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1. Introduction

Technological innovations can contribute to the evolution of production systems and the attainment of more sustainable and healthier food products (Bigliardi and Filippelli, 2022). While a range of new technologies are continually being developed with the aim of improving productivity and quality for consumers, their industrial adoption and implementation are strongly influenced by consumer acceptability (Priyadarshini et al., 2019). Despite their various health and environmental benefits, food innovations sometimes encounter resistance from a portion of the population (Rabadán, 2021; Ronteltap et al., 2007; Siegrist and Hartmann, 2020). Several factors explain this reluctance, including changes in sensory properties related to innovative processes, fear of loss of "naturalness" or traditionality, mistrust of new technologies, and cultural habits (Hindsley and Ashton Morgan, 2022; Yang and Hobbs, 2020).

Innovation in traditional sectors such as dairy production is sometimes even more problematic as it can be a cause of cognitive dissonance, as consumers tend to reject innovations that may be perceived as altering the authenticity of traditional foods (Almli et al., 2011). Yet there are innovations that make dairy products healthier and more sustainable. This is the case with the From'Innov process, patented by INRAE (Garric et al., 2016). This new process saves up to 25 % water and energy (Chamberland et al., 2019), while producing cheeses with lower sodium and fat content, without the use of additives. On one hand, the nutritional and environmental benefits associated with this innovative process can promote its adoption by consumers. On the other hand, potential sensory modifications, as well as the technological breakthrough that can be perceived as a loss of naturalness and authenticity may limit its acceptability among consumers. Therefore, it is important to analyze these tensions and evaluate under what conditions an innovation of this nature can contribute to the development of products that generate health and environmental benefits, in a way that is compatible with consumer preferences. Indeed, a better understanding of the factors influencing consumer perception of these new foods is needed to highlight certain possibilities for overcoming any reluctance (Guiné et al., 2020).

In a previous study involving two cheeses obtained using the innovative From'Innov process and a leading commercial cheese on the market (Martin et al., 2023), we showed that consumers' willingness-to-pay (WTP) was increased by the dissemination of information on the environmental (water savings, energy savings, and reduction of pollutant residues during manufacturing) and nutritional (less salt, less saturated fat, and more protein) advantages of cheeses produced using the From'Innov process. In addition, the WTP for innovative cheeses has not been significantly altered by information revealing the use of the new process. Finally, we underlined the crucial importance of hedonic appreciation (and therefore sensory properties) in shaping the overall acceptability of the cheeses studied, as well as the possibility, to some extent, of compensating for a lower hedonic appreciation by providing

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positive information (improved nutritional and environmental qualities).

However, cheeses produced using the From'Innov process offer other advantages that could not be tested in the initial experiment, for fear of overburdening the protocol, but which nonetheless deserve to be studied. For instance, the From'Innov process also makes it possible to add probiotic starter cultures that contain strains of bacteria such as *Propionibacterium freudenreichii*. Probiotic microorganisms are defined as living microorganisms that, when administered in adequate amounts, confer a health benefit on the host (FAO/WHO, 2002). The dairy propionic bacterium *P. freudenreichii* has "Generally Recognized as Safe" (GRAS) status, as well as European Qualified Presumption of safety (QPS) status. This microorganism is widely studied for its probiotic properties (Rabah et al., 2017). It is marketed as a probiotic in various countries, including France, Finland, and Japan. In humans, its consumption modulates the intestinal microbiota in favor of bifidobacteria and to the detriment of clostridia (Hojo et al., 2002; Seki et al., 2004). The modulation of intestinal motility has also been reported in a clinical study (Bouglé et al., 1999). Several studies have shown the protective effect of *P. Freudenreichii* on the intestinal epithelial barrier with, in particular, an ability to limit the intensity of intestinal inflammation (colitis) (Foligné et al., 2010; Rabah et al., 2020). Moreover, the From'Innov process makes it possible to obtain cheeses that contain less sodium without altering the perceived salty taste. This low sodium content makes it possible, for example, to obtain a Nutri-Score of C for a soft cheese such as camembert, whereas almost all the soft cheeses on the French market have a Nutri-Score of D. The Nutri-Score is the system that French public authorities have chosen to recommend, without imposing it (Hercberg et al., 2022). Several European countries have also adopted this system. This logo, displayed on a voluntary basis and placed on the visible face of food packaging, provides consumers with legible and easily understandable information on the overall nutritional quality of a product when shopping. They can thus compare products and orient their choices toward foods of better nutritional quality (Crosetto et al., 2017; Ducrot et al., 2015 and 2016; Julia et al., 2016).

The present study complements the one carried out in 2023 by Martin et al. by specifically examining the impact of two new pieces of information (introduction of probiotics and improvement of the Nutri-Score via the new process) on the WTP of two cheeses made using the From'Innov process and a traditional commercial cheese. It seemed interesting to us to determine whether the use of an integrated score (Nutri-Score) was as effective as detailed information in promoting innovative cheeses. Indeed, several studies also show that the effect of information on consumers' WTP may vary depending on how it is presented to them (Grashuis, 2021; Ruggeri et al., 2021; Ufer et al., 2022). The impact of sensory properties and consumer perception regarding processes (innovative versus traditional) were also studied. We formulated the following hypotheses: i) confirmation of the significant impact of sensory properties on product acceptability, ii) confirmation of the non-significant impact of information concerning the innovative From'Innov process, and iii) positive assimilation of information concerning the introduction of probiotics in innovative cheeses and the improvement of their Nutri-Score.

Two secondary objectives were added to this study. The first was to identify potential areas for improvement in the sensory properties of innovative cheeses, with the aim of enhancing their hedonic appreciation. The second was to assess the relevance of a new WTP evaluation method, based on the identification of "acceptable price ranges". This objective was driven by very practical reasons. In previous studies (Martin et al., 2021; Martin et al., 2023), we have used price lists for direct WTP measurement. However, we observed that these lists were tedious for consumers to fill in, and generated a negligible number of errors (inconsistencies in the boxes ticked). Moreover, determining the proposed prices (range, number of prices, increment) requires subjective decisions that are likely to represent a bias. The new approach has been designed to solve this problem.

By addressing these objectives, we aimed to contribute to a better understanding of the conditions for the acceptance of innovative products with health benefits and, more broadly, to the development of knowledge on the determinants of food preferences.

2. Materials and methods

2.1. Experimental conditions

The experiment was conducted in June 2022 in a tasting room at the INRAE (National Research Institute for Agriculture, Food and Environment). The local ethics committee for research (Université Bourgogne-Franche-Comté) approved this study (# CERUBFC-2022–04-25–012). Individuals received oral and written information about the study and provided written informed consent before participating. They received €10 compensation for their participation in a session that lasted approximately 1 h.

2.2. Participants

A sample of 141 consumers was recruited from a database containing around 10,000 volunteers for sensory analysis and consumer testing. This database was authorized by the Commission Nationale de l'Informatique et des Libertés (CNIL, France). A questionnaire was used to select consumers of soft cheese with a bloomy rind (including occasional consumers). Among them, a selection was made to balance gender, age, and level of education (Table 1).

For the purposes of the study, these 141 subjects were divided into two groups to obtain variation in the order of the revelation of information. We balanced the two groups as much as possible in terms of age, gender, and socioprofessional categories. Group A received information concerning global nutritional quality (Nutri-Score), followed by information concerning the probiotics. Group B received the information in the reverse order.

Table 1 shows that the characteristics (sex, age, and level of education) of both the entire consumer panel and the two groups were close to those observed for the French population in terms of age, sex, and level of education (Chi^2, $p > 0.05$).

