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How can the design thinking process improve an innovative insect-based food experience?

ABSTRACT

This work set out to show that the novel problem-solving process called design thinking (DT) can advance the acceptance and consumption of insects as food. The DT approach involving a multidisciplinary team comprised three stages: (1) an exploratory evaluation through questionnaires to raise consumer empathy, (2) an ideation stage to enable visualization and rapid prototyping, which resulted in the creation of twelve food products using mealworm larva and cricket flour and (3) an experimentation stage, where the five most promising ideas (packaging and products) were selected and tested on consumers. Four consumption trends were identified: vegetarianism (intellectual), challenge (social relationship), luxury (emotional) and sport (health). Prototypes corresponding to consumer needs were developed. After identifying the positive and negative effects elicited by the prototypes, the most promising ones were tested. Exposing consumers to small

KEYWORDS

entomophagy
well-being
acceptability
healthy food
food innovation
consumer perception

manageable steps during a food experience with insects dispelled false beliefs and overcame revulsion. The outcomes of this study are encouraging for the development of innovation in the food industry, favouring the acceptance of new foods and supporting the provision of healthier food choices for the general western population. These findings can also help companies adapt to the growing scarcity of resources and improve the value of innovations they offer the market.

INTRODUCTION

The consumption of insects, or entomophagy, is practised in South East Asia, Central and Southern Africa and parts of South America, but is uncommon in European and American industrialized cultures (Van Huis et al. 2013). Europeans generally associate the consumption of edible insects with poor countries (Van Huis et al. 2013; Verbeke 2015), danger, aversion and disgust (Rozin and Fallon 1980; Fallon et al. 1984; Rozin et al. 2008).

Entomophagy can be considered as an alternative food consumption (AFC) option (Bataat and Peter 2020) that could help achieve environmental sustainability (van Huis et al. 2013). Envisioning insects as human food requires a better comprehension of the social, cultural, psychological and sensory determinants of current eating habits, together with consumers' dietary preferences and practices. To map the way forward towards greater acceptance of entomophagy and consumer well-being, we used a technique not yet discussed, developed or tested in the food domain – design thinking (DT). Quoting Liedtka, '[t]his practice is popular in management circles but appears resistant to rigorous empirical inquiry to assess its utility as a method for improving organizational outcomes related to innovation' (2015: 925).

In the last decade, DT has become a popular technique for innovation in the business community and is slowly making its way into the food value chain (Olsen 2015). DT has been heralded as a faster and cheaper learning approach to solving innovation problems involving multidisciplinary teams (Buhl et al. 2019). DT and marketing can also promote the development of sustainability-oriented innovation such as insect-based products through converting products that hitherto elicited disgust into products that deliver well-being (Buhl et al. 2019; Scott and Vallen 2019).

To be able to develop good solutions, an understanding of the target consumers is needed – how they think and what they feel about the problem to be solved (Olsen 2015). The inclusion of consumer opinion in the development process has also become increasingly important in food science and technology (Tuorila and Hartmann 2020). Many authors have shown that the food innovation process can be made easier when consumers test and express their opinions of new concepts at an early stage (Grunert 1997; Moskowitz 2000; Steenkamp and Van Trijp 1996; Busse and Siebert 2018).

DT procedures and techniques can help food companies improve their market learning resources (Liedtka 2015) and simplify prototyping to identify new directions for further development through consumer-driven food innovation processes (Brown 2008; Olsen 2015). In collaboration with a multidisciplinary team, the use of tools to unleash creativity can also offer suggestions for how open innovation processes can be conducted in the food industry (Olsen 2015). In this light, we considered that using DT to assess consumer perceptions of insect consumption could be relevant.

This study evaluated the perception of western consumers and their hedonic and sensorial experience of insect consumption. Our purpose was to gain a better understanding of such consumption and of how to improve the corresponding acceptance rates. To this end, a multidisciplinary team of designers, marketing experts and food scientists took a user-oriented approach to seek relevant solutions. The aim was thus to empirically test the propositions suggested by Liedtka on the reduction of cognitive biases due to DT to determine ‘whether these assertions bear out in reality’ (2015: 13). This article emphasizes the great potential of collaboration and co-creativity in food innovation, which has been scantily explored in marketing (Althuizen et al. 2016; Damperat et al. 2019), just as there are few studies that investigated the influence of team members’ individual perceptions on collective creative performance (Tu 2009; Wang et al. 2016). Although DT has acquired considerable importance within organizations, the academic studies published on the subject mainly adopt a theoretical perspective (Johansson-Sköldberg et al. 2013).

In the DT process, three stages are important in developing successful products: exploration (also called need finding or exploratory phase), ideation (brainstorming or idea generation) and experimentation (testing or prototyping) (Liedtka 2015; Seidel and Fixson 2013). In our study, the investigation of consumers’ habits and ideas at stage one (consumer empathy) revealed four consumption trends corresponding to different consumption motivations: vegetarianism (intellectual), challenge (social relationship), luxury (emotional) and sport (health). The ideation stage then enabled visualization and rapid prototyping. Here it resulted in the creation of twelve food products using mealworm larva and cricket flour. In the experimentation stage, the five most promising prototypes were tested with consumers and resulted in improved consumer well-being in a food experience with edible insects.

THEORETICAL FRAMEWORK

Entomophagy – A healthy, sustainable practice that elicits disgust in western countries

It is estimated that the global human population will exceed 9 billion by 2050, a massive increase in consumers for an estimated 200 million tonnes of meat production (FAO 2009). To meet this continuous increase in demand, while pursuing a healthier, sustainable food chain, the current food production systems need to make a significant progress (Boland et al. 2013). Interest in alternative protein sources is high (Verkerk et al. 2007), and curiosity for insects as a source of human food has increased (Looy et al. 2014; Rumpold and Schlüter 2013; Gallen et al. 2018).

