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Consumer acceptance of insect-based alternative meat products in Western countries

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ABSTRACT

During the past few years, entomophagy has been increasing in significance. As insects are generally high in protein, they are principally considered as meat substitutes. Nevertheless, in Western countries, meat substitute consumption is actually very low, principally due to food neophobia and poor sensory qualities in comparison with meat. In insect particular case, food neophobia is clearly high. To reduce insect food neophobia, previous studies suggest to insert invisible insect in food preparation and/or to associate them with known flavors. In this study, a survey on entomophagy perception and hedonic tests were realized to assess the level of sensory-liking of hybrid insect-based burgers (beef, lentils, mealworms and beef, mealworms and lentils). Participants' overall liking of the four burgers differed between genders and was influenced by burger appearance and taste. Women clearly preferred beef burger appearance, whereas men preferred the appearance of beef and insect-based burgers. Concerning insect-based burger taste, participants (men and women) rated it intermediately, between that of the beef and lentil burger, with a preference for the mealworm and beef burger. Results also showed that people with previous entomophagy experience was limited but that they gave globally higher ratings to all preparations. In conclusion, insect tasting sessions are important to decrease food neophobia, as they encourage people to "take the first step" and become acquainted with entomophagy. Nevertheless, insect integration into Western food culture will involve a transitional phase with minced or powdered insects incorporated into ready-to-eat preparations, as people are not ready to add insects to their diets in "whole form."

1. Introduction

Meat plays an important role in the consumption patterns of most Western consumers (Elzerman, Hoek, van Boekel, & Luning, 2011; Schösler, Boer, & Boersema, 2012). Consumption of animal-based foods has increased throughout the world since the 1960s, due principally to the sensory qualities of meat, increased production efficiency of the meat industry, and rising global average income and standard of living in growing populations characterized by changing food preferences (Elzerman et al., 2011; Reynolds, Buckley, Weinstein, & Boland, 2014; Steinfeld et al., 2006). Meat consumption is not predicted to decline in upcoming years; to the contrary, global meat production is projected to more than double, from 229 million tonnes in 1999/2001 to 465 million tonnes by 2050 (Steinfeld et al., 2006). Unfortunately, meat production is responsible for well-known environmental pressure due to the inefficient conversion of plant protein to meat protein (Aiking, 2011; Pimentel & Pimentel, 2003). A trend of reversal appears to be required, which could be materialized by a reduction in meat portion size ("less is better" strategy), the promotion of "meatless days" or the consumption of meat substitutes (Aiking, 2011; De Boer, Schösler, & Aiking, 2014; De Boer, Schösler, & Boersema, 2013b). Meat substitutes, also referred as meat replacers, meat alternatives, or meat analogs, are protein-containing foods that are primarily vegetable based and that replace the function of meat as a hot meal component (Hoek et al., 2011). These products are principally made of pulses (mainly soy), cereals, or fungus protein, but the utilization of new protein sources, such as insects and seaweed, has been considered (Aiking, 2011; De Boer et al., 2013b; Hoek et al., 2011). Nevertheless, in Western