2.3. Products

2.3.1. Commercial cheese (classic process)

The commercial cheese was Camembert de Campagne Président, which is produced by a company of the Lactalis group and can be bought in a supermarket (Centre Leclerc Cleunay, Rennes, France). This cheese, which is popular in France, was chosen because it is representative of

Table 1
Composition of the consumer panel.

		Group A (n = 73)	Group B (n = 68)	All (n = 141)	French pop.[1]
Sex	Women (%)	52.1	50.0	51.1	51.6
	Men (%)	47.9	50.0	48.9	48.4
Age (year)	20–39 (%)	27.4	30.9	29.1	31.2
	40–59 (%)	30.1	29.4	29.8	34.4
	60 and over (%)	42.5	39.7	41.1	34.4
Level of education	< Bac[2] (%)	19.2	23.5	21.3	28.4
	Bac and Bac + 2 (%)	30.1	29.4	29.8	40.3
	> Bac + 2 (%)	50.7	47.1	48.9	31.3

[1] French population, 2018 figures, INSEE (National Institute of Statistics and Economic Studies).

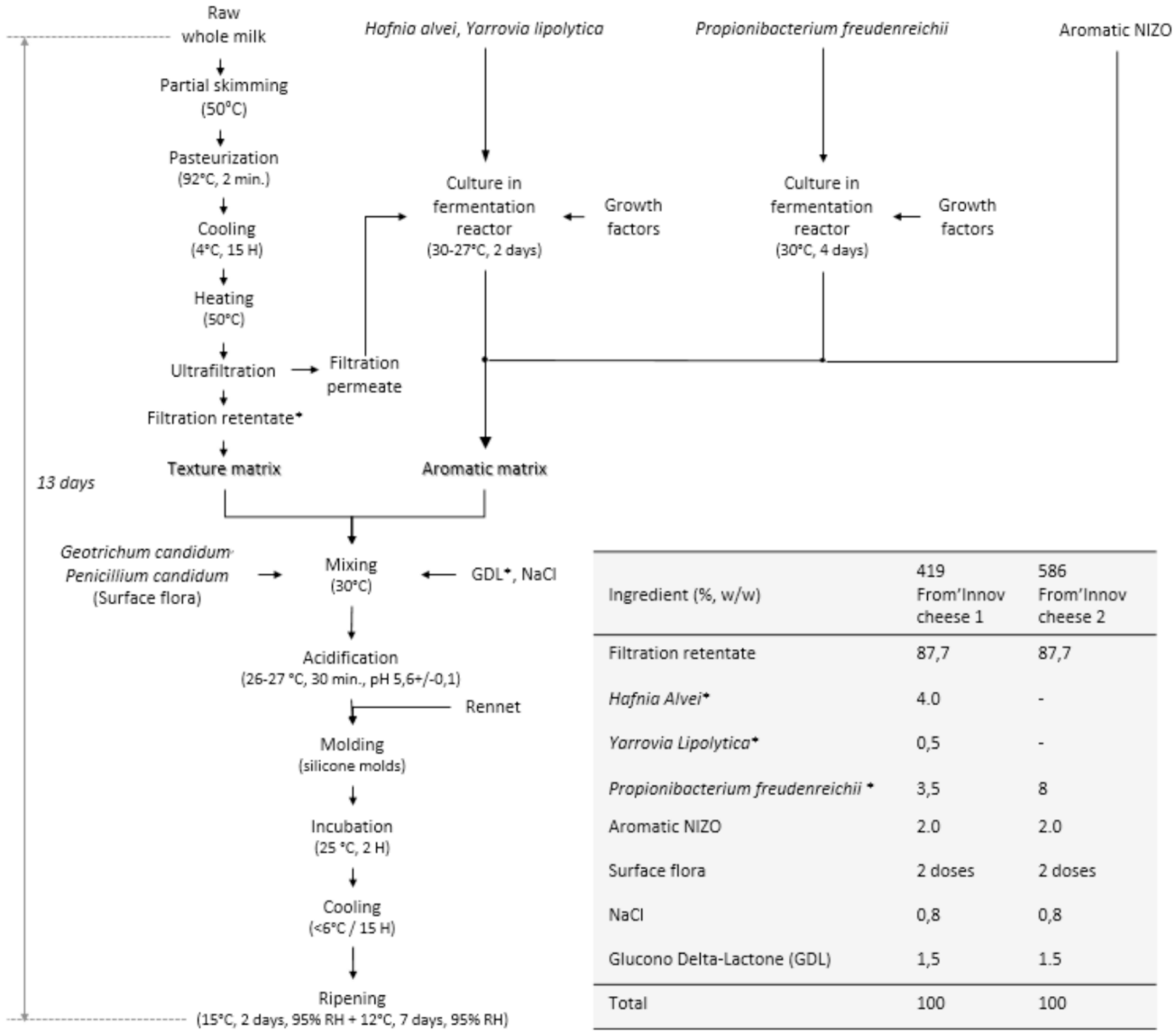
[2] Baccalaureate (bac): French high school diploma. "Bac + 2": two years of study after the baccalaureate.

soft Camembert-type cheeses produced by the cheese industry, both in terms of manufacturing process and sensory characteristics. The commercial cheese was made using a classic process based on four successive steps: coagulation, draining, salting, and ripening. At the time of this experiment, its price was approximately €2.18 in supermarkets (€1.79 – €2.79). The Camembert de Campagne Président was marketed in a 250-g size and packaged in multilayer paper packaging. The list of ingredients that appeared on the packaging was as follows: pasteurized cow's milk (France), salt, and ferments. It was also specified that the cheese did not contain lactose or animal rennet and that it was suitable for vegetarians. The characteristics highlighted by the manufacturer on the packaging of commercial cheese were as follows: "Thanks to its longer ripening, it is well done and rich in taste. This is the secret of its softness and its character.".

2.3.2. *From'Innov cheeses (innovative process)*

The two From'Innov cheeses were produced using an innovative process patented by INRAE (From'Innov process, Garric et al., 2016) (Fig. 1). This new process differs from the traditional method by profoundly transforming the various unit operations used to produce cheeses. From'Innov process is based on membrane filtration technology, which separates the dry matter from the milk (all constituents except water, minerals, vitamins, and a few small peptides), thus controlling the composition of the curd. Two matrices (sets of ingredients) are produced in parallel, one for texture and the other for flavor. These two matrices are then assembled in specific proportions. As a result, production time is reduced to just a few days, compared with several weeks for conventional processes. The cheeses were made by a dairy technology research team (UMR 1253, STLO, Rennes), which respects all necessary food safety procedures. The Departmental Directorate for the Protection of Populations (DDPP) of Rennes (France) validated the health control plan (Hazard Analysis Critical Control Point). An accredited laboratory (LABOCEA, Fougères, France) performs microbiological analyses of four pathogens on all our products after demolding (*Listeria monocytogenes*, *Salmonella spp.*, coagulase-positive *staphylococci*, and *Escherichia coli*).