Entomophagy, the consumption of insects as human food, presents a novel approach to securing a nourishing, sustainable food supply (Anankware et al. 2015; Yen 2009; Myers and Pettigrew 2018). Insects are consumed by an estimated 2 billion people around the globe, mostly in Africa, Asia and parts of America (Ramos-Elorduy 1997; van Huis et al. 2013). Currently, entomophagy has gained much attention in several western urban-developed countries (mostly Western Europe and North America) and is becoming a common topic in the media. The introduction of edible insects into the western diet could help meet the world’s main ongoing challenges (FAO 2013; Looy et al. 2014; Rumpold and Schlüter 2013), namely (1) the environmental challenge of greenhouse gas emissions, freshwater consumption, food waste,

animal welfare, prevention of the risk of zoonotic infection and feed conversion efficiency (van Huis et al. 2013) and (2) the nutritional challenge; very rich in protein, rich in fibre, vitamins and minerals, lipids and amino acids, insects have excellent nutritional profiles (Ramos-Elorduy 1997; Bukkens 1997; Verkerk et al. 2007; van Huis 2013). Hence the progressive adoption of insects as part of the western diet may offer a solution and make an excellent alternative to meat overconsumption (Boland et al. 2013; Raubenheimer and Rothman 2013; van Huis et al. 2013).

Western societies have cultural and psychological barriers that stand in the way of accepting insects as food (Ruby et al. 2015; Gmuer et al. 2016; Martins and Pliner 2006; Gallen et al. 2018). According to Tuorila and Hartmann (2020), disgust, along with food neophobia and related traits, has been identified as a major barrier to accepting novel food alternatives.

Insects can be mentally categorized as ‘culturally inedible’, being viewed more often as pests than as food (Fischler 1990). Foods that deviate from the cultural norm or that are unknown generally hold little sensory appeal (Tan et al. 2015; Tucker 2014). Western consumers may recoil at the prospect of ingesting insects (Harris 1985; Looy and Wood 2006; van Huis et al. 2013; Looy et al. 2014; Tan et al. 2015) and so show low willingness to eat them (Hartmann et al. 2015; Schösler et al. 2012). Consumer behaviours such as consuming atypical protein sources may be environmentally and economically positive, yet often elicit a visceral affective reaction that inhibits their widespread adoption (Powell et al. 2019). Protein-rich foods are often closely associated with health and feeling good. However, this does not apply to insects, because consumers tend to reject foods that evoke disgust or appear to lack naturalness (Tuorila and Hartmann 2020; Sulmont-Rosse et al. 2019).

Insects combine the three classes of elicitor: core disgust elicitors (evoked by stimuli that threaten oral incorporation), contamination elicitors (e.g. poor hygiene) and animal-reminder elicitors that cue us to our animalistic nature (e.g. mortality or deformity). According to Powell et al. (2019), many green practices involve exposure to the elicitors of strong emotions, such as disgust, and the role of emotions in deterring sustainable lifestyle choices has been largely ignored. This research explores how design can prompt sustainable behaviours by increasing willingness to try insect-based products. The process of DT, by its inclusion of users in the design process, can potentially help achieve environmental sustainability goals if it makes people aware of their impact on the environment and so changes their behaviour. Design is used to tackle social issues and create innovative solutions (Margolin and Margolin 2002). It has been engaged in different aspects of sustainability discourse and practice with the recent active interest of industry in environmental and social issues (Ceschin and Gaziulusoy 2016).

Acquainting consumers with the properties of these new food sources is fundamental to understanding and improving their acceptance (Steenkamp and van Trijp 1996; Tuorila 2007; Kemp 2013). To date, little attention has been paid to how consumers evaluate the sensory properties of edible insects. Few studies have addressed visual and taste perceptions, psychological and cultural barriers, and the marketing dimension of insects as food (Looy et al. 2014).

DT and food innovation

The process of food development around the world has been inefficient. Several studies have reported that most new products (77–88 per cent) do not

achieve satisfactory results when launched on the market (Stewart-Knox and Mitchell 2003). There is a need to increase the efficiency of the methodologies used in the development of new products to increase success rates. For example, while the Stage–Gate process has proved very effective in most development applications, it is viewed as too linear, too rigid and too tightly planned to deal with today's fast-paced and often quickly changing world (Grönlund et al. 2010; Cooper and Sommer 2016).

The design management approach presents considerable challenges for innovating industries (Seidel and Fixson 2013; Lu and Liu 2016; Paula et al. 2018). The food sector accounts for 20 per cent of the top brands, yet the emphasis on design is still marginal, with innovation often in the hands of marketing and R&D departments. Design management is a promising avenue when pressure to innovate is strong. It guides manufacturers in integrating design into the production process, provided the strategy is well defined and adapted to the organization and its context (Gallen and Pantin-Sohier 2014). A more innovative design strategy is likely to have a higher payoff in company performance (Gemser and Leenders 2001).

DT uses the designer's methods to connect people's needs with what is technically and commercially viable (Brown 2008). This process emphasizes observation, collaboration, fast learning, visualization of ideas, rapid prototyping and concurrent business analysis (Lockwood 2010), making it possible to use it in many areas, including the redefinition of problems in the food sector.

Several authors have considered the study of consumer perception as one of the most important factors in achieving market success (Siro et al. 2008). Making consumers part of the innovation process supports successful changes in the development of new products (Kemp 2013; Grunert and van Trijp 2014). This integration of consumers into food sector innovation processes is particularly critical today because their needs are guided more and more by the awareness of environmental, animal welfare and health issues and traceability in food production and processing (Busse and Siebert 2018). The use of DT can be extremely important in developing new products and in investigating their acceptance among the consumers, because it emphasizes consumer empathy. To be successful, innovation teams need to understand their consumers and integrate their needs in the early innovation process stages of opportunity/need identification and idea development (Costa and Jongen 2006). Walking together in product development may be the best solution for understanding how consumers think and what they feel in relation to the problem the team is aiming to solve (Olsen 2015).

