VIRTUAL FLAVOR: ENHANCING WILLINGNESS TO EAT INSECT-BASED FOODS IN WESTERN SOCIETIES VIA VIRTUAL REALITY EXPERIENCES

ABSTRACT

Entomophagy, or the consumption of insects, is emerging as a viable and sustainable protein alternative for consumers in Western societies. Although eating insects is not new to many cultures (e.g., Asian cultures), it represents a novel and unconventional eating practice in the Western world (e.g., the United States and Europe). This practice is often characterized by food taboos, neophobia, cultural barriers, and negative media portrayals. Despite the numerous health and sustainability benefits of insect-based foods, the acceptance and adoption of entomophagy in Western countries remain limited. In this research, we explore the connection between the adoption of entomophagy and Virtual Reality (VR), demonstrating VR's potential as an effective tool for enhancing willingness to eat (WTE) insect-based foods. Specifically, through three experiments, we show that consumers who receive information about insect-based foods through VR experiences (considering both simulated and actual use) exhibit a greater willingness to eat these products compared to those not exposed to the technology. We also discuss the powerful role of VR compared to other mediums (such as smartphones) in persuading consumers to try insect-based foods.

Keywords: Insect-based food, Sustainability, Entomophagy adoption, Willingness to eat, Virtual Reality

1. INTRODUCTION

Entomophagy (or insects eating) is one of the alternative food consumptions that might be adopted by consumers in Western food cultures, which has the potential to contribute to both individual food well-being and to sustainability and health issues (Lisboa et al., 2024). Although eating insects is not new for many cultures (e.g., Asian culture), it represents a novel and unconventional eating practice in the Western world (e.g., United States and Europe), often characterized by food taboos and by a negative advertising in the media (Batat and Peter, 2020). Large drivers of the aversion towards this "novel" food practice are especially disgust and food neophobia (Gmuer et al., 2016; Hartmann and Siegrist, 2016; Szlachciuk et al, 2024; Verbeke, 2015).

Despite this, entomophagy is a new trend that has the potential to disrupt Western societies soon. According to Research and Markets (2022), the consumption of insects in the western world is dramatically increasing (approximate 30% growth per annum) and the market size is estimated to reach $9.60 billion by 2030. The demand is driven by lower greenhouse gas emissions if compared to the livestock and poultry industries as well as by high nutritional value of the insect-based food.

Promoting insects as food in a desirable manner and increase the willingness of consumers to eat (WTE) this food are not easy tasks in the Western countries (Brunner and Nuttavuthisit, 2020). However, willingness to eat insect-based food by Generation Z is becoming popular and especially young consumers (Barska, 2014; Platta et al., 2024) seem to be the strongest promoters of the introduction of insects into the Western market (Fellows, 2014). This happens especially because they care about health and environmental issues (Platta et al., 2024).

Virtual Reality (VR) is a growing trend in marketing, particularly in retail and shopping. Retail giants such as Amazon (VR kiosks) and Alibaba (Buy + mobile VR platform) are already implementing it in their e-shopping and transforming the retail ecosystem (Xi and Hamari, 2021). Furthermore, VR is a valid data collection tool for consumer behavior studies in the food industry (Xu et al., 2021) and can be a new way to convince consumers to try insect-based food.

This work aims to explore the potential role of virtual reality in promoting insect-based food. Specifically, through three experiments, we show how consumers who are receiving information on insect-based food through the medium of virtual reality (fictitious/simulated use and actual use) are more willing to eat such products compared to people who are not experiencing the technology. Additionally, we also discuss the powerful role of VR compared to other medium (such as normal smartphone) in convincing consumers to eat insect-based food. We therefore discuss the crucial role that VR can play for promoting the adoption of such new and sustainable food habits.