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countries, the quantity and frequency of meat substitute consumption are actually very low (Elzerman et al., 2011; Hoek et al., 2011, 2013). Food neophobia (i.e., reluctance to try novel foods), primarily the fear of a negative sensory experience, is the most important person-related factor determining meat substitute acceptance (Hoek et al., 2011; Pelchat & Pliner, 1995; Pliner & Hobden, 1992). Information on proper use, positive taste or similarity to familiar food ("tastes like food X"), and exposure over time have been found to facilitate the acceptance of these unfamiliar foods (Cardello, Maller, Masor, Dubose, & Edelman, 1985; Hoek et al., 2013; Pelchat & Pliner, 1995; Tuorila, Meiselman, Cardello, & Lesher, 1998). A first step to reduce food neophobia is to present the substitute in a meal context in due to increase familiarity with the product (Elzerman et al., 2011). Concerning product-related factors, low sensory attractiveness is a key barrier to meat substitute acceptance among non-vegetarian consumers (Hoek et al., 2011). Effectively, the imitation of meat, a high complex product with a well-appreciated, distinctive flavor and texture, remains a technological challenge (Hoek et al., 2013). Finally, occasional consumers of meat substitutes generally recognize ethical (in terms of animal welfare or environmental impact) or nutritional aspects of these products, but this recognition is not sufficient to compensate generally negative attitudes toward and beliefs about them (De Boer, Schösler, & Boersema, 2013a; Hoek et al., 2011; Tucker, 2014). Educational programs, communication, and information provision are valuable to increase consumers' awareness about the impacts of food choices on themselves and the environment (Vanhonacker, Van Loo, Gellynck, & Verbeke, 2013; Vermeir & Verbeke 2008).

Among the new environmentally friendly sources of protein, insects appear to be valuable candidates (Belluco et al., 2013; FAO, 2009; Gahukar, 2011). Insects have (1) high fecundity rates, with year-round breeding; (2) high conversion rates; (3) low environmental impact, due principally to low greenhouse gas emissions; (4) small breeding space requirements; and (5) in some species, the ability to recycle organic industrial and/or agricultural byproducts to feed livestock or humans (Bednárová, Borkovcová, Mlcek, Rop, & Zeman, 2013; Defoliart, 1995; DeFoliart, 1997; Rumpold & Schlüter, 2013a, 2013b; Van Huis, 2013; van Huis et al., 2013; Yen, 2009; Yi et al., 2013). Alongside these environmental benefits, insects are very nutritious; they are, for example, particularly rich in high-quality protein (Bednářová, Borkovcová, & Komprda, 2014; Rumpold & Schlüter, 2013a; van Huis et al., 2013). Mealworm larvae (*Tenebrio molitor*, L.; Coleoptera: Tenebrionidae) and crickets (*Teleogryllus testaceus*, F.; Orthoptera: Gryllidae) contain up to 50% and 75% protein in dry weight, respectively, which is made of essential amino acids such as phenylalanine, tyrosine, and tryptophan (Bednářová et al., 2014; Caparros Megido et al., 2015; Rumpold & Schlüter, 2013a; Siemianowska et al., 2013). Despite the many benefits of insects as food, insect food neophobia is clearly established, in Western countries, and may be explained by knowledge of the animals' origins and habitats or by anticipated negative post-ingestional consequences (Caparros Megido et al., 2014; Rozin, Haidt, McCauley, Dunlop, & Ashmore, 1999; Schösler et al., 2012; Verbeke, 2015). Few studies have focused on consumers' perceptions and readiness to adopt insects as meat substitutes in Western culture (Tan, Fischer, van Trijp, & Stieger, 2016; Verbeke, 2015). Most of the studies have not involved tasting sessions, and their main finding has been a very low degree of willingness to eat edible insects in Western countries (De Boer et al., 2013b; Schösler et al., 2012; Vanhonacker et al., 2013; Verbeke, 2015). To reduce insect neophobia, a first possible solution is to educate consumers on cultural, nutritional, and ecological issues associated with entomophagy; however, several studies have shown that this approach is poorly effective (Lensvelt & Steenbekkers, 2014; Mignon, 2002; Verbeke, 2015). A second solution is to increase the frequency of edible insect exposure and experimental tasting (Caparros Megido et al., 2014). People who have already eaten insects have significantly more positive attitudes toward entomophagy and are more willing to eat and cook insects in the future (Caparros Megido et al., 2014; Lensvelt & Steenbekkers, 2014). Nevertheless, the invisible inclusion of insects in a preparation (i.e., pizza with insect protein or biscuit with insect flour) and the association of insects with known flavors (i.e., insects coated with paprika or chocolate) appear to trigger less aversion than the presentation of visible and unflavored insects (Caparros Megido et al., 2014; Lensvelt & Steenbekkers, 2014; Schösler et al., 2012; Tan et al., 2016).