Fig. 1 presents the innovative manufacturing process that was followed for the manufacture of the two From'Innov cheeses. For more details on the From'Innov process, see Garric et al., 2016. Two variants of From'Innov cheeses were tested. In the first (From'Innov cheese 1), a strain of bacteria (Hafnia alvei) and a strain of yeast (*Yarrovia lipolytica*) were added. Consequently, the dose of *Propionibacterium freudenreichii*



Ingredient (%, w/w)	419 From'Innov cheese 1	586 From'Innov cheese 2
Filtration retentate	87,7	87,7
*Hafnia Alvei**	4.0	-
*Yarrovia Lipolytica**	0,5	-
Propionibacterium freudenreichii **	3,5	8
Aromatic NIZO	2.0	2.0
Surface flora	2 doses	2 doses
NaCl	0,8	0,8
Glucono Delta-Lactone (GDL)	1,5	1.5
Total	100	100

Fig. 1. From'Innov cheese production diagram. In the table of ingredients, "*" indicates the differences between the two From'Innov cheeses. For more details on the From'Innov process, see Garric et al., 2016.

(probiotic) was slightly reduced (3.5 %). From'Innov 2 cheese contained neither Hafnia alvei nor *Yarrovia lipolytica*, but the dose of *Propionibacterium freudenreichii* (probiotic) was higher (8 %). These differences in the formulation of the aromatic matrix made it possible to obtain two From'Innov cheeses with different aromatic properties.

After 9 days of ripening, the From'Innov cheeses were packed and stored overnight at 4 °C. The next day, the products were packed in a classic camembert box immediately prior to their transport at 4 °C in a refrigerated vehicle to the place of experimentation (INRAE, Dijon, France). The commercial cheese was transported at the same time and under the same conditions as the two experimental cheeses. The three cheeses were stored at 4 °C over a period of 3.5 (minimum) to 7.5 days (maximum) before they were consumed during the experimental sessions.

It has been shown that the From'Innov process makes it possible to reduce the salt content in cheeses by at least 20 %, without causing a significant reduction in the perceived salty flavor (unpublished data). For the present study, the salt content of the From'Innov cheeses was 31 to 34 % lower than that of the commercial cheese (Table 2). This salt reduction, combined with the composition of other nutritional components, allowed the two studied From'Innov cheeses to obtain a Nutri-Score of C instead of the Nutri-Score of D obtained by the commercial cheese selected for this study and for almost all the other commercial cheeses in the same category.

Fig. 2 shows that the two From'Innov cheeses had a surface flora comparable to that of the commercial cheese chosen for this study and, more broadly, to those of commercial cheeses of the same type that can be found on the market. On the other hand, the paste has many small cells and the color is lighter than that of the commercial cheese. This appearance is inherent to the new process. A longer ripening process would have made it possible to obtain a softer cheese paste but to the detriment of the environmental advantages of the new cheeses. The ripening step is indeed energy consuming. We were aware that these sensory characteristics were likely to influence consumer appreciation, but we wanted to test products that maximized environmental benefits.

2.3.3. Sample preparation

The cheeses were kept in a cold room at 4 °C. One hour before the session, the cheeses were removed and placed at room temperature. Slicing (1/8 cheese per sample, i.e., approximately 30 g) took place 20 min before each session to avoid desiccation. After slicing, the samples were placed on plates coded with a three-digit number. The same codes were used throughout the entire experiment. Each cheese therefore had a single code. Each plate contained 2 samples of the same cheese. The three plates were placed in the tasting booths just before the arrival of the subjects. For each cheese, the first sample was used for Step 1 and the second sample was used for Step 3 (paragraph 2.4). The internal temperature of the samples during Step 1 was approximately 10 °C. The appearance of the different products offered to participants is presented in Fig. 2.

Table 2
Nutritional information for 100 g.

	Commercial cheese (235)	From'Innov 1 (419)	From'Innov 2 (586)
Energy value (KJ)	1184.5	1005	1004
Fat (g)	22	18.5	18.5
Saturated fatty acids (g)	14.7	12.3	12.3
Sugars (g)	0.5	0.5	0.5
Protein (g)	20	17.2	17.1
Salt (g)	1.3	0.9	0.9
Fibers (g)	0	0	0
Fruit, etc.* (%/100 g)	0	0	0
Sodium (mg)	520	344	360
Nutri-Score	D	C	C

*Fruits, vegetables, legumes, nuts, rapeseed, walnut, and olive oils.

2.4. Successive steps of the protocol

The sessions began with general information about the experiment, followed by a reading of the information sheet detailing the conditions of participation and the reciprocal commitments of experimenters and participants. Then, the subjects signed an informed consent form and the experiment began.

Step 1: Measurement of hedonic appreciation and willingness to pay based on blind tasting.

Subjects were asked to taste a coded sample of each cheese, then to give a hedonic rating and WTP for each one. At this stage, consumers could only base their judgments on sensory properties. No other information was available. We considered this context as the first information situation (sensory information).

Step 2: Assessment of satisfaction with nine sensory properties.

Subjects were asked to taste a new coded sample of each of the three cheeses, then to specify their level of satisfaction for nine sensory properties. This step aimed to characterize the products and specify the impact of nine sensory characteristics on hedonic appreciation (penalty analysis).

Step 3: Measurement of WTP, after communication of information on manufacturing processes.

After receiving information on the manufacturing processes of the three cheeses, the subjects were again asked to give their WTP (second information situation for WTP evaluation).

For each product, a fictitious label including a brand name, as well as a brief description of the expected taste, was created especially for this study (Fig. 3). The aim of the labels presented was to make the information given to consumers more concrete. Indeed, information on the main characteristics of commercial cheeses is mainly available on the label on the front of the packaging. We chose to replace the actual name of the commercial product so that consumers could not refer to a known brand or product and thus focused only on the taste of the product and the nature of the process used. The fictitious trade names were inspired by a popular French cheese whose trade name is Ortolan (a small bird). The Goldfinch and the Lark are two other small birds. The expression "de caractère" was printed on the packaging of the commercial product. We have kept it, as it is an expected characteristic for this cheese. For the two From'Innov cheeses, we used the expression "Doux et nature" (mild and natural) found on the labels of some commercial cheeses and which, according to the dairy technology experts involved in the project, corresponded well to From'Innov cheeses. These labels were also used for Steps 4 and 5.

Step 4: Measurement of WTP, after communication of information on Nutri-Score or probiotics.

Subjects were again asked to give their WTP for the three cheeses, after receiving either information on the better Nutri-Score of From'Innov cheeses compared with that of commercial cheese (group A subjects), or information on the presence of probiotics in From'Innov cheeses and the absence of probiotics in commercial cheese (group B subjects). This stage corresponds to the third information situation for WTP evaluation.

Step 5: Measurement of WTP, after communication of information on Nutri-Score or probiotics.

The group of subjects who received the Nutri-Score information in the previous step received the probiotic information, and vice versa. The subjects then gave their WTP again (fourth and final information situation).

Step 6: Complementary questionnaire.

