

5. Conclusion

This study highlights both the opportunities and challenges in introducing camelina oil to consumers. Although the product was unfamiliar to the majority of participants (only 12 % had seen it in stores), 45 % expressed a liking for it, and WTP increased significantly when the oil was identified and further enhanced by information on health and environmental benefits. These results suggest a real potential for market development, especially when supported by adapted communication that emphasizes camelina's nutritional and ecological value.

However, the introduction of gene-editing (GE) in the messaging resulted in a significant decline in WTP, confirming continued consumer skepticism toward biotechnological processes in food production. Regarding the concerns about technology (loss of naturality, economic bias, …), it will be important to assure the concordance between the conditions of use of biotechnology on one hand, and the health and environmental goals that biotechnology could address (or not) on the other hand.

Besides the GE issue, many consumers are nonetheless still interested in the consumption of organic camelina oil, even if it appears as a novel food with clear sensorial typicity. Accounting for consumer preferences is therefore one possible key for developing better adapted camelina crop in complement to improvements of the agronomic performance, seed quality, land use allocation for this crop, but also farmers' incentives and supply chain organizations.

CRediT authorship contribution statement

Anne Saint-Eve: Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Jean-Denis Faure:** Writing – review & editing, Investigation, Conceptualization. **Alexandra Jullien:** Writing – review & editing, Conceptualization. **Christophe Martin:** Writing – original draft, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Stéphan Marette:** Writing – original draft, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Ethical statement

This experiment complied with all ethical guidelines released at both national and European levels. The current research has received formal approval from the CNRS on the 11th of September 2024 (UMR6265 / 2–24,208).

The authors ensure that the work described has been carried out in accordance with The Code of Ethics of the World Medical Association (Declaration of Helsinki).

Participants gave informed consent via the statement "I am aware that my responses are confidential, and I agree to participate in this survey" where an affirmative reply was required to enter the survey. They were able to withdraw from the survey at any time without giving a reason.

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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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Data availability

Data will be made available on request.

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