To decrease the well-known food neophobia related to insects and to meat substitutes, we decided, in this present study, to test the level of sensory-liking of mealworms-based burger patties allowing us to hide insects and to present them in a familiar way. Mealworms were chosen as insect model since it is, between the three edible insect species actually reared and sold in Europe (mealworms, migratory locusts and house crickets) the easiest to rear, the "greenest", the cheapest and the less neophobic (Caparros Medigo, Alabi, Haubruge, & Francis, 2015; Caparros Megido et al., 2014; Caparros Megido et al., in press; Li, Zhao, & Liu, 2013; Oonincx et al., 2010). Using hedonic testing, this product was compared with fully meat and vegetable burgers, as well as hybrid vegetable burgers (as suggested by De Boer et al. (2013b).

2. Material and methods

2.1. Respondent profile

The experiment was conducted at the Paul Lambin Institute (Woluwe-Saint-Lambert, Belgium). During the study period (15/01/2014–27/02/2014), 159 students from several disciplines (medical biology, dietetics, and chemistry) attended a brief presentation of the testing session (schedule and duration of the tasting session and the potential presence of insects) and had the opportunity to register for it. Seventy-nine (51%) students agreed to participate in the study. The students were aged 18–25 years and were considered to be potential future insect consumers.

After being isolated in a tasting booth, participants were invited to respond to the first part of the questionnaire. This part of the survey solicited sociodemographic information from participants and included the following five questions: (1) have you already heard about entomophagy (yes or not)? (2) If yes, through which channel: television, radio, newspaper, internet or other? (3) What are your preconceptions about eating insects: curiosity, disgust, fear, primitive behavior or nothing (check-all-that-apply question)? (4) Have you already eaten insects or insect products (yes or not)? and (5) If yes, was it a positive experience?

All respondents participated voluntarily, were recruited in the Paul Lambin Institute by email and received no monetary compensation for their participation. Potentially allergic subjects to crustaceans or mites were not invited to participate. Ethical approval was granted and all participants gave written consent.

2.2. Sample preparation

Mealworms (*Tenebrio molitor* L.) reared in our laboratory on wheat flour, brewer's yeast, and wheat bran were used in this study. The insects were fasted for 24 h before they were killed by freezing, to ensure that they have excreted all feces. This procedure allowed us to reduce the bacterial load in the insect gut and to offer a safe product for human consumption. Nevertheless, microbiological tests were conducted to ensure the harmlessness of insect preparations to respondents.

Four different burger patties were prepared using three main ingredients: unflavored ground beef, green lentils, and mealworms

Table 1
Burger composition (%; BB = Beef, MBB = Mealworm/Beef, LB = Lentil, MLB = Mealworm/Lentil).

Ingredients	Burgers			
	BB	MBB	LB	MLB
Unflavored grounded beef	95.00	45.00	/	/
Green lentils	/	/	95.00	45.00
Mealworms	/	50.00	/	50.00
Grated carrots	2.06	2.06	2.06	2.06
Onions	2.47	2.47	2.47	2.47
Double tomato paste	0.41	0.41	0.41	0.41
Garlic	0.02	0.02	0.02	0.02
Salt	0.03	0.03	0.03	0.03
Pepper	0.01	0.01	0.01	0.01