2. LITERATURE REVIEW

2.1 ENTOMOPHAGY & INSECT-BASED FOOD

Entomophagy is considered as an alternative food consumption, rich of sustainability and health benefits. In general, many are the positive aspects that can be mentioned in favor of eating insects, such as the low farming cost, low water consumption, and the healthier protein intakes compared to other food, such as meat (Van Huis, 2016; Guiné et al., 2021). FAO (Food and Agriculture Organization of the United Nations; 2017) forecasted a compelling need of increase in production by 70% to sustain the world in 2050, with meat products demand, like beef and poultry, expected to double-up. One of the major limitations of the increase in supply of these products is the high costs of feed, including meat meal, fishmeal and soybean meal, which constitute 60–70% of manufacturing costs. Therefore, insects could make a significant contribution to the global food supply chain in the future (Sun-Waterhouse et al., 2016).

2.2 EXPERIENCES THROUGH VR

Consumers are increasingly asking for more emotional, entertaining, and pleasurable experiences with food (Mendini et al., 2019). They are also more open to healthy eating behaviors (Batat et al., 2017). Food marketing is more and more connected with experiential marketing, where consumers are immersed in experiences where they can sense, feel, think, act, and relate with the product (Schmitt 1999); in this regard extended reality technologies can be seen as a medium to entertain the consumers even more that traditional food experiences.

According to Loureiro et al., (2019) virtual reality (VR) is seen as "the environment in which the participant-observer is totally immersed in a completely synthetic world, which may or may not mimic the properties of a real-world environment". The market size of VR is projected to increase from less than $12 billion in 2022 to more than $22 billion by 2025 (Statista, 2023). One of the relevant benefits of VR is its ability to replicate real life food decision making in a laboratory setting (e.g., Ledoux et al., 2013), where results observed using real products can be replicated in virtual/augmented reality settings considering the food experience (Siegrist et al., 2019). In fact, VR has been endorsed as a valid tool for consumer behavior studies for the food industry (Xu et al., 2021; Low et al., 2024). For instance, aspects of consumer food behavior were studied in VR environments, such as a supermarket (Schnack et al., 2019; Siegrist et al., 2019; Verhulst et al., 2017) or food buffet (Persky et al., 2018; Ung et al., 2018), in which participants could walk around and become immersed in the virtual space using a human mobile device (HMD). These studies provided interesting insights into how consumers select food in a VR world, demonstrating that behavior in VR is in many respects like behavior in real life. To demonstrate further support to this, van Herpen et al. (2016) suggested that virtual supermarkets better stimulate shopping behavior than the use of pictures; and Waterlander et al. (2015) and Xu et al. (2021) pointed out that shopping patterns in virtual supermarkets are comparable to those in

real settings, providing evidence on the idea that they are valid tools for measuring food purchasing behavior.

2.3 WILLINGNESS TO EAT INSECT-BASED FOOD THROUGH VR

Consumer studies show that Westerners' willingness to eat insect-containing food is low (e.g., Hartmann et al., 2015; Verbeke, 2015). The readiness to adopt insects as food is in fact estimated to be somewhere between 5 and 19 per cent for a typical Western country (Vanhonacker et al., 2013; Verbeke, 2015; Hartmann and Siegrist, 2017) and this percentage must rise if we want to effectively make changes and contribute to our health and the planet. Westerners' aversion to insects is generally considered a product of cultural transmission just as other cultural food aversions and taboos (Fessler and Navarrete, 2003; Rozin and Haidt, 2013). A large driver of this aversion is thought to be linked to the emotion disgust (Baker et al., 2016; Balzan et al., 2016; Gmuer et al., 2016; Hartmann and Siegrist, 2016, Verbeke, 2015; Yen, 2009) and it is generally believed that insect-containing foods elicit disgust because Westerners falsely categorize insects as a pathogen risk, and, thus, as food contaminators (Jensen and Lieberoth, 2019; Rozin et al., 1986). Therefore, disgust and food neophobia are considered as the main factors in the refusal to eat insects.