The subjects had to answer a questionnaire intended to collect sociodemographic characteristics and to identify their consumption habits and attitudes toward new foods. The questions concerned the following variables: age, sex, socioprofessional category, income, education level, number of people in the household, number of children, responsibility for household purchases, frequency of meat consumption, frequency of consumption of different cheeses, type of cheeses preferred

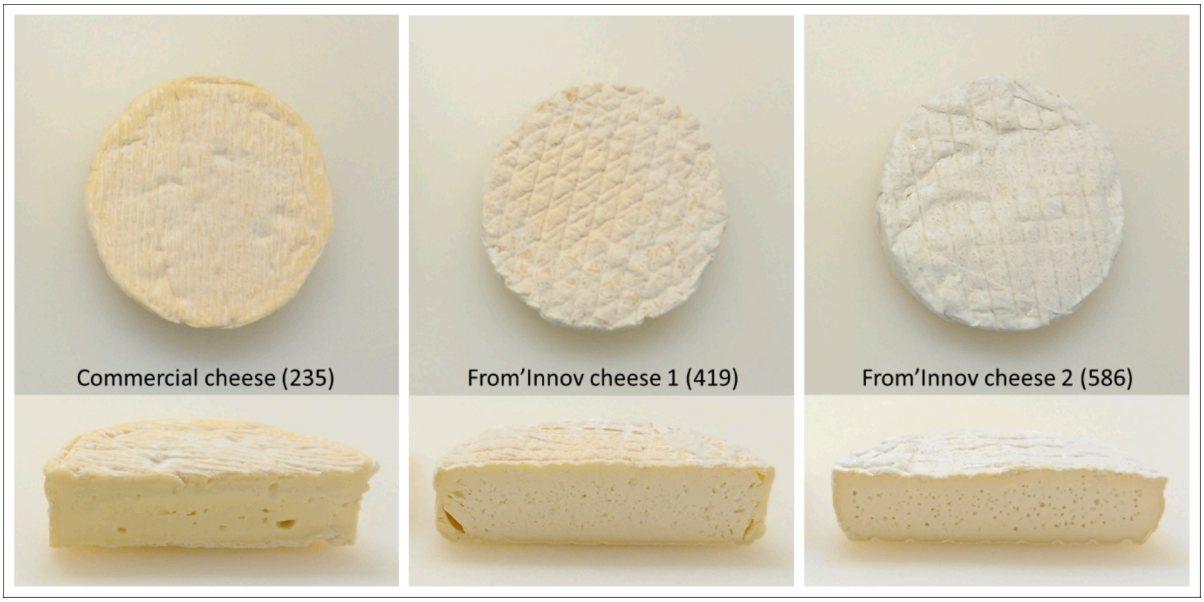


Fig. 2. Appearance of the three cheeses studied.

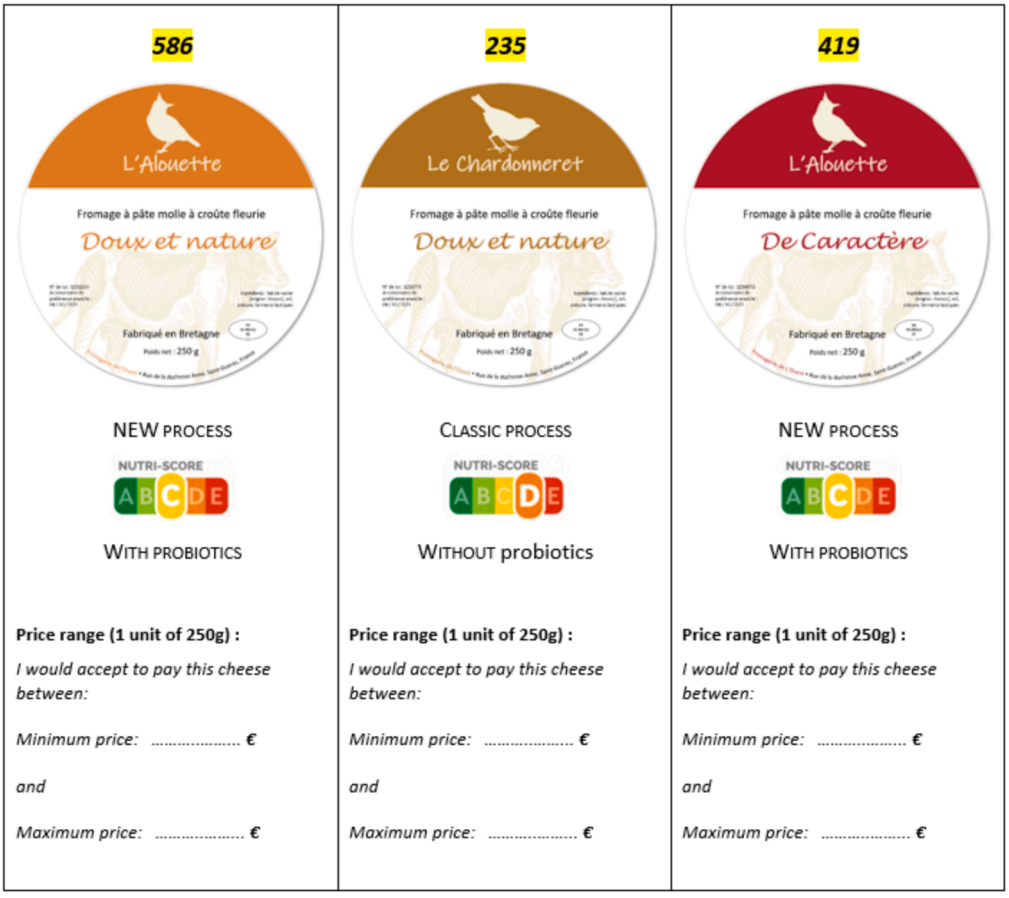


Fig. 3. Response grid for collecting consumer willingness to pay. The product labels and the description of the process used were only displayed in Step 3 of the protocol. Descriptions of the Nutri-Scores and probiotics were only displayed in Steps 4 or 5 (depending on whether the participant was in consumer group A or B).

and most consumed, purchase of cheese from organic farming, main criteria for buying cheese, knowledge and beliefs about cheese and its quality and properties, beliefs about new foods, and projection of cheese consumption in years to come. The results of this questionnaire will not be discussed in this document as, in fine, they did not provide any information to explain consumers' hedonic appreciation scores or WTP.

During Step 3, Step 4, and Step 5, consumers did not taste the cheeses again. They could, however, consult the hedonic ratings and WTP they had given in the previous stages.

The order of cheese evaluation was the same across all five stages

(Step 1 to 5). In a given session, all subjects were presented cheeses in the same order. However, the order of cheese presentation varied from one session to another. In this way, the order of cheese presentation was balanced across the entire consumer panel.

The sessions lasted a maximum of 1 h each, including the reception of the participants and the compensation phase. Therefore, the duration of the experiment itself was close to 45 min. This duration is a classic timeframe for this kind of experiment. No participant complained about the workload and the experimenters did not detect any sign of fatigue in the participants.

2.5. Hedonic appreciation measurement

After tasting the three samples in the specified order, the subjects were asked to rate their hedonic appreciation on a linear scale with "I do not like at all" and "I truly like" labels at the start and end of the scale, respectively. No other label appeared along the scale. The instructions given were as follows. "Observe and taste the 3 samples, then indicate your hedonic appreciation on the scales below. For each product, you can tick where you want on the scale according to your appreciation.".

The marks made on the hedonic appreciation scales resulted in continuous scores ranging from 0 ("I did not like at all") to 10 ("I truly like").

2.6. Sensory satisfaction

The subjects were asked to successively taste the three cheeses and specify their level of satisfaction with nine sensory properties: appearance of the rind, cheese paste color, intensity of smell, firmness, fatty/sticky, homogeneous/smooth, salty taste, fruity note, and character. Data were collected using a just about right (JAR) scale (Popper et al., 2004), which corresponded to ratings ranging from 1 to 5 for one or more characteristics of the product of interest. On the scale, 1 corresponds to "Not enough at all"; 2 corresponds to "Not enough"; 3 corresponds to "JAR" (Just about right), i.e., ideal for the consumer; 4 corresponds to "Too much"; and 5 corresponds to "Far too much". These nine characteristics were chosen by the cheese experts involved in this study, on the one hand because they are likely to be impacted by the new process, and on the other because these characteristics are important criteria for the acceptability of this type of cheese.