DT focuses mainly on the comprehensive understanding of a particular problem, for which several possible solutions are created and tested with potential consumers (Beverland et al. 2015; Buhl et al. 2019). Large problems are divided into smaller ones and solved by practical step-by-step procedures (Olsen 2015; Brown 2008). Instead of simply solving one particular problem, DT facilitates the creation and sharing of previously unthinkable possibilities (Kolko 2015). Using this technique, the best way is to start with an exploratory stage, which helps to understand the problem in hand and its context, observe consumers in real-life situations and then, based on these insights, define a suitable problem frame. There follows an ideation stage, when participants generate a range of ideas that might solve the user's problem. The next stage is experimentation, when the most promising ideas are selected, prototyped and tested with potential consumers according to predefined criteria. After each step, the ideas are adjusted according to consumer responses and repeated

until an optimal but viable and sustainable solution is found (Beckman and Barry 2007; Brown 2009; Liedtka 2015; Zheng 2018).

The DT approach can increase the chances of creating insect food products that have positive effects for consumers. The consumption of insects has re-emerged in recent years, but the practice is still marginal and experiential (van Huis 2016). Goff and Delarue (2017) explain that consumers balk at the idea of tasting insect-based products (in this case chips were used) but overcome their reluctance after the first bite, indicating that western societies might be willing to take a first step towards insect consumption, at least as processed foods. Insects are most often served as an accompaniment to aperitifs, combined with well-known taste makers such as chocolate, curry and garlic, or are incorporated into sugar-based products. They are also sometimes consumed in purpose-designed outlets, so-called insect bars (Megido et al. 2014, 2016; Lombardi et al. 2018; Melgar-Lalanne et al. 2019). These practices reveal that the acceptance of insects as food is gradually changing, although their consumers are still motivated by curiosity, transgression or rising to a challenge (Sheppard and Frazer 2015). According to a study by Verbeke (2015), young adults who are most likely to consume insects would be considered 'early adopters'. In terms of research, the renewed interest of entomologists in insects as a source of food is very recent (Raubenheimer and Rothman 2013; Van Huis 2013), and the work has most often been applied to the medical and agricultural sectors (Looy et al. 2014). Using user-centred research helps us understand consumers' desires and classify them according to lifestyle, facilitating the development of more responsive products for each target audience and thus improving their acceptance. DT puts into practice sensitivity and the designer's method in complex problem-solving. Pruneau and Langis (2015) reported that some universities have begun using DT in combination with ICT to train their students to solve complex problems, for example, environmental problems, and to create actions to repair, preserve, manage or improve the environment. They refer to these types of design as 'social design' (whose goal is social innovation: Kimbell and Julier 2012) and 'collaborative design' (Paulini 2012; Seidel and Fixson 2013).

DT PROCESS TO ACHIEVE FOOD INNOVATION

This section focuses on the implementation and use of a DT approach to highlight (1) the organization and the necessary steps to achieve food innovation and (2) the main biases it avoids in the food innovation process. It simultaneously presents the DT process and its contribution to the creation of new food products and shows how this approach can avoid the main biases occurring in the food innovation process when different disciplinary teams work separately. This is followed by the three main stages of the analysis grid described by Liedtka (2015) and Damperat et al. (2019) of a co-creative process based on DT that can easily be implemented in the food sector. This implies more consumer empathy, frequent prototyping and collaboration than is common in the food sector today. As Liedtka (2015) states, work in multidisciplinary teams can reduce reliance on self and avoid an egocentric empathy gap, which causes decision-makers to consistently overestimate the similarity between what they value and what others value (Van Boven et al. 2000). Clarity of user needs leads to a greater fluidity of ideas, which in turn broadens the diversity of ideas produced: innovation teams develop products with consumers, not for them. Damperat et al. (2019) underline the importance of empathy;

the clearer the users' needs are to the team members, the easier it will be for them to generate ideas. Furthermore, according to Liedtka (2015), creating multiple options provides a positive mechanism for lessening the effects of the planning fallacy (overoptimism), hypothesis confirmation bias (looking for confirmation of a hypothesis) and the endowment effect (attachment to the first solution). In this sense, using these innovation processes based on how people learn offers new opportunities for the food domain.

An integrated multidisciplinary team

To contribute to innovation in the food industry, a DT process was used with an integrated team of nine junior food designers; a senior food designer with expertise in branding, packaging and food innovation; a DT scholar; two researchers in marketing specialized in food consumer behaviour; and a researcher in food science. Each team member contributed different areas of expertise and different skill sets in their subjects. This research was a collaborative endeavour of the University of Angers, the University of Nantes and the Food Design Lab of l'Ecole de Design Nantes Atlantique, France. It was carried out at the Food Design Lab.

Three main steps to create and improve the value of a food innovation

This research was based on the three main aspects that capture the core of this new food approach: consumer empathy (through exploration), visualization and rapid prototyping (through ideation) and collaboration (through experimentation). The study was approved by the ethical board of the University of Angers (no. UA-CER-2021-01).

The research followed a progressive DT approach with these three stages over a period of 45 days. Figure 1 gives an overview of the steps followed and the points covered in each step. For an easier understanding of this approach, the data collection and the analysis of each step will be presented together. The results of each step conditioned the rest of the approach. Table 1 summarizes the protocol used for implementing the food innovation process.

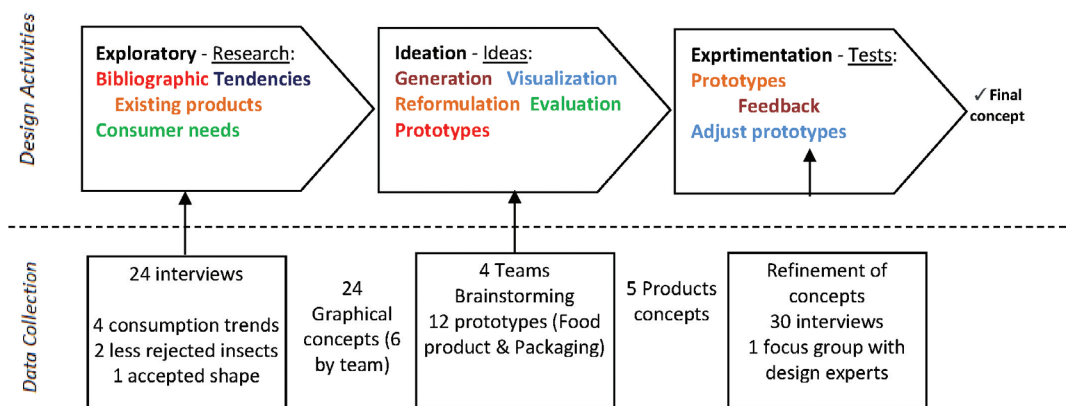


Figure 1: Overview of data collected over the three stages of the DT process.