(burger compositions are presented in Table 1). A beef burger (BB) was prepared with 95% unflavored ground beef, a lentil burger (LB) contained 95% green lentils, a mealworm/lentil burger (MLB) was prepared with 45% green lentils and 50% insects, and a mealworm/beef burger (MBB) contained 45% ground beef and 50% insects. The remaining 5% of each burger consisted of a common aromatization portion containing onions, carrots, tomato paste, garlic, salt, and pepper. Green lentils and mealworms were precooked 30 min and 10 min, respectively, in 500 ml boiling water (99.5 °C ± 0.5 °C) before integration into the patties as recommended by Klunder, Wolkers-Rooijackers, Korpela, and Nout (2012). After precooking, burger ingredients were mixed for 3 min with a hand blender (Prep'Line® HB7131; SEB, Ecully, France) to obtain a homogenous mixture. The mixtures were formed into patties with a burger press (90 × 30 mm). All preparations were 4.5 cm in diameter and 1 cm thick, and weighed 25 g. The molded patties were cooked for 15 min at 180 °C ± 5 °C in a preheated hot-air oven. They were flipped at 7.5-min intervals to ensure uniform cooking and uniform color. No cooking oil were added or sprayed.

2.3. Microbiological analysis

The four burger types were analyzed immediately after preparation. The two insect burgers (MBB and MLB) were also analyzed after refrigeration for 2 days in a new plastic box. Burger samples were crushed in a universal blender (M20; IKA, Stauffen, Germany); the blender's grinding chamber was autoclaved before utilization. Ten grams of ground material were suspended in 90 ml sterile isotonic quarter-strength Ringer solution (ref. BR001; Biokar, Beauvais, France) in a Stomacher® plastic bag (Seward, Worthing, United-Kingdom) and homogenized in a paddle blender (80 Biomaster, Seward, Worthing, United-Kingdom) for 1 min at normal speed. The suspensions were serially diluted tenfold (up to 10^{-8}) in isotonic quarter-strength Ringer solution. One milliliter of suspension was plated on each of several media for the detection of different organisms. All culture media were obtained by Biokar, unless otherwise specified. Total numbers of aerobic mesophilic microorganisms were determined on plate count agar (BioRad, Hercules, CA, USA) after incubation at 30 °C for 72 h. *Escherichia coli* (glucuronidase positive) were detected as blue colonies on ECC agar after incubation at 44 °C for 24 h. For *Clostridium perfringens* detection, 1 ml dilution was heated at 80 °C for 10 min in sterile tubes. Then, molten Perfringens agar medium was poured in the tubes. The tubes were incubated at 37 °C and observed daily for 4 days to detect the appearance of black colonies.

2.4. Burger tasting session

The second part of the survey concern the rating of each sample on four nine-point hedonic scales (appearance, odor, taste and overall liking) ranging from "extremely dislike" to "extremely like." Before the tasting session, respondents were instructed orally and in writing to avoid after-tastes and to neutralize taste (drink water and eat salt-free rusk) between each sample. They were also informed about the safety of the burger preparations (microbiological analysis) and the potential allergenicity of arthropods. For the tasting session, a randomly selected numerical code was assigned to each preparation, which was presented individually and randomly to participants. Preparations were presented hot on small plastic plates, and respondents were not required to eat the entirety of each sample. Each preparation was systematically removed from the tasting area before presentation of the next preparation.

Finally, participants were asked to respond to third part of the survey which comprised the following five questions: (6) in your opinion, which burger(s) contain(s) insects? (7) After eating insects, has your perception of entomophagy changed? (8) Do you think we will eat insects in the future? (9) Are you ready to add insects to your customary diet? and (10) If yes, in which form would you cook insects? (minced, powdered or entire)

2.5. Statistical analysis

Statistical analyses were performed using Minitab® (ver. 16.0 for Windows®; State College, PA, USA). For each hedonic scale, a first order interaction (2 (gender) × 4 (preparation) × 2 (question 1) × 2 (question 4) × 2 (question 7)) analysis of variance (ANOVA) with a general linear model (GLM) was performed to highlight factors potentially influencing (knowledge of entomophagy or a previous experience of edible insect tasting) the hedonic evaluation of the burgers or a factor that was potentially influenced by the tasting session (perception of entomophagy). Secondly, a Kruskal-Wallis test was applied to characterize this influence on the hedonic evaluation of the four burgers. Finally, Cohen's *d* index has been calculated as effect size to measure the magnitude of the differences found between genders (Cohen, 1988).