2.7. Willingness to pay

Previous papers clearly show a strong correlation between how well participants like a product and their WTP (Castellari et al., 2019; Marette et al., 2010; Royne et al., 2011). Indeed, liking captures a prominent part of consumers preferences for a product. However other criteria also matter for consumers, such as their perception of long-term effects of this product consumption on both health and environment, the condition of production, the societal impact, or the presence of contamination. While hedonic appreciation of sensory properties or liking is not expected to change based on disclosed extrinsic information, the WTP allows the researcher to measure how the combination of liking and other criteria impacts the demand. WTP is a complete measure of the relative weight of different criteria influencing the demand (Roosen et al., 2007).

An open-ended question was used to evaluate the willingness to pay values (Steps 1, 3, 4, and 5). Consumers had to indicate the price at which they would be willing to buy each cheese, indicating a price range defined by a minimum price and a maximum price. Consumers had the option of indicating zero for both prices to indicate that they would not buy the cheese at all. They were informed that the willingness to pay they would indicate did not involve actually purchasing the products. The choices were virtual and there were no product sales. We emphasized that there were no right or wrong answers and that participants should simply answer as if they were in a shopping situation in a supermarket.

2.8. Information messages

The codes 235, 419 and 586 have been used in information messages, where appropriate, to designate commercial cheese, From'Innov 1 cheese and From'Innov 2 cheese respectively.

2.8.1. Manufacturing process

The experimenters provided information regarding the processes used for the different cheeses by orally commenting on two simplified graphs that illustrated both processes and their main differences. Afterward, the subjects had the opportunity to ask questions if they wished. However, the experimenters framed the responses so that all consumers received the same level of information.

2.8.2. Nutritional value of the cheeses

The information (written and oral) concerning the nutritional value of the cheeses was based on the Nutri-Score and its logo. This information made it possible to indicate to consumers that From'Innov cheeses had a better Nutri-Score than commercial cheese and therefore that the overall nutritional quality of the From'Innov cheeses was more favorable to their health.

Exact wording of the message:

"The new process makes it possible to obtain cheeses of better nutritional quality. The Nutri-Score is a logo affixed to packaging that ranges from A to E and from green to red; it is established according to the nutritional value of a food product. The most nutritionally favorable foods are graded A. The least nutritionally favorable foods are graded E. Similar to almost all nonlight camembert-type cheeses, cheese 235, which was made using the classic process, has a Nutri-Score of D (Nutri-Score D label displayed). Cheeses 586 and 419 were made with the new process and contain approximately 25 % less salt, without a significant decrease in the perceived saltiness. In addition, the fat content of these cheeses is reduced by more than 15 % compared to those made by the classic process. Such a reduction allows cheeses 586 and 419 to obtain a Nutri-Score of C, reflecting a more favorable composition from a nutritional point of view (Nutri-Score C label displayed)."

It should be noted that the 25 % salt reduction mentioned in the information message corresponds to the average level of reduction practiced in the range of products manufactured with the From'Innov process compared to commercial cheeses. In this study, the reduction in fat content was even greater (approximately –33 % compared to that of the commercial cheese, see Table 2).

2.8.3. Probiotic content of cheeses

The information (written and oral) on probiotics was relatively short and highlighted the recognized effects of this type of probiotic, namely, the strengthening of the intestinal flora and protection against intestinal disorders.

Exact wording of the message:

"The new process allows for a more efficient addition of probiotics. According to the definition of the WHO (World Health Organization), 'Probiotics are live microorganisms which, when ingested in sufficient quantities, exert positive effects on health, beyond the traditional nutritional effects.' Probiotics can temporarily strengthen the intestinal flora and help relieve various intestinal disorders. No probiotics were added to cheese 235, which was made using the classic process. Probiotics have been added to cheeses 586 and 419, which were made using the new process."

3. Data analysis

3.1. Data preparation

For each subject-product pair, the average of the minimum and

maximum prices was calculated to determine an average WTP per subject-product. Values equal to zero (do not want to buy) were kept. Given the fairly large variability in the extent of the price ranges given from one consumer to another, the data were centered by subject. That is, the average of all the prices given by a given subject were subtracted from the average willingness to pay for each of the products. These subject-centered WTP values were used for all subsequent analyses (Wilcoxon tests and regression analysis).

3.2. Analyses

The hedonic appreciation scores given to the three cheeses after blind tasting were analyzed using a two-factor variance analysis (ANOVA, type III) with the following model: hedonic appreciation = subject + product + error. This analysis was followed by a multiple comparison test of means (Tukey HSD, threshold set at 5 %) to study the differences between the mean scores of the three cheeses.

Penalty analysis made it possible to determine which sensory characteristics had a positive or negative impact on hedonic appreciation. For this purpose, hedonic appreciation scores (Step 1) and the data collected using the JAR scale (Step 2) were used. This method is commonly used in sensory data analysis to identify potential directions for the improvement of products (Pagès et al., 2014).

To study the impact of information on processes and the cumulative impact of information on the Nutri-Score and probiotics, mean WTP values were calculated for each cheese and each stage, and Wilcoxon tests (paired samples) were performed to test the significance of the differences between pairs of WTP values.

To verify a possible effect of the order of the information messages about the Nutri-Score and probiotics on WTP, a regression analysis was carried out (least squares model). The model used considered all factors, including the order in which the Nutri-Score information and probiotic content were presented.

4. Results

4.1. Hedonic appreciation and willingness to pay based on sensory properties (blind tasting)

The commercial cheese and the From'Innov 1 and 2 cheeses received scores of 7.67, 4.66, and 4.31 respectively on a scale of 10 (Fig. 4). The analysis of variance showed that there were significant differences between the products. The commercial cheese was significantly preferred to the two From'Innov cheeses ($p < 0.0001$). The hedonic appreciation scores of the two From'Innov cheeses were not different from each other ($p = 0.371$).

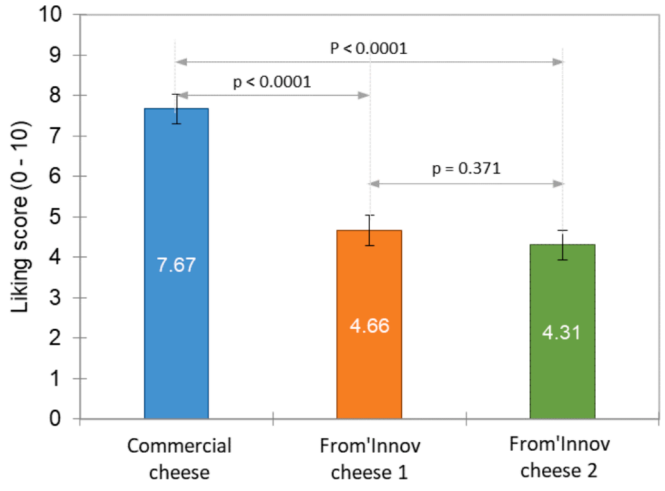


Fig. 4. Liking scores by product (blind tasting) and multiple comparison test of means (Tukey HSD).

The WTP values collected from the blind tasting were consistent with the hedonic appreciation scores (Figs. 4 and 5). However, the WTP values were more discriminating since they made it possible to differentiate the two From'Innov cheeses from each other. From'Innov 1 cheese obtained significantly higher WTP values than From'Innov 2 cheese.