Table 1: Protocol used for implementing the food innovation process.

Stages/activities followed in each stage	Cognitive biases	Remedies	
Kick-off	Presentation by the project initiators of the aims, the organization of the workshop and the guidelines for stage 1		
Stage 1: Exploratory To study users' dissatisfaction with existing products in order to respond to them with a new product or service (Damperat et al. 2019)	Clarifying the challenge and seeking inspiration (day 1) <ul style="list-style-type: none"> – Building a multidisciplinary team (food science, design, marketing) – Clarification of the challenge (what? for whom? why?) – Search for information on the possible resolution axes identified by the project initiator – Search for inspiring projects to meet the challenge and share these projects with the team <ul style="list-style-type: none"> ✓ Literature search ✓ Presentation of the results of a qualitative study conducted by the project initiators on 37 consumers (21 interviews + two focus groups) testing different types of insects on representations of insects, preferences and willingness to taste (Gallen et al. 2018) ✓ Research trends and existing products ✓ Presentation of the market, stakes and business strategies by an expert in business leader in food industry 	Egocentric empathy gap: Projection of own preferences on others	Work in a team
	Defining the needs of users/customers (between day 1 and day 30) <ul style="list-style-type: none"> – Preparation of interviews and observations. Putting oneself in the place of users – Survey, observation and analysis of the difficulties, needs and wishes of stakeholders – Identification of contradictions, tensions and surprises related to the challenge ✓ Exploratory qualitative study on 24 consumers testing different types of insects on representations of insects, preferences and willingness to taste 	Projection bias: Projection of past into future Focusing illusion: Overemphasis on particular elements	Collect deep data on others Immersing themselves in the user's experience

Stages/activities followed in each stage	Cognitive biases	Remedies
Stage 2: Ideation To devise all possible solutions to meet the needs of users and then select the best solution for solving the problem (Damperat et al. 2019)	Disseminating and sharing information (day 30) <ul style="list-style-type: none"> – Team sharing of information collected that is useful for resolving the challenge ✓ Restitution of the exploratory stage to the team – Identification of information pathways constituting axes for resolving the challenge – Preparation of questions for brainstorming 	
	Generating ideas and devising the first solutions (day 30) <ul style="list-style-type: none"> ✓ Distribution of the team into four working groups according to the trends identified in the exploratory stage: vegetarianism, challenge, luxury, sport – Production of ideas through brainstorming with the instruction ‘no filtering, no judgment’ ✓ Use of mind-mapping (Figure 2) – Selection of preferred ideas – Working out the first solutions based on the preferred ideas ✓ Brainstorming: Proposal of six concepts per working group (24 in all: divergence) (Figure 1) 	Projection bias: Projection of past of future Egocentric empathy: Projection of own preferences on others Planning fallacy: overoptimism Hypothesis Confirmation bias: Look for confirmation of hypothesis Endowment effect: Attachment to first solutions Work in teams with collaborative tools Improve ability to imagine experiences of others Work with multiple options by creating multiple concepts
	Converging towards a solution (day 30) <ul style="list-style-type: none"> – Selection of the solution to be used based on a vote ✓ Selection of three concepts per group by the experts in design, marketing, business management (twelve concepts in all – convergence): vegetarianism (muesli, falafel, cheese soufflé) / challenge (breadsticks, shot to drink, arancini) / luxury (chocolate truffles, spices, sauce balls) / sport (popcorn, smoothie, cereal bars) – Improvement of the solutions: 	

Continued

Table 1: Continued

Stages/activities followed in each stage	Cognitive biases	Remedies	
	<ul style="list-style-type: none"> ✓ User composite drawn up for each target (Figure 3). ✓ Use scenarios (Figure 4) for each solution ✓ Concept sheets (Figure 5) drawn up for each solution in order to define the concepts by answering the questions who? what? when? where? how? and why? 		
<p>Stage 3: Experimentation</p> <p>To create a physical copy of the solution, as a product, in order to quickly collect consumer feedback (Damperat et al. 2019)</p>	<p>Materialization of the solution (between day 30 and day 45)</p> <ul style="list-style-type: none"> ✓ Experimentation of the twelve concepts: recipe formulation (Figure 6) ✓ Confrontation with expertise in design, marketing and food science: reformulation and evaluation of ideas ✓ Taste tests among the group ✓ Selection of the five most promising concepts (Figure 7) ✓ Prototyping: Packaging, graphic identity, brand ✓ Refinement of the concepts: Recipes and packaging 	<p>Planning fallacy Hypothesis Confirmation bias Endowment effect</p> <p>Say/do gap: Inability to describe own preference</p> <p>Planning fallacy Hypothesis Confirmation bias</p> <p>Endowment effect</p>	<p>Help decision-makers become better testers</p> <p>Work with multiple options</p> <p>Disconfirming data focus</p> <p>Conduct reflection on the results of real experiments</p>
	<p>Consumer test:</p> <ul style="list-style-type: none"> ✓ Test of the prototypes with 30 consumers (perceptions, taste test, preference) <p>Feedback and adjustments:</p> <ul style="list-style-type: none"> ✓ Presentation of the results of the consumer test to the team ✓ Focus group with the design experts ✓ Recommendations on the elements to be adjusted 		