3. Results

3.1. Sociodemographic characteristics and preliminary knowledge of entomophagy

Thirty-five (44%) men and 44 (56%) women participated in the study. All participants were Belgian, and the majority (88%) were of Caucasian origin; 12% of participants identified as African, Asian, and Latin American.

Thirty-nine percent of respondents were familiar with entomophagy, principally through television exposure (45%), followed by internet (19%), newspaper (16%), other (12%; including travel, tasting sessions, family, and friends), and radio (8%). The main response regarding preconceptions about entomophagy was curiosity (69%), followed by fear (14%), disgust (13%), and primitive behavior (4%). Only 26 (33%) respondents had tasted insects previously, but 81% of these people had positive memories of the experience.

3.2. Pre-tasting and hedonic analyses

Pre-tasting microbiological analyses revealed total viable counts, expressed in log colony forming units (cfu)/g, below the standard legal maximum for fresh minced meat (5.70; BB, 4.88 log cfu/g; MBB, 5.04 log cfu/g; MLB, 5.28 log cfu/g; LB, 5.23 log cfu/g) (CE No 2073/2005, 2005). Moreover, no *E. coli* or *C. perfringens* was found in the samples.

In the analysis of participants' ratings, an interaction was found between the gender and two organoleptic properties (overall liking and appearance) involving a separated analysis of these properties according to the gender (Table 2). Following the ranking methodology of Sullivan and Feinn (2012) (adapted from Cohen (1988)), these results are strengthened by a very large effect size (over 0.8) except for the overall liking of lentil burgers considered as medium.

Concerning the overall liking of men and women, it seems similar, at the first side, as the BB was the best rated followed by the MBB, the MLB and the LB for both sexes (Table 3). Nevertheless, women liked significantly more the fully beef formulation in comparison with the three others ones while men liked significantly more the burger formulations containing beef or insects (BB, MBB and MLB) in comparison with the fully vegetable one. Concerning the burger appearance, men still rated the two insect burgers intermediately between the BB, which is the most preferred, and the LB. In the other side, women rated intermediately the LB between the BB, always the preferred one, and the two insect burgers. For the two genders, although it is not statically significant, the MBB appearance is better rated than the LBB one. Concerning the two last organoleptic properties, participants of both genders preferred the taste of the BB, followed in order by the MBB, the MLB, and the LB while they rated similarly the odor of the four burger formulations (Table 3).

When looking at factors that potentially affected hedonic evaluation, it can be seen that people that have already eaten insects rated higher the burgers' overall liking, taste and appearance while people that only affirmed knowing entomophagy rated higher the burgers' overall liking and taste with no effect on the burgers' appearance (Table 4).

3.3. Post-tasting survey

Seventy percent of respondents correctly identified at least one insect-based burger among the four preparations. Among them, only 44.4% correctly identified both insect-based burgers. Globally, 12% and 18% of respondents misidentified the BB and LB, respectively, as insect based.

The perception of insect consumption evolved positively in 84% of participants after the tasting session. Overall liking and the taste of the burger were the characteristics that positively influenced participants' general perception of entomophagy after the tasting session (Table 4).

Moreover, 79% of respondents thought that we will eat insects in the future and 68% of them were ready to add insects in their customary diet. The preferred form of integration was minced (48%), followed by powder (33%) and whole insects (19%).

4. Discussion

During the hedonic evaluation of the four burgers proposed in this study, participants rated the beef burger (BB) as the best followed by the mealworm/beef burger (MBB), the mealworm/lentil burger (MLB) and the lentil burger (LB) in term of overall liking. Despite this global rating, GLM analysis has shown that a distinction must be done between genders. Effectively, women clearly preferred the BB, whereas men preferred the BB and the insect-based burgers. To explain this difference and determine how to increase the acceptability of insect-derived products, a focus on product attributes (e.g., taste, appearance, and odor) is needed.