4.2. Sensory properties impacting hedonic appreciation (penalty analysis)

Fig. 6 illustrates the results of the penalty analysis. Each graph indicates the sensory properties that penalized the appreciation of the cheese, either by lack of intensity (sign −) or by excess (+sign). The % of subjects who declared that a given sensory property was too intense or not intense enough is indicated on the abscissa. The properties mentioned by less than 25 % of the subjects (vertical dotted bar) are not exploitable (grayed out). Another vertical line (dotted line) has been placed at 50 % (majority of consumers) to aid in the interpretation of the results. The effect on the hedonic appreciation score is indicated on the ordinate (penalty score). The higher this value, the greater the negative impact on the valuation.

The acceptability of the commercial cheese was penalized due to the fattiness (too intense) and lack of firmness (Fig. 6a). These were the only penalizing sensory properties mentioned by the consumers. However, these aspects were penalizing for only approximately 1/3 of the subjects. Therefore, these are not considered major flaws. All the others were rated as being close to ideal.

From'Innov cheeses 1 and 2 (Fig. 6b-c) were particularly penalized by several olfactory characteristics, which were judged not intense enough (overall smell, character, fruity notes). These characteristics were penalizing for a majority of the consumers. Some textural characteristics also had a negative impact on the acceptability of these cheeses, e.g., too firm, not fatty enough (too dry), and not homogeneous enough. Appearance also worked against these cheeses (rind not bloomy enough, paste too white). For From'Innov cheese 1 (Fig. 6b), we noticed a disagreement within the consumer panel regarding the perceived intensity of the salty taste. Some consumers thought it wasn't intense enough, while others thought it was too intense. Opinions concerning the intensity of the salty taste of From'Innov 2 cheese were more unanimous. Its taste was judged to be not intense enough, which contributed negatively to the acceptability of this cheese (Fig. 6c).

4.3. Impact of the information provided on the acceptability of cheeses.

4.3.1. Manufacturing process (classic versus innovative)

The impact of manufacturing process information on product acceptability was studied by comparing the WTP given after blind tasting (Step 1) and the WTP given after process information was provided (Step 3). Wilcoxon tests showed that information concerning the processes did not have a significant impact on WTP for From'Innov cheeses, but caused a significant increase in the WTP for the commercial cheese ($p = 0.002$) (Fig. 5).

4.3.2. Nutri-Score & probiotics

The cumulative impact of the information concerning the Nutri-Score and the probiotics could be assessed by comparing the WTP given after the information on the manufacturing processes was received (Step 3) and the WTP given after the last information message was provided (Step 5). The results (Fig. 5) showed that the two information messages globally led to a significant increase in WTP for the two From'Innov cheeses ($p < 0.0001$). Conversely, these information messages caused a significant decrease in WTP for the commercial cheese ($p = 0.022$).

Table 3 shows that the two orders of presentation of the information regarding Nutri-Score and probiotics had a similar impact. Indeed, the t values and the associated probabilities were equivalent, regardless of

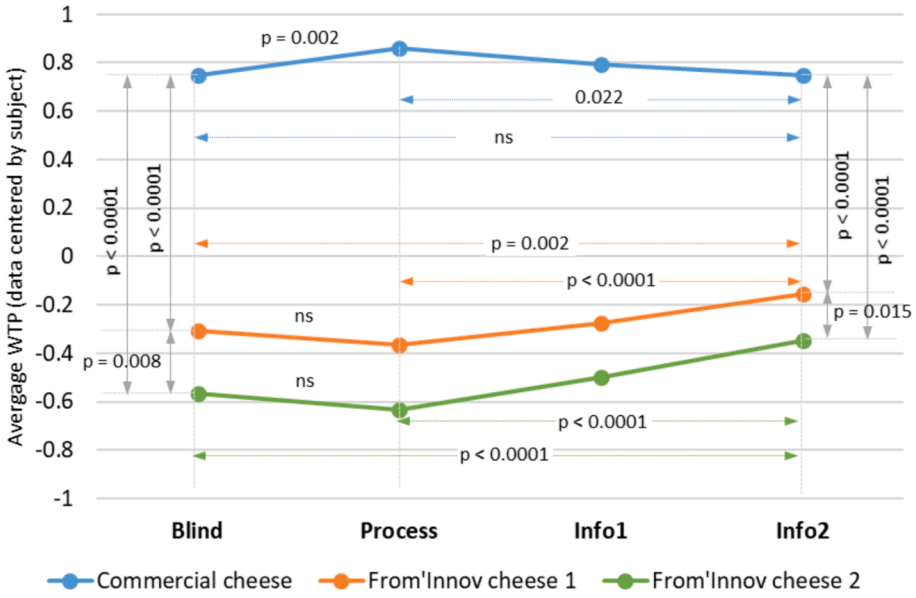


Fig. 5. Impact of the information provided on the acceptability of cheeses (change in WTP). p values extracted from Wilcoxon tests; threshold set at 5 % (ns = not significant).

the product studied. Each order of presentation was seen by only half of the subjects, which explains the probabilities above the 5 % threshold for both the commercial cheese and From'Innov 1 cheese. For the entire consumer panel, the WTP for the From'Innov cheeses increased significantly following the dissemination of these two pieces of information (Fig. 5).

4.3.3. Complete information (cumulative impact of the three messages)

The comparison of the WTP given after the blind tasting (Step 1) and the WTP given after the last information message (Step 5) makes it possible to study the cumulative impact of all the information messages (process, Nutri-Score, and probiotics). For each product, a Wilcoxon test made it possible to test the significance of the overall effect of the three pieces of information (without considering the order of presentation of the last two information messages).

As seen in Fig. 5, for the commercial cheese, the cumulative impact of the three messages was not significant ($p = 0.911$). The increase in WPTs resulting from information on manufacturing processes was offset downward by the two health messages. The regression analysis confirmed this result, regardless of the order of the last two information messages. On the other hand, the three information messages collectively made it possible to increase the WTP of the From'Innov cheeses. Indeed, for these two products, the two health-related information messages made it possible to obtain higher WTP values than those obtained during the blind tasting ($p < 0.0001$). Despite this increase, the WTP values for the From'Innov cheeses remained significantly lower than the WTP for the commercial cheese ($p < 0.0001$).

5. Discussion

Food choices result from the integration of a large number of factors (Chen and Antonelli, 2020). In this study, we simplified things by creating a situation where the characteristics of the product were reduced to their sensory properties, the nature of the manufacturing process, the nutritional quality summarized via the Nutri-Score, and the presence or absence of probiotics. Although simplified, this approach still made it possible to study the weight given to each of these factors in the construction of the overall acceptability of the different products.

Hedonic appreciation of sensory properties

The blind tasting revealed that the commercial cheese was significantly preferred to the two From'Innov cheeses. These preferences resulted in significantly lower hedonic appreciation scores and WTP values for the From'Innov cheeses. These differences can be completely attributed to the sensory properties of the products since, at this stage of the experiment, this was the only information available to the participants.

From a methodological point of view, it should be noted that while the hedonic appreciation scores and the WTP values were consistent (same classification of the products studied), the latter were more discriminating. Indeed, the WTP values show a significant difference between the two From'Innov cheeses, while the hedonic appreciation scores for these two products are not significantly different. However, this result may be specific to this data set. It is therefore difficult to conclude that either method is superior in a wider context on the basis of this observation alone.