Puteri et al. (2023) call for further research on how to use digital channels and tools to support the adoption of insect-based food in Western countries. VR, in particular, seem to be a powerful experiential medium to spread the willingness to eat of insect-based food. Further, it seems to be more effective in promoting the desired consumer behavior than traditional mediums (e.g., regular 2D/non-360-degree appeals, print ads, website) (Kristofferson et al., 2022). VR is in fact a valid tool for investigating consumers' behavior toward food (Xu et al., 2021). VR is able to offer a 'feeling of presence' even closer to real life than Immersive Realities can, and has demonstrated high internal validity, comparable to natural settings, and has exceeded the immersion of traditional sensory booths (Gouton et al., 2023; Low et al., 2024). VR can also be used for substituting the product with a manipulated image (e.g. presenting a plant-based burger as a beef burger), thus helping to identify preconceived barriers before product launch (Garvey et al., 2024; Low et al., 2024). VR can therefore drive food innovation and offer better connections with consumers, potentially yielding valuable insights that can lead to disruptive and successful product innovation or new food habits (Low et al., 2024), such as it can be used to persuade consumers to try insect-based food by offering a more experiential approach to this food adoption. We therefore hypothesize:

H1*: Consumers exposed to information related to insect-based food through a simulated VR experience are more willing to eat (WTE) this type of food compared to consumers that are not exposed to such an experience.*

H2*: Consumers exposed to information related to insect-based food through a real VR experience are more willing to eat (WTE) this type of food after the experience (compared to the same consumers before the experience).*

H3*: Consumers exposed to information related to insect-based food through a real VR experience demonstrate greater changes in their willing to eat (WTE) this type*

of food compared to consumers that are exposed to a different medium (i.e., smartphone).

3. METHODS AND RESULTS

3.1 Study 1 – EXPECTED VR experience

106 Gen Z students (44 male, age=21.54), all familiar with VR technologies, enrolled at a major US university participated to the study in exchange for course credits (through a participant pool). This study used a one-factor (information through a virtual reality experience: yes vs. no) between-subjects design. All respondents viewed a paragraph on nutritional, sustainability, ethical and safety information regarding insect-based food (i.e., insect-based power bar) at the beginning of the survey (see Fig. 1 for further details on the stimulus).

** INSERT FIGURE 1 ABOUT HERE **

After that, participants were randomly assigned to one of the two conditions: participants in the "no" condition expressed their feelings about insect-based food with no additional information related to the experience; participants in the "yes" condition expressed their feelings about insect-based food in a virtual reality experience setting. In particular, those participants had to imagine receiving information on insect-based food through a VR setting. As controls, we checked for the emotions of the sample about the fear of eating something new or unfamiliar foods (i.e., neophobia food – Pliner and Hobden, 1992; Sogari et al., 2018) and found no statistical differences among the conditions. Finally, participants responded to the main dependent variables: "willingness to try insect-based food" ("How willing are you to eat a power bar made of insect-based ingredients?", 1=very unwilling, 7=very willing) and "positive attitude toward insect-based food" ("I like it", "I am positive about it", "I am favorable"; 1=not at all, 7=very much). This variable has been measured adopting a reduced version of a validated scale (Coulter and Punj, 2004; Coulter, 1998) and its Cronbach's alpha is 0.97.

We performed a one-way ANOVA using the VR condition as independent variable on the willingness to try insect-based food. Participant in the "yes" condition showed a significantly higher willingness to try insect-based food compared to others (M_{Yes}=21.27, SD_{Yes}=7.92; M_{No}=17.30, SD_{No}=8.94; $F(1,104)=5.12$, $p<.05$; **H1 supported**).

3.2 Study 2 – ACTUAL VR experience

The goal of this second study was to test for consumers' attitudes towards insect-based

food acquiring related information through a real VR experience (**H2**). To do so, students participating in a marketing class were invited to experience VR based on the topic of entomophagy.