Exploratory stage: Definition of needs

This first stage comprises data-gathering to define user needs and outline the problem (Brown 2008). To prepare this study, a literature review was done, and the results of a qualitative study conducted by the project initiators a few months earlier were presented to the team. This study was conducted in two French cities (Nantes and Angers), involving two focus groups each with eight participants and 21 individual interviews. The selected participants were young urban-dwelling adults, because this category tends to be

less neophobic (Tuorila et al. 2001; Verbeke 2015). In all, 37 'naive' subjects (46 per cent female, age 18–30 years) were selected.¹ The focus groups and individual interviews were conducted with the help of an interview guide as described in Gallen et al. (2018). The subjects were presented with different types of edible insects and food products containing insects.² This study enabled observations of consumers' lifestyles and the collection of insights into representations of insects, preferences and willingness to taste (e.g. Patnaik and Becker 2010; Dahl et al. 1999; Seidel and Fixson 2013). This first step enabled us to clarify the aim and familiarize participants with it. First, the members of the research team took advantage of first-hand data collection, which enabled them to develop perspective-taking skills in understanding and adopting the viewpoints of others. Second, in order for the team to clearly know user needs and understand user dissatisfaction and unfulfilled wishes, this study replicated as an exploratory qualitative study on 24 French consumers (50 per cent female, age 18–59 years). It was testing different types of insects (the same as stated above) and using elicitation of representations (e.g. Dahl et al. 1999) and preference analyses. This exploratory stage was based (1) on a qualitative research focused on developing an understanding of users by interviewing and interacting with them and (2) on visualization, which involves the use of verbal imagery to capture individual and common ideas (Lockwood 2010; Kelly and Litterman 2001; Tversky 2002). The visualization was performed from the consumers' answers, and a discussion was held with the team to identify the different profiles of consumers interested in consuming insects. The exploratory qualitative study ($N = 24$) confirmed the results of the previous study ($N = 37$), namely that:

- the idea of eating insects elicited disgust in western consumers because they were associated with danger and dirtiness;
- respondents were aware of the protein intake of food products with insects but wavered between disgust and curiosity;
- four reasons might encourage consumers to eat insect-based food products:
 - a desire to replace animal proteins because they believe eating animals is unacceptable (intellectual motivation),
 - the appeal of challenge and social enhancement, especially among young people (socialization and sharing with friends and family – social motivation),
 - a desire for an extraordinary, exceptional emotional experience (emotional motivation),
 - increased protein intake for better sports performance (health motivation);
- the two least rejected types of insects were mealworms and crickets;
- whole insects were considered inedible in western culture, and insects were better accepted in the form of powder incorporated into familiar food products.

The narrative material on the representations of insects and impressions of disgust emerging from the qualitative study ($N = 24$) enhanced decision-makers' imaginative abilities. These activities avoided projection bias (projection of past into future) and focusing illusion (overemphasis on particular elements) by generating a broad range of definitions of needs.

1. They were recruited on a voluntary basis from the student population of two universities in France (Nantes and Angers). None of them presented food allergies or followed dietary restrictions for any reasons.
2. Natural insects (mealworms, crickets, grasshoppers, mole crickets, bamboo worms, silkworms), flavoured insects (mealworms and crickets with curry flavour and BBQ sauce), processed insects (a chocolate cake and cheese shortbread made from mealworm powder).

In accordance with the design process, consumption trends were also monitored on the world market and searched for in the literature. This confirmed that most manufacturers offered insects incorporated into familiar products (bread, pasta, crisps, etc.). It also showed that manufacturers referred to insects either in the brand names used (e.g. eat bugs), in the name of the product (e.g. bites with cricket flour) or in the graphic depiction. Finally, this discussion was completed with a presentation by an expert in business management on market issues and business strategies for the innovation of insect-based food products in order to clarify consumer needs.

Ideation stage: Generation of ideas

The objective of the ideation stage was to think of all the possible ways to meet the needs of previously identified users ('divergence stage') and then to select the best solutions for problems ('convergence stage'). DT suggests several methods for synthesizing insights from the user research (Kolko 2015). 'Personas' is one of these methods that help align the researched information in a qualitative way, in order to condense it into a so-called point of view, which determines the subsequent direction of the process (Thoring and Muller 2011).

The ideation stage began with the restitution of the exploratory stage to the whole research team. The team then generated a range of ideas that might solve the users' problems and improve their well-being in a food experience with insects. This synthesis step represented the problem in a way that was favourable to solving it and made connections between the elements. From the results of the exploratory study, two types of insects were selected (mealworms and crickets) and one form (powder incorporated into food products). Four consumption trends were identified to guide the ideation stage: the consumption of insects can be part of vegetarian consumption (intellectual motivation), can satisfy consumers looking for adventure or challenge (social motivation), can be promoted through high-end positioning, even luxury (emotional motivation), and finally can target persons practising sport (physical health motivation). Four personas were created from these trends. This information enabled the team to work on the four dimensions of consumer well-being.

Four working groups corresponding to the four identified consumption trends were thus formed with food designers for the brainstorming and mind-mapping step (Osborn 1953). From brainstorming, each group produced six concepts corresponding to their target (persona). They were graphically represented. In all, 24 ideas were produced (divergence stage) (Figure 2). Visual representations (drawings, graphs, concept maps) allow an in-depth study of the problem: visually, verbally, numerically, sequentially and emotionally (Green 1993). Visual representations rest the brain and facilitate the exchange of information between solvers (Pruneau and Langis 2015). This second stage thus includes sense-making tools such as mind-mapping (Figure 3), which facilitate team-based processes for drawing insights from the exploratory stage and create a common mind across team members, and brainstorming, which helps generate hypotheses about potential opportunities. User composites were drawn up for each target (see example in Figure 4). Three concepts per group, making twelve in all, were then selected by the experts in food design, marketing (consumer behaviour) and food science (convergence stage), according to the lifestyles of

the consumers interviewed, with the literature and the market. The selected products were:

- muesli, falafel, cheese soufflé for the vegetarian target;
- breadsticks, shot to drink, arancini for the target seeking challenge;
- chocolate truffles, spices, sauce balls for the luxury target;
- popcorn, smoothie, cereal bars for the sport target.