Both From'Innov cheeses scored relatively low, below the middle of the preference scale. There is very little data on the practical significance of the mid-point of the hedonic rating scale. It is therefore difficult to predict with any certainty the real chances of success of the two From'Innov cheeses tested in this study. We can, however, cite the work of Gauchez et al (2020) on breads, which shows that the appreciation score corresponding to a rejection rate of 50 % (consumption refused for half of consumers) is 44.5 out of 100, i.e. slightly below the mid-point of the scale used to assess overall appreciation. As the From'Innov cheeses tested in this study obtained scores below the mid-point of the measurement scale, we can therefore assume that their acceptability is unsatisfactory and that their sensory properties need to be modified. We highlighted the sensory criteria that, by excessive or insufficient intensities, penalized the hedonic appreciation of these cheeses. The flexibility of the From'Innov process will make it possible to correct these penalizing elements, which will lead, in the future, to formulations that are more in line with consumer expectations, namely, more marked olfactory notes, a softer and homogeneous texture, and a paste color less white. It is important to remember that the comparison was quite hard with regard to the From'Innov cheeses because the commercial cheese selected was a leading cheese on the market and therefore already highly appreciated by consumers. In addition, the long ripening period and highly developed tastes of this commercial cheese were characteristics highlighted at the marketing level. A simple extension of the ripening period of the From'Innov cheeses would perhaps reduce the gap between them and the commercial cheese. Indeed, a large number of aromas are produced during this period (Smit et al., 2005). However, it

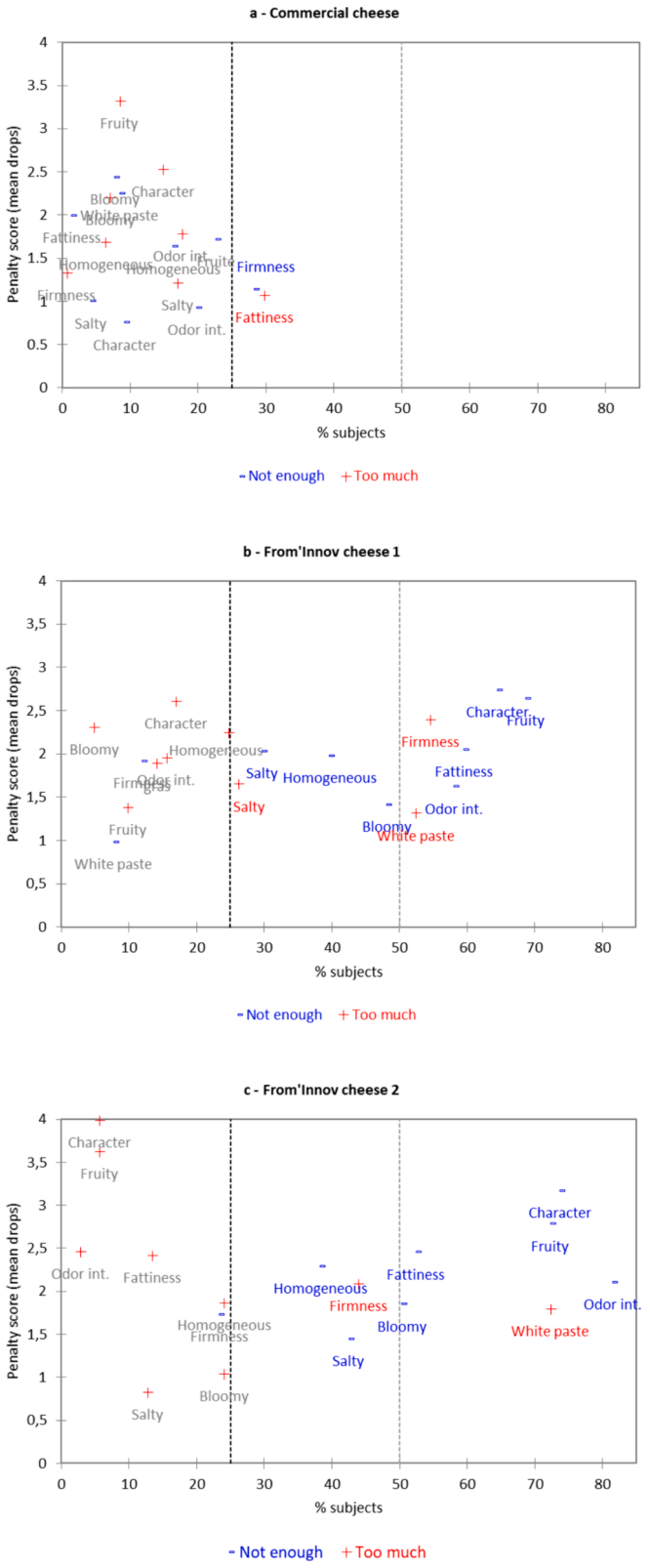


Fig. 6. Penalty analysis. Percentage of responses on the x-axis and the penalty scores on the y-axis (mean drops). In red are the properties perceived as too intense/present. In blue are the properties perceived as not intense/present enough. In gray are the sensory properties for which the response percentage was too low to make a conclusion (<25 % of the consumer panel). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

Table 3
Impact of the different information on the WTP – Regression (Least Square) considering the order of information concerning Nutri-Score and probiotics. Estimated coefficients, t values, and standard errors.

Independent variables (1/0)	Estimated coefficient	Standard error	t value	P value
Commercial cheese	**0.86**	**0.07**	**13.08**	**< 0.0001**
Nutri-Score then probiotics	−0.12	0.11	−1.03	0.302
Probiotics then Nutri-Score	−0.11	0.12	−0.93	0.352
From'Innov cheese 1	**−0.36**	**0.07**	**−5.53**	**< 0.0001**
Nutri-Score then probiotics	0.22	0.11	1.95	0.051
Probiotics then Nutri-Score	0.20	0.12	1.72	0.087
From'Innov cheese 2	**−0.63**	**0.07**	**−9.65**	**< 0.0001**
Nutri-Score then probiotics	**0.30**	**0.11**	**2.67**	**0.008**
Probiotics then Nutri-Score	**0.27**	**0.12**	**2.33**	**0.020**

In bold: significant variables at the 5% level. For each of the products, a p value less than 0.05 means that the evolution of WTP depends on the order of information (probiotics then Nutri-Score or Nutri-Score then probiotics).

is also important to remember that ripening is an energy-intensive step that is likely to have a significant impact on sustainability (Mirade et al., 2012).

The significant reduction in salt in the From'Innov cheeses penalized the acceptability of the From'Innov 2 cheese. This same reduction in the From'Innov 1 cheese led to disagreement among consumers about the intensity of the salty taste. Moreover, it is possible that the salt reduction also impacted the olfactory characteristics of the From'Innov cheeses. Indeed, sodium chloride is known to increase the release of volatile compounds through a salting-out effect (Flores et al., 2007). Thus, the decrease in salt content could at least partially explain why the aromas and odors of the From'Innov cheeses were generally judged to be not very intense, despite the aromatic bacteria used in the composition of these products. Overall, it seems that the achieved reduction in saltiness has reached the limits of what can be done in this type of product in terms of sensory acceptability. This result clearly illustrates the difficulties that can be encountered by processors when reformulating their products to improve their nutritional quality.