28 Gen Z students (10 males, age=24.18) enrolled at a major European university participated to the study. At the beginning of the class, we asked students several questions about novel food and entomophagy; most importantly, we asked them to rate "willingness to eat insect-based food" ("How willing are you to eat a power bar made of insect-based ingredients?", 1=very unwilling, 7=very willing). After the filling out of a first quick survey (pre-experience), each student was invited to experience information on entomophagy through VR, one at the time while other students worked on a class exercise. Specifically, students experienced a VR 360° informative video of less than 3 minutes (available on YouTube) through a VR headset Oculus Meta Quest 2 (128 GB) in which they received specific information about the benefits of insect-based food from food experts. 360° video was a pre-recorded video of real environments made using specialist cameras (i.e., 360°-VR, e.g. (Yu, Lee and Luo, 2018)) where the users can "look around" in the virtual environment, in a way that is not possible with standard 2D videos. This has not to be confused with Computer Generated or CG-VR, where users are able to make decisions about where to go, what to "touch" and how to interact in the environment, which often causes major feeling of physical sickness in participants (Yeo et al., 2020).

At the end of the class, students filled in a second survey (post-experience) where we asked whether they were more "willing to eat insect-based food" after the VR reality experience ("After experiencing the 360° video, how willing are you to eat a power bar made of insect-based ingredients?", 1=very unwilling, 7=very willing).

This study used a one-factor within-subject design (no VR experience at "class beginning (pre-experience)" vs a VR experience at "class end (post-experience)"). In the "class beginning (pre-experience)" condition, participants had no experience about insect-based food using a VR headset whereas participants in the "class end (post-experience)" received all the information on insect-based food through a 360° video using a VR experience. In particular, we analyzed whether there were any particularly interesting changes in regard to willingness to eat insect-based food going on between the beginning of the class (pre-experience) and the end of the class (post-experience) by doing a pre-post study.

According to our t-test, participants at the end of the class showed a significantly higher willingness to eat the insect-based power bar compared to the class beginning, namely the VR experience was persuasive ($M_{pre\text{-}experience}$=3.36, $SD_{pre\text{-}experience}$=1.95 vs. $M_{post\text{-}experience}$=4.25, $SD_{post\text{-}experience}$=1.90; t(27)=3.18, p<.001; **H2 supported**). Given the small size of our sample, we additionally tested the difference of willingness to eat insect-based power bar before and after the class using the non-parametric Wilcoxon matched-pairs signed-rank test (Wilcoxon, 1992). The test confirmed that the VR experience caused a change in the students' willingness to eat (z=3.37, p<.001). Interestingly but not surprising participants were reluctant to eat insect-food at the very beginning of the class (pre-experience survey). Their reluctancy had to do with disgust (e.g., "It's disgusting."), mental aversion ("I have a phobia of insects. Only the thought of it makes me uncomfortable."), contamination ("I think it's difficult for me to think about insects

as something safe and clean for my body to eat."). However, after the experience, participants declared (post-experience survey) to be more willing to eat insect-based food also in the future, pointing out how concepts such as sustainability, environmental respect, healthy food might also play a role in shifting towards this new eating habit (e.g., "I think that this type of food could include a good proportion of proteins and it's sustainable for the planet."; "It's really about a sustainable future, I would be even more motivated to try it."; " I think that this type of food could include a good proportion of proteins and it's sustainable for the planet.").

3.3 Study 3 – Actual VR experience vs. smartphone

The goal of this third study was to compare consumers' attitudes towards insect-based food by acquiring related information through either a real VR or smartphone experience, while controlling for their initial willingness to eat this food (**H3**). Specifically, we tested the third hypothesis by considering different types of insect-based food (namely, power bars, chips, and pasta) to address the potential limitation of using only a single type of insect-based food in the first two studies and to strengthen the research's impact by applying it to a broader spectrum of insect-based products.