Use scenarios (see example in Figure 5) and concept sheets (see example in Figure 6) were made to answer the questions who? what? when? where? how? and why?, a DT method called 'The 5 Whys' (Serrat 2017). These collaborative tools leverage difference by encouraging a set of behaviours around withholding judgement, avoiding debate and paying particular attention to the tensions that difference creates in the process of seeking higher-order thinking and creating more innovative solutions. They avoid projection, egocentric empathy and focusing biases (Liedtka 2015).



Figure 2: Example of illustrations from brainstorming (diversity of ideas generated).



Figure 3: Example of techniques used: Mind-mapping.

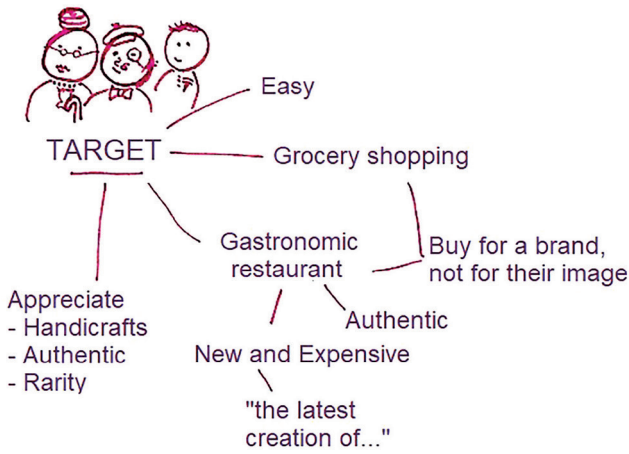


Figure 4: Example of user composite illustration (fluency in generating ideas).

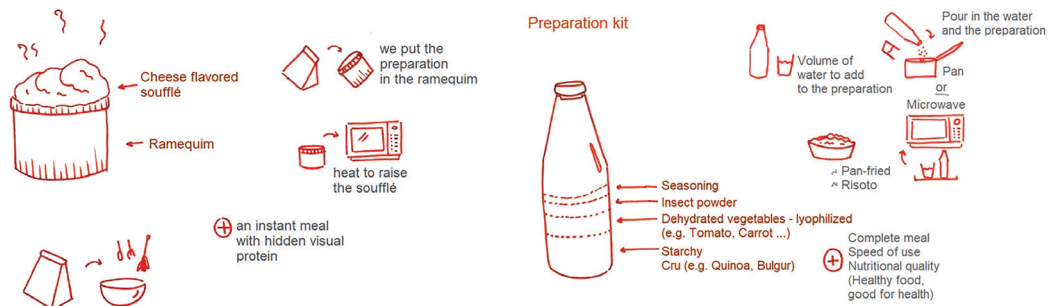


Figure 5: Example of usage scenario illustration.

Adventurer

1. in the evening, aperitif / board game.
 Target: young, millennials.
 Concept: Mikados made from insect flour.



Figure 6: Example of concept sheet illustration (ease of convergence to a single solution).

Experimentation: Prototyping and testing the solution

Prototyping the solution

This stage consisted in creating a physical copy of the solution chosen after the convergence stage, in order to quickly collect consumer feedback. This materialization process consisted in transforming ideas for testing and refining (Brown and Wyatt 2010). With the help of the expert in food science, the twelve selected product concepts were formulated with cricket powder and mealworm powder (Figure 7). The products were tested among the group, and the recipes were adjusted. This first hedonic taste test allowed the selection of the most promising ideas. Five concepts were selected: muesli (vegetarian target), breadsticks (target seeking challenge), chocolate truffles (luxury target), and smoothie and cereal bar (sport target) to balance hedonic and health desires. For each product, packaging with a brand and a graphic identity were created and prototyped (Figure 8). The reason for prototyping in DT was to drive real-world experimentation for learning rather than to display, persuade or test. The mock-ups were adjusted with the help of the senior food designer and marketing researchers. Prototyping techniques help make abstract ideas tangible and decrease the risk of say/do bias introduced by consumers (inability to accurately describe own preference). Prototypes make new ideas more concrete for consumers who can evaluate and give feedback more easily. Furthermore, prototypes aid pre-experiencing by providing a concrete and tangible artefact that lets decision-makers create more vivid manifestations of the future.



Figure 7: Circulation of ideas, illustration (quality of materialization).



Figure 8: Promising concepts tested.

Testing the solution

The prototypes (the five most promising food products with their packaging) were tested on 30 French consumers with an interview guide, testing perceptions, taste and preferences. Concerning the mental representations associated with mealworm powder and cricket powder, the positive evocations concerned (1) ecology, nature, an alternative resource, (2) the supply of proteins, the health aspect and (3) a new experience. Negative evocations concerned (1) disgust, dirt and diseases, (2) texture (soft, crisp, sticky, dry) and (3) taste (bitter, bland, acid).

The interview guide then took account of perceptions and evaluation of packaging and food products, taste tests, preferences and intentions of behaviour towards the prototypes. Consumers were asked about their perception of the prototypes. The products were associated with the consumption patterns we had envisaged. When respondents were asked about the targets, they imagined the truffles for rich consumers or as a gift and mentioned emotional benefits ('it's for pleasure', 'it's comforting', 'to cheer up'). Concerning muesli, the targets were consumers 'concerned with eating a balanced, healthy, and natural diet', 'more respectful and more ethical foods' (intellectual aspect).

Breadsticks were made to be consumed 'as an aperitif, with friends', 'for those who want to have their friends taste novel things' (social relationship). Finally, the cereal bar and the smoothie were well understood as products intended for consumers who practise sports, who want to take food supplements and proteins (health aspect). For all the packaging, the respondents focused their attention on the dimensional (volume, size) and graphic elements of the packaging (colour, lettering, depiction of the insect, product name, flavours) together with the flavours stated on the pack. For the products, they focused their attention on texture, colour and odour.