Taste is an important factor in the acceptability of a novel food product. Effectively, the willingness to try a new food with limited

Table 2
Overall liking, appearance and taste of the four tested burgers when proposed to participants (n = 79). (DF: Degrees of Freedom; F: F statistic and P: significance level; Composition: burger composition; Knowledge: have you already heard about entomophagy? Already tasted: have you already eaten insects or insect products?; Perception: after eating insects, has your perception of entomophagy changed?).

Factor	DF	F	P	DF	F	P	DF	F	P
	Overall liking			Appearance			Taste		
Gender	1	0.46	0.497	1	0.01	0.940	1	0.39	0.533
Composition	3	6.61	**<0.001**	3	3.02	**0.031**	3	8.20	**<0.001**
Knowledge	1	9.75	**0.002**	1	1.12	0.291	1	14.75	**<0.001**
Already tasted	1	14.08	**<0.001**	1	15.21	**<0.001**	1	6.23	**0.013**
Perception	1	20.99	**<0.001**	1	2.59	0.109	1	14.81	**<0.001**
Gender × composition	3	2.71	**0.046**	3	2.64	**0.050**	3	0.99	0.400
Gender × knowledge	1	1.34	0.247	1	0.07	0.796	1	0.19	0.665
Gender × already tasted	1	0.18	0.669	1	0.51	0.476	1	0.25	0.616
Gender × perception	1	0.69	0.407	1	1.07	0.303	1	0.77	0.383
Composition × knowledge	3	0.10	0.959	3	0.13	0.942	3	0.37	0.776
Composition × already tasted	3	1.02	0.384	3	1.05	0.370	3	1.42	0.238
Composition × perception	3	2.25	0.083	3	0.96	0.411	3	1.17	0.323

Bold values indicated significant results.

Table 3
Results of burger tasting sessions using nine-point hedonic scales (♀: women, ♂: men, *d* = Cohen's index; ±SEM).

Burger		BB	MBB	MLB	LB	Statistical analyses	*P*
Overall liking	♀	7.05 ± 0.23a	5.95 ± 0.28b	5.34 ± 0.31b	5.32 ± 0.28b	$F_{3,148}$ = 8.23	**<0.001**
	♂	6.62 ± 0.20a	6.44 ± 0.28a	6.06 ± 0.28a	5.18 ± 0.21b	$F_{3,132}$ = 7.03	**<0.001**
	d	1.99	1.75	2.44	0.57		
Appearance	♀	6.39 ± 0.29a	5.05 ± 0.30b	4.95 ± 0.32b	5.42 ± 0.26ab	$F_{3,148}$ = 5.03	**0.002**
	♂	5.97 ± 0.29a	5.82 ± 0.23ab	5.59 ± 0.26ab	4.91 ± 0.24b	$F_{3,132}$ = 3.39	**0.020**
	d	1.45	2.88	2.19	2,04		
Taste		6.85 ± 1.56a	6.00 ± 1.93b	5.58 ± 2.04bc	5.06 ± 1.87c	$F_{3,315}$ = 13.06	**<0.001**
Odor		6.43 ± 1.60a	6.08 ± 1.44a	5.82 ± 1.45a	6.19 ± 1.35a	$F_{3,315}$ = 2.36	0.072

Bold values indicated significant results.

Table 4
Average evaluation of the organoleptic properties of the four burgers according to GLM analysis-derived influencing factors (±SEM).