68 Gen Z students (31 males, age=22.05) enrolled at a major US university and with a sufficient familiarity with 360° videos participated to the study in exchange for course credits (through a participant pool). At the beginning of the experiment, we asked students several questions about entomophagy (e.g., "How willing are you to eat ____ made of insect-based ingredients?", with "a power bar", "chips" and "pasta" as specification; 1=very unwilling, 7=very willing) and familiarity with 360° videos ("How familiar are you with 360 videos?"; 1=not at all, 7=very much) to verify their eligibility. After the filling out of a first quick survey (pre-experience), students were randomly assigned to two different groups: the first one was composed of students invited one at a time to experience information on entomophagy through VR on the supervision of a research assistant unaware of the scope of the research (28 students); the second group was composed by students that had their experience using their own smartphone in a class (40 students, same procedure as the one followed for the other group). Specifically, all students watched the same video presented during the Study 2. Students in the first group experienced the video using a VR headset whereas students in the second group experienced the same video without benefitting from the immersive experience that could have with the VR headset. At the end of the experiment, all students filled in a second survey (post-experience) where we asked whether they were more willing to eat different types of insect-based food after their experience ("After experiencing the 360° video, how willing are you to eat ____ made of insect-based ingredients?", with "a power bar", "chips" and "pasta" as specification; 1=very unwilling, 7=very willing).

This study used a 2x2 mixed model design (Murrar and Brauer, 2018) setting as a between-subject factor (VR vs. smartphone) and exposure to the video as a within-subject factor (pre-experience vs. post-experience). In the "pre-experience" condition, participants had no experience about insect-based food whereas participants in the

“post-experience" condition received all the information on the insect-based food through a 360° video using a VR experience (“VR” condition) or their own smartphone (“smartphone” condition). In particular, we analyzed whether there were any interesting changes in regard to willingness to eat insect-based food going on between the beginning of the class (“pre-experience”) and the end of the class (“post-experience”) by doing a pre-post study and among the two different experiences (VR and smartphone). Per each insect-based food, we evaluated the willingness to eat that food for those scenarios: pre- and post-experience differences among groups, differences present after experiencing the video independently of the setting used, changes in differences between exposure to the video (pre- vs. post-experience) and between setting used (VR vs. smartphone).

Before the experience, participants in the “VR” group did not report a significant different WTT compared to participants in the “smartphone” group (Table 1). After the experience, participants in the “VR” group report a higher WTT compared to participants in the “smartphone” group, but this difference was not statistically significant (Table 2). Independently of the setting used (VR or smartphone), participants reported a higher WTT after the experience (Table 3). However, when evaluating the changes in the post-experience differences among settings used controlling for the pre-experience WTT levels, participants in the “VR” setting demonstrated a higher change compared to participants in the “smartphone” setting (Table 4, **H3 supported**).

Table 1 - Pre-experience WTT among groups

Type of food	M_1	SD_1	M_2	SD_2	t	p-value
Power bar	3.50	1.69	3.43	2.06	.16	n.s.
Chips	3.36	1.75	3.33	1.98	.07	n.s.
Pasta	2.64	1.42	2.78	1.94	-.31	n.s.

1 VR; 2 Smartphone

Table 2 - Post-experience WTT among groups

Type of food	M_1	SD_1	M_2	SD_2	t	p-value
Power bar	4.61	1.71	3.86	2.14	1.51	n.s.
Chips	4.54	1.82	3.90	2.04	1.32	n.s.
Pasta	3.89	1.75	3.38	2.13	1.06	n.s.