For the visual evaluation of the packaging (Table 2), three important negative aspects were mentioned by consumers: the colours of packaging, which did not match the product (breadsticks and muesli); a lack of clarity in information (insufficient) (bar and smoothie); and, finally, the graphic depiction of the insect (muesli), which deters purchase. The positive aspects were the natural appearance (guarantee of quality) (breadsticks, muesli), a healthy product based on insects (muesli, smoothie) and transparency to view the product (smoothie).

For the visual evaluation of the products (Table 3), the colour influenced their perception, in particular as regards quality and taste. On the positive side, there was an attraction for the natural and artisanal aspects of all five products. The smell was also very important, as it prefigured the taste. The colour was perceived as a guarantee of quality. The consumer seemed very sensitive to the golden appearance of the truffles, which evoked luxury and superior quality. The fact that a tested product looked like a known food product reassured consumers.

The taste and texture of the products were then evaluated (Table 4). For breadsticks, tastes were considered innovative, but not distinctive enough, even bland. The texture was appreciated when thin. The muesli was appreciated because of its crunchy texture, its known appearance (looked like muesli) and its chocolate taste. The taste was congruent with the texture. Most of the respondents liked the truffles (texture and taste) because of their conformity with a traditional truffle and the chocolate taste. The bar was only moderately appreciated owing to its insufficiently crisp texture and too-bland taste. The smoothie was the least appreciated product because of its grainy texture and the mismatch between the colour of the product (pink) and the taste (cucumber).

The most popular product was the chocolate truffle because of its chocolate taste. Next came the muesli, which also contained chocolate but whose packaging was deemed too neutral. The breadsticks were found too bland, with packaging that did not necessarily fit the young target. The cereal bar had a too-pasty texture and rather simple packaging. The least appreciated product was the smoothie, owing to a too-great discrepancy between the colour of the packaging and the taste.

Finally, the measure of disgust felt towards insect powder showed that the DT process enabled incremental innovation: this kind of innovation was necessary to transform the radical idea into a form acceptable to the consumers (Norman and Verganti 2014), improving the experience of eating insects. Before product testing, mealworm powder and cricket powder aroused disgust, scoring respectively 5.68 and 4.20 on a scale from 1 to 10. When the insect powder was incorporated in known, packed products, the disgust felt for mealworm powder and cricket powder decreased to respectively 2.75/10 and 2.63/10.

Table 2: Visual evaluations of the packaging.

	What users did not like	What users liked
Breadsticks	Dark, red, blood	Natural, exotic, elegance, authenticity, openness, game
Muesli	Lack of colours, depiction of the insect	Simplicity, natural (wheat, colour), family side (breakfast, to share), healthy
Chocolate truffles	Sober, lack of information	High end, winter product, confidence and quality, clarity in packaging (we know it is chocolate by the colour)
Bar	Lack of clarity in information, medicines, chemical, pet food	Bright colours = energy and proteins
Smoothie	Lack of clarity in information, medicines, chemical, pet food	To take away, transparency, sporty and healthy product

Table 3: Visual evaluations of the products.

	What users did not like	What users liked
Breadsticks	Not very straight shape, no sauce, a little dry, a little thin, lack of originality	Look like breadsticks, handcrafted, natural, lumpy, light, great for snacking, flavours
Muesli	Not sweet enough, floury, large lumps	Crunchy, like a muesli, good flavour, artisanal, crisp, pleasant smell, golden, natural
Chocolate truffles	Too brown, dark, earthy, large, hard	Jewel, small gold splinters, elegant, luxurious, chocolate smell, Christmas truffles, inspires confidence, superior quality
Bar	Not golden enough, dark colour, dense product, not fresh, very dry	Crisp, looks like a protein bar, traditional, delicious, nourishing, crunchy, soft, natural, attractive, wellness bar
Smoothie	Colour, composition, thick, smell of cucumber	Nice colour, homemade, fresh, consistent, good ingredients

Table 4: Taste evaluation of the products.

	What users did not like	What users liked
Breadsticks	Too thick, hard, pasty, dry, heavy, floury texture Tastes not distinctive enough, bland, not spicy enough, too salty	Innovative tastes Preference for thin breadsticks
Muesli		Crunchy, looks like muesli, slightly sweet, chocolate
Chocolate truffles	Too-soft texture, sticks to teeth, not cooked, too pasty	Golden appearance, crispy inside, conforms to traditional truffles, not bitter, melting
Bar	Soft, floury, pasty texture, not crisp and crisp enough Taste not sweet enough, bland taste	Don't feel insects, it smells like chocolate
Smoothie	Too compact, too thick, rough, grainy texture Odour (cucumber) incongruent with the colour (pink) Acid taste, surprising, no red fruit taste	Fresh

Feedback and adjustments

The results of the consumer test were presented to the team. Finally, a focus group was held with the nine food designers to propose recommendations on some points to be adjusted. This last step involved a reflection on the results of real experiments (called after-event review), because understanding why events happen as they do is important (Ellis and Davidi 2005).

The packaging needs to be more evocative for the young target (challenge), and brighter colours are recommended for athletes. Transparency is very important so that consumers can see the product. Interesting results appeared for the graphic depiction of the insect: graphically, crickets disgusted the consumers less than mealworms, while the qualitative study ($N = 24$) showed that consumers were less reluctant to consume worms because they had no head, wings or legs (Figure 9). When graphical depiction did not allow the insect to be identified and was incongruent with the insect contained in the product, consumers felt worried. This was the case for the cereal bar and smoothie packaging on which the insect represented looked like a fly, whereas the product contained cricket powder (Figure 10). They hardly evoked the presence of the insect but were interested in seeing the ingredients. The list of ingredients must be clearly stated. For the product, the recipes need to be worked on to achieve an optimal resulting taste, but the order of preferences could easily have been the same with no insects in the product. The taste of the product was the first criterion of choice. Finally, the texture should suggest product freshness. All this needs to be taken into account in further research.

This pre-experience with innovative products improved user feedback, reducing the availability bias by helping innovators and their customers imagine novel ideas more easily. Moreover, presenting prototypes to external users helps decision-makers reflect on the results of real experiments. They can reflect on experimental results to stimulate an 'after-event review' (AER)



Figure 9: Graphic representation of cricket and mealworm.