Organoleptic properties	Factors	Yes	No	Statistical analyses	P
Overall liking	Knowledge	6.38 ± 0.14a	5.76 ± 0.13b	$F_{1,287}$ = 10.66	**0.001**
	Already tasted	6.42 ± 0.15a	5.83 ± 0.67b	$F_{1,287}$ = 8.56	**0.004**
	Perception	6.30 ± 0.10a	5.08 ± 0.21b	$F_{1,287}$ = 30.57	**<0.001**
Taste	Knowledge	6.39 ± 0.16a	5.59 ± 0.16b	$F_{1,287}$ = 12.25	**0.001**
	Already tasted	6.20 ± 0.20a	5.80 ± 0.14b	$F_{1,287}$ = 5.69	**0.018**
	Perception	6.24 ± 0.26a	4.86 ± 0.24b	$F_{1,287}$ = 27.17	**<0.001**
Aspect	Knowledge	5.33 ± 1.16a	5.54 ± 1.71a	$F_{1,287}$ = 0.55	0.558
	Already tasted	5.94 ± 0.18a	5.30 ± 0.11b	$F_{1,287}$ = 9.12	**0.003**
	Perception	5.45 ± 1.67a	5.47 ± 2.05a	$F_{1,287}$ = 0.01	0.929

Bold values indicated significant results.

taste experience (e.g.: insects) will more likely depends on participants' level of interest and/or neophobia than on their expectations about the sensory experience (Caparros Megido et al., 2014; Martins & Pliner, 2005; Tan et al., 2015, 2016). In this study, the level of willingness to try insects was high in our target population, as 69% of the participating students were curious about tasting insects. Our findings support the hypothesis that younger consumers are ready to adopt new meat substitutes or novel food as insects (Schösler et al., 2012; Tuorila, Lähteenmäki, Pohjalainen, & Lotti, 2001; Verbeke, 2015). The taste evaluation showed that the LB and BB had the lowest and highest ratings, respectively. Meat has a central place in Western meals, due principally to its appearance and taste, key sensory qualities that vegetable-based meat replacers cannot imitate (Elzerman et al., 2011; Hoek et al., 2013; Holm & Møhl, 2000; Schösler et al., 2012). The low rating for the LB could also be explained by the choice of a vegetable that was not familiar to respondents, which may have influenced their sensory evaluation (Tuorila et al., 1998). The consumption of lentils and dries bean is quite low in Western countries, principally because of flatulence, the evocation of an ''old-fashioned'' image, and long cooking time, which leads people to perceive their preparation as very cumbersome because it requires skill and food knowledge (Mitchell, Lawrence, Hartman, & Curran, 2009; Schneider, 2002; Schösler et al., 2012). The use, as comparator, of a more conventional veggie burger made of soy or pea, could have been a better choice for the purpose of our study. No matter the chosen plant-based meat substitutes, they are globally less accepted in Western countries and non-vegetarian consumers generally judge their sensory qualities to be worse than those of meat, primarily because they expect sensory attributes to be similar. Again, these results show the importance of producing meat substitutes with meat-like sensory properties (Hoek et al., 2011, 2013). Participants rated the taste of insect-based burgers intermediately, between that of the BB and LB, with a preference for the MBB and higher-than-neutral scores for the two burgers. These results show that insect-based substitutes are acceptable to consumers and that the hybrid meat burger was preferred in comparison with the hybrid vegetable burger, probably because the MBB at least partially retained the sensory qualities of meat and seemed more familiar to consumers (De Boer et al., 2013b; Tan et al., 2016). When looking at factors that potentially influenced the taste evaluation, it seems that participants' background is important. Effectively, people that have already heard about entomophagy or eaten insects in the past rated higher the burgers' taste. Nevertheless, in this study, only 39.0% of participants had heard about entomophagy and only 33% of respondents had eaten insects previously while 81% of them reported this previous experience was positive. Concerning the entomophagy knowledge, Caparros Megido et al. (2014) reported such knowledge among 93.8% of persons aged 19–25 years. This difference can probably be explained by population selection; the present study was conducted in a dietetic school with students who were not particularly interested in insects, whereas Caparros Megido et al. (2014) surveyed participants during a visit to an insectarium. Another explanation could be the use of the word ''entomophagy,'' instead of a simpler phrase such as ''the eating of insects'' or ''insects as food''. In a study profiling consumers who were ready to adopt insects as a meat substitute, Verbeke (2015) found that 71.5% of participants had heard about the eating of insects and only 5.1% had never heard about it. As participants in our study may have missed the significance of the word ''entomophagy,'' our results do not necessarily mean that they had never heard about the eating of insects. Further studies are needed to highlight the linguistic misunderstandings existing in the entomophagy sector and to found terms that are easily understood and attractive (Evans et al., 2015; Wood & Looy, 2014). For example, use of the words ''mealworms'' and ''insects'' could consistently link consumers with their negative feelings toward insects, likely helping to maintain a psychological barrier to edible insects. The use of foreign words such as ''*chapulines*'' (i.e., crickets from the *Sphenarium* genus) could decrease neophobia by framing insect products as ethnic food (Wood & Looy, 2014).