1 VR; 2 Smartphone

Table 3 - Post- vs. pre-experience WTT

Type of food	M_1	SD_1	M_2	SD_2	t	p-value
Power bar	4.18	1.99	3.46	1.90	7.20	<.001
Chips	4.16	1.96	3.34	1.97	6.14	<.001
Pasta	3.59	1.99	2.72	1.74	5.64	<.001

1 Post-experience; 2 Pre-experience

Table 4 - Changes in post- vs. pre-experience WTT among VR vs. smartphone setting

Type of food	M_1	SD_1	M_2	SD_2	t	p-value
Power bar	1.11	.88	.45	.68	3.49	<.001
Chips	1.18	1.19	.58	.98	2.29	<.05
Pasta	1.25	1.29	.60	1.19	2.13	<.05

1 ($M_{post} - M_{pre}$) VR setting; 2 ($M_{post} - M_{pre}$) Smartphone setting

4. CONCLUSIONS

Despite the limitations of the current research, such as for instance the small samples used and the focus on the willingness to eat and not on the actual behavior of tasting insect-based food, with this research we contribute to a better comprehension of enablers of willingness to eat insect-based food (Hartmann et al., 2015; Verbeke, 2015) through the exploration of VR (Ledoux et al., 2013; Loureiro et al., 2019; Siegrist et al., 2019) as a facilitator medium for entomophagy adoption. As research shows, consumers are willing to experience new and engaging food experiences (Mendini et al., 2019) and VR can play an important role in offering new and engaging food experiences to modern consumers (Gouton et al., 2023; Kristofferson et al., 2022; Low et al., 2024). Our results confirm that generation Z consumers´ WTE insect-based food was higher when integrated with virtual reality. Specifically, Study 1 confirmed that those consumers who were exposed to the idea of experiencing insect-based food through VR showed significant higher willingness to eat. In addition, study 2 showed that the willingness to eat increases significantly after watching informative 360° videos about insect-based food through an in-person VR experience. Such findings add new and meaningful insights to the role of VR in entomophagy adoption in Western countries. Finally, Study 3 provides further support for previous findings, demonstrating the powerful role of VR compared to other medium devices (i.e., smartphones). Further, consumers exposed to information about insect-based food through a VR experience showed greater changes in their willingness to eat (WTE) this type of food compared to those exposed to the same information via a different medium (i.e., smartphone). This effect holds true across different types of insect-based food (i.e., power bars, chips, and pasta). These findings provide new and meaningful insights into the role of VR in promoting entomophagy adoption in Western countries, confirming that VR is an effective tool for investigating consumer behavior toward novel foods like insect-based products (Xu et al., 2021). In addition, with this research we add knowledge to the field reinforcing the idea that VR seem to be more effective in promoting desired consumer behavior – such as enhancing willingness to try - than traditional mediums (e.g., normal smartphones videos) (Kristofferson et al., 2022).

Beyond our scholarly contributions, the results are also highly relevant to food marketing experts and practitioners. VR can be effectively utilized by insect-based food companies, chefs, and policymakers to encourage Generation Z consumers to adopt these alternative food products. Immersive experiences, such as VR, provide a unique opportunity to integrate gaming and entertainment elements—features particularly

appealing to Gen Z—while simultaneously increasing their willingness to try (WTT) insect-based foods. From a managerial perspective, this opens up new avenues for creating memorable, emotionally engaging brand experiences that go beyond traditional advertising. Additionally, VR can be used to showcase the sustainability and environmental benefits of insect-based foods in a more tangible, convincing way, bridging the gap between awareness and actual behavior change. By lowering the psychological and cultural barriers associated with entomophagy through immersive storytelling and visualization, companies can shift perceptions more effectively. Finally, from a policy making standpoint, using VR and smartphones to communicate the nutritional benefits and versatility of insect-based products can help educate and evangelize consumers and build trust, which is critical for early adopters of products of the insect-eating world.

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APPENDIX

Figure 1: Information provided to participants in Study 1

NUTRITIONAL FACTS 100g : energy value 1487 kJ / 349 kcal, fat 13g * of which saturated 4.4g, carbohydrates 33g * of which sugars 23g, fiber 24g, protein 20g, salt 0.1g

INGREDIENTS: Almonds 8,6%, roasted pumpkin seed protein 14%, dates 35%, Chicory syrup 20%, **cricket flour 8%**, Cocoa roasted 12%, Cocoa nibs 2,3%, Orange essential oil 0,1%