Figure 10: Incongruent insect representation.

focused on successes and failures (Ellis and Davidi 2005) to identify their specific causes. 'Effortful reflection', in conjunction with external feedback, accelerates performance (Ansell et al. 2009) and lessens the effects of planning fallacy, hypothesis confirmation bias, endowment effect and availability bias.

DISCUSSION AND CONCLUSION

In the last few years, the consumption of insects has increased, and some products can already be seen in supermarkets. In the Netherlands, it is possible to find more than 500 products such as burgers, schnitzels and nuggets (produced by a Belgian company) that contain about 16 per cent of lesser mealworm flour; the insects can also be bought freeze-dried (van Huis 2016). Although the acceptance of insects as food is gradually growing (Verbeke 2015), more research is needed to make these products more acceptable to the French population. Techniques that assist in this process are, therefore, needed.

The DT approach has been shown to increase the chances of creating insect food products that have positive effects for French consumers. Studies have reported great success of this process in the innovation and development of new products: it reduces the cognitive bias of innovation teams, stimulates creative confidence and improves learning (Olsen 2015). Teams have more successful outcomes when debating ideas, processes or changes to concepts during concept generation, but less successful outcomes during concept selection (Seidel and Fixson 2013; Pelled et al. 1999).

The first step in the process, the exploratory stage, is crucial for the rest of it (Olsen 2015). Understanding the needs of consumers in the exploration stage allows better planning of the next steps. In this study, consumers reported feelings adverse to well-being when reporting insect consumption, such as disgust, especially if the insects were presented whole. Nevertheless, consumers revealed a positive influence on well-being for worms and crickets as powders incorporated into familiar products as the best accepted insect and

the best form of consumption. Mealworm and cricket flour were, therefore, used in this study.

The results were consistent with literature. Sheppard and Frazer (2015) cited appearance and texture as primary disgust elicitors, indicating that processing is an important step for acceptance. Other studies have also reported similar results, claiming that appearance and texture of the insect are perceived as stronger barriers than the taste attribute (Sogari et al. 2018). People will be more willing to eat insects when they are no longer perceived as unfamiliar and unusual (La Barbera et al. 2018). In Kenya, termite and lake fly flours are used to make crackers, muffins, sausages and meat loaf: this processing facilitated commercialization (Ayieko et al. 2010). As consumer familiarity progresses, a gradual increase in the concentration of insects in flour might be effective (Ruby et al. 2015). However, making insect-based foods more familiar does not necessarily mean that people will not be repelled, even if the consumption experience itself increases familiarity, and the quality of this experience seems fundamental (La Barbera et al. 2018). Investing in sensory, gastronomic and advertising messages can help (Deroy et al. 2015). According to Kauppi et al. (2019), taste and nutrition factors play an important role in endorsing edible insects; marketing tactics should thus promote those aspects.

The exploratory stage identified the needs and behaviours of consumers regarding the consumption of insects, such as a desire to replace animal protein, attraction to challenges and social improvement, desire to live an extraordinary and exceptional emotional experience and to increase the intake of animal proteins. This step (identifying consumer lifestyles, preferences and consumption patterns) implies significant environmental impacts and determines sustainability-oriented innovation (Hansen and Grosse-Dunker 2013; Schrader and Belz 2012) and well-being (Ares et al. 2014, 2015).

The second step, the ideation stage, enabled visualization and rapid prototyping, which resulted in the creation of twelve food products to satisfy the four consumption trends: vegetarianism (muesli, falafel, cheese soufflé), challenge (breadsticks, shot to drink, arancini), luxury (chocolate truffles, spices, sauce balls) and sport (popcorn, smoothie, cereal bars). Olsen (2015) cited lower failure rates for new products using DT in the food industry. However, simple prototype testing with consumers is rare. Little information is found on prototyping for food innovation and product development. Even so, food concept testing has become quite common (Moskowitz 2000) to understand what motivates food consumers to demand products (Grunert and Valli 2001), as performed by the multidisciplinary team during this research. Identifying these motivations is important, because consumers demand products according to the consequences that consumption of these products will have for them (Walker and Olson 1991; Peter et al. 1999), including their well-being, confirming that this technique is relevant in food science.

During the experimentation stage, after identifying the positive and negative effects of the prototypes, the five most promising ones (Figure 8) were selected, minimizing the cost of failures and avoiding major negative surprises. The prototypes were tested with French consumers, and the results showed a strong consumer well-being, dispelling false beliefs and overcoming revulsion by gradual exposure to small manageable steps during a food experience with insects, according to Bandura (1997).

This research focused on enhancing the attractiveness of a sustainable food product that lacks first-sight appeal, which is particularly challenging

in the food industry where consumers are looking for products that convey pleasure, healthiness and environmental sustainability. The DT approach made it possible to increase the positive experience that consumers can gain from consuming the prototypes tested and adjusted. These results may help decision-makers in the food industry improve the value of the innovations they bring to the market, and specifically for insect-based products.

Further research should evaluate the use of DT in the acceptance of edible insects in other populations. Eating habits reflect cultural ideas about eating properly (Marshall 2005), and culture is expected to influence consumers' conceptualization of well-being. DT can also be applied among consumers already familiar with edible insects to verify that the needs of this target audience are met. Foods that deviate from the cultural norm or that are unknown generally hold little sensory appeal (Tan et al. 2015; Tucker 2014). Another idea for future research would be to look at sociodemographic variables, such as age, gender and income. This may be a limitation of this study since these variables can influence perceived food-related well-being (Diener et al. 2003). Lastly, it would be useful for our team to have a chef for the creation of recipes, and a semiotics expert for the package design in order to analyse how non-verbal elements such as images, visual structure, colours, lettering and their combinations produce meanings (Kehret-Ward 1988). More research is needed in the fields of semiotics and perception, focusing particularly on well-being expectations to know how package design (e.g. insect depiction) arouses specific reactions in the consumer.

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