Concerning appearance of the burgers, only the BB was similarly liked by men and women. For the three other burgers, women preferred the appearance of the LB and men preferred that of the insect-based burgers. Women generally consume more vegetables than do men and are thus more familiar with vegetable products, which may be correlated with a higher evaluation (Fagerli & Wandel, 1999; Sobal, 2005). Moreover, despite our efforts to mix the insects into the patties as thoroughly as possible, the visible presence of small amounts of mealworm exoskeleton in some insect-based burgers could explain the lower appearance ratings given by women, who are generally more neophobic and less adventurous than men (De Boer et al., 2013b; Schösler et al., 2012; Verbeke, 2015). Finally, appearance evaluation was positively affected by a previous experience of insects' eating. This result shows again the importance of tasting sessions as they encourage people to ''take the first step'' and become acquainted with edible insects (Lensvelt & Steenbekkers, 2014). Moreover, recall of positive experience with a particular food had been shown to increase one's liking and selection of that food (Robinson, Blissett, & Higgs, 2011, 2013).

Concerning the burgers' odor, the similar sensory ratings could be explained by the use of aromatization content, which probably harmonized the odor blend of the four burgers by deodorizing and/or masking the smells of other products in the preparations (Hirasa & Takemasa, 1998).

Finally, most (~70%) of the participants were convinced that we will eat insects in the future and were ready to include insects (principally minced or powder) in their diet. These results are consistent with those reported by Caparros Megido et al. (2014), but contrast with those of Vanhonacker et al. (2013), De Boer et al. (2013b), and Verbeke (2015), who found that the potential for the introduction of insects as food currently ranges from non-existent to dependent on form. This difference may be explained by study design; the previous studies did not include tasting sessions and, as previously written, people probably rely only on non-experimental sources of information (e.g., emotional memories, self-knowledge, or intuitive theories) to respond instead of the real insect sensory properties.

5. Conclusion

Edible insects are responsible for a well-known food neophobia. To decrease this effect, we decided to present edible insects in an invisible and familiar way in the form of an insect-based burger. This strategy seems to decrease the insect food neophobia since participants rated the burgers' taste and appearance with higher-than-neutral scores, positioning them between a fully meat burger and a fully vegetable burger. These results confirm that the insect integration into Western food culture could be done using a transitional phase in which minced or powdered insects are incorporated into familiar ready-to-eat preparations. Nevertheless, two major factors related to the participants' background were found to affect the hedonic evaluation of the burgers: a previous knowledge of entomophagy and a previous experience with insect tasting. These two factors had a positive impact on the taste ratings but appearance ratings were only influenced positively by a previous insect tasting. These results suggest the importance of informing people on edible insects and, particularly, increase the number of insect tasting sessions to acquaint people with edible insects.

Finally, gender seems also to be a key factor, principally in the appearance of insect-based products. To gain a more in-depth understanding of this gender difference in sensory studies on edible insects, the systematic use of scales measuring motivational food orientation as the Food Choice Motives items developed by De Boer, Hoogland, and Boersema (2007) is recommended to highlight personality traits connected with the potential acceptability of insects as food.

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