Perception of the innovative process

The revelation of the nature of the manufacturing processes used and the innovative character of one of the two processes caused an increase in the acceptability of the commercial cheese. However, we did not observe any significant modification of the WTP of the cheeses obtained using the innovative process. The information concerning the processes was therefore well integrated since it caused changes in the WTP of one of the cheeses. Given that previous studies have shown that consumers could be wary of new technologies (Siegrist and Hartmann, 2020), we could have expected a decrease in WTP for the From'Innov cheeses. However, this was not the case in this study. Instead of penalizing the cheeses obtained using the innovative process, consumers valued the cheese obtained using the traditional process. A similar result was obtained in a previous study that focused on cheeses obtained using the same innovative process (Martin et al., 2023). This is an important finding for dairy processors potentially interested in this new technology. The acceptance or rejection of innovations by consumers is the result of a complex decision-making process that involves an assessment of the perceived risks/benefits associated with the innovation (Rontel-tap et al., 2007; Cavallo et al., 2020). In the present study, information about the processes was produced in the form of simplified diagrams explaining the main differences between the classic process on the one

hand and the new process on the other hand. This presentation highlighted the fact that these differences were essentially based on a reorganization of the different stages of the conventional process and not on the use of additives liable to degrade the naturalness of the products obtained. Thus, it can be assumed that consumers did not perceive any particular danger from these modifications because this information did not cause a significant reduction in the acceptability of the From'Innov cheeses. However, cheese is a traditional food product; thus, at least some consumers may think it unnecessary or irrelevant to change its manufacturing process. Indeed, innovations may be perceived as altering the authenticity of traditional foods (Almli et al., 2011). This attachment to the traditional process may explain the increased acceptability of the commercial cheese after the disclosure of the process information.

Despite this result, the impact of revealing the nature of the processes did not radically change the acceptability of the products, which seemed, in this study, to be essentially guided by the sensory properties of the cheeses.

Perception of health-related information (Nutri-Score and probiotics)

The revelation of information concerning the better Nutri-Score of the From'Innov cheeses and the presence of probiotics significantly increased the acceptability of these cheeses. This means that the consumers were receptive to these health-related benefits. The order of presentation of health-related information had no impact. This increase seems to have taken place in an additive format; that is, each piece of information contributed to the increase in acceptability. This positive assimilation shows that the hedonic appreciation of the new cheeses, although weaker than that of the commercial cheese, was sufficient; otherwise, such changes would not have occurred. Indeed, Saint-Eve et al. (2021) pointed out that the WTP for products with a low hedonic score does not change with the revelation of positive information since the hedonic score was too low to have the WTP be reversed with only information. However, in the present study, despite the increase in the acceptability of cheeses following information about the Nutri-Score and probiotics, the acceptability of the From'Innov cheeses remained lower than that of the commercial cheese. It seems that sensory properties primarily guided the acceptability of these cheeses.

Concerning the commercial cheese, the information about the Nutri-Score and the probiotics had the opposite effect; i.e., this information caused a decrease in its acceptability, which was evaluated via the WTP. The information disseminated therefore had a symmetrical effect in that it increased the acceptability of the From'Innov cheeses and decreased that of the commercial cheese. However, the acceptability of the commercial cheese in the state of complete information (sensory properties, nature of the manufacturing process, Nutri-Score, presence of probiotics) remained significantly higher than that of the From'Innov cheeses.

In a previous study on the same type of products (Martin et al., 2023), information concerning the advantages of the From'Innov process in terms of health and the environment made it possible to compensate for a lack of hedonic appreciation of the order of 1.1 and 1.9 on a scale of 10. In the present study, the differences in terms of hedonic appreciation were much greater (3 to 3.4 on a scale of 10). Even if the information presented in the two studies was different, these results give an idea of the limits of the impact of this type of information—in comparison with that of sensory properties—in the construction of overall acceptability. It would be interesting to continue the investigations pursued herein by carrying out a study that made it possible to more precisely define the capacity of information linked to sustainability to compensate for a lack of hedonic appreciation.

New method for collecting WTP

This work provided an opportunity to test a new approach to estimate WTP. Our intention was not to carry out an in-depth comparison between different methods, but simply to propose a solution that avoids two disadvantages linked to the use of price lists to measure WTPs, and to test the practical feasibility of this approach. In previous experiments (Martin et al., 2021, Martin et al., 2023), we used price lists to measure WTP. We observed that these lists were tedious for consumers to fill in, and generated a negligible number of errors (inconsistencies in the boxes ticked). Moreover, determining the proposed prices (range, number of prices, and increment) requires subjective decisions that are likely to represent a bias. The new approach has been designed to solve this problem.

Our feedback from this first use is very positive. Firstly, the new data collection method was well understood by participants. Indeed, particular attention was paid by the experimenters to the reaction of consumers to the instructions given concerning the mode of expression of WTP. No questions were asked to suggest that participants had any doubts about the execution of the task. Secondly, we also found that this method allowed for faster data collection compared to collecting WTP using a price list. Finally, preparing the data for analysis was very simple, as it only involved calculating the average of the maximum and minimum prices for each subject and product.

It now seems essential to carry out a dedicated complementary study to compare this new approach with comparable existing methods (Breidert et al., 2006; Miller et al., 2011; Schmidt and Bijmolt, 2020).

6. Strength and limitations

In this study, we used a direct method for estimating WTP in a hypothetical context. This hypothetical context implies a bias. According to Schmidt and Bijmolt (2020), on average, the hypothetical bias is around 21 %. However, the authors specify that direct methods, as in this study, are more accurate than indirect ones, and that the hypothetical bias is less significant for low-value products, such as the cheeses studied. In any case, our aim here was not to determine a real purchase price, but rather to compare WTP from one stage to the next, with the intention of estimating the magnitude of the impact of different information. We therefore believe that the hypothetical bias is, in our case, not a real limitation.

The information available for assigning WTP was limited in comparison with a real-life situation where a multitude of elements can come into play in the construction of consumer judgment. The conclusions drawn from this study for each of the factors studied are therefore specific to the context defined by our protocol. Other factors could potentially challenge these conclusions, and to study their impact, it would be necessary to repeat this experimental approach by including them in the protocol. In the same way, the conclusions drawn from this work are specific to the products studied. For other types of products, it will be necessary to carry out further studies, possibly by replicating the approach presented here. However, we believe that the main results of this study provide information that could be of interest to dairy processors interested in using new technologies to obtain healthier, more sustainable products.

7. Conclusion

The results of the present study show that consumers' willingness-to-pay is not influenced by information about the innovative aspect of the From'Innov process, and that information about the health benefits associated with this new process can, to some extent, enhance the willingness-to-pay of these cheeses. This study also made it possible to show the limits of the impact of health-related information on the overall acceptability of the cheeses studied and to confirm the crucial importance of sensory properties and their hedonic appreciation. This is an important finding for dairy processors potentially interested in this new technology. These results also reinforce the idea that, for this type of product, communicating information about the health benefits of food products is a good strategy, but that the acceptability of healthier cheeses – and therefore their consumption – is above all conditioned by sensory properties appreciated by consumers.

Ethical statement

The experiment was conducted in June 2022 in a tasting room at the INRAE (National Research Institute for Agriculture, Food and Environment). The local ethics committee for research (Université Bourgogne-Franche-Comté) approved this study (# CERUBFC-2022-04-25-012). Individuals received oral and written information about the study and provided written informed consent before participating. They received €10 compensation for their participation in a session lasting approximately 1 hour.

Credit authorship contribution statement

Christophe Martin: Writing – review & editing, Writing – original draft, Supervision, Resources, Project administration, Methodology, Investigation, Formal analysis, Conceptualization. **Marielle Harel-Oger:** Writing – review & editing, Validation, Resources, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization. **Gilles Garric:** Writing – review & editing, Validation, Resources, Methodology, Conceptualization. **Stéphan Marette:** Writing – review & editing, Validation, Methodology, Investigation, Funding acquisition, Conceptualization.

Declaration of competing interest

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

Data availability

Data will be made available on request.

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