Correlates of the willingness to consume insects: a meta-analysis

B. Wassmann*, M. Siegrist and C. Hartmann

Department of Health Sciences and Technology, ETH Zürich, Universitaetstrasse 22, 8092 Zurich, Switzerland;
bwassmann@hest.ethz.ch

Received: 5 October 2020 / Accepted: 27 December 2020

© 2021 Wageningen Academic Publishers

OPEN ACCESS

REVIEW ARTICLE

Abstract

Although insects are a sustainable meat alternative, the willingness to consume (WTC) them remains generally low. We synthesised the effects of WTC correlates reported in 37 studies and also investigated the moderating effects of certain study characteristics. Across a large number of studies, affect-based factors, such as ‘food neophobia’, ‘disgust’ and ‘the expected unpleasant taste of insects’, were consistently strongly correlated with WTC ($\bar{r} = -0.33$ -0.55). Information-based factors, such as ‘the perceived sustainability of insects as food’ and ‘the perceived nutritiousness of insects as food’, also impacted WTC ($\bar{r} = 0.32$ -0.55). However, the number of contributing studies in this regard was low. Curiosity appears to be relevant to WTC because ‘food sensation and innovation seeking’ ($\bar{r} = 0.29$) positively impacted WTC. ‘Age, education and gender’ were relatively unrelated to WTC ($\bar{r} = -0.14$ -0.00) across a large number of studies. Combatting affective barriers through gradual and/or early exposure – i.e. increasing the ‘familiarity with the concept of eating insects’ ($\bar{r} = 0.10$) and allowing consumers’ experiences with ‘insect consumption’ ($\bar{r} = 0.35$) to develop over time – will help foster entomophagy acceptance in the long run. In comparison, information-based interventions may have limited effectivity, but they can be implemented in the short term. As meta-regressions have shown, future researchers must consider whether the presentation of the edible insects has moderating effects, e.g. presenting specific as compared to non-specific products ($\beta = -0.47$) or actual products ($\beta = -0.56$) and pictures of such products ($\beta = -0.55$) as compared to mere verbal descriptions. Classical psychological entomophagy factors have been explored comprehensively, and research should also adopt a more market-oriented focus.

Keywords: entomophagy, consumer acceptance, food neophobia, sustainable protein, meat alternative

1. Introduction

The world demand for animal protein continues to increase along with a rapidly growing population. However, conventional meat production systems cannot sufficiently meet these needs, and they also carry high environmental costs. Alternative, more sustainable protein sources are therefore needed (Boland *et al.*, 2013). According to a UN report, one answer to these global concerns could be the more widespread adoption of insects into the human diet (Van Huis *et al.*, 2013). Firstly, insects are high in protein and key macronutrients and lower in cholesterol than many other meat products (Belluco *et al.*, 2013; Nowak *et al.*, 2016; Payne *et al.*, 2016). Secondly, the production of insects may have lower costs as compared to livestock production in terms of feed conversion efficiency, greenhouse gas and ammonia emissions, water and land use and animal welfare

(Halloran *et al.*, 2016; Oonincx *et al.*, 2010; Smetana *et al.*, 2015). In fact, the production of insects can have a lower environmental impact than many other meat alternatives, such as cultured meat or milk-, gluten and myco-based proteins (Smetana *et al.*, 2015).

Although there is a growing awareness of these nutritional and environmental benefits, the willingness to consume (WTC) insects remains low for the majority of the population, especially in Western countries (Hartmann *et al.*, 2015; Verbeke, 2015). To identify the psychological barriers responsible for this, research on the acceptance of entomophagy (e.g. the practice of eating insects) has expanded in recent years. While there have been several reviews compiling these studies qualitatively (Hartmann and Siegrist, 2017b; Kim *et al.*, 2019; Mancini *et al.*, 2019a; Sogari *et al.*, 2019a), the current meta-analysis is

one of the first attempts at a quantitative synthesis. We therefore present not only an overview of factors related to entomophagy acceptance but also estimates of their effect sizes. This allows for an approximate quantification of the importance of various WTC correlates (both as individual factors and in comparison with one another) and certain study characteristics of past entomophagy acceptance research (in terms of moderating effects). Furthermore, we provide an overview of methodological aspects of previous entomophagy studies and identify which variables have been investigated frequently and – in turn – which variables should be given more attention. Our findings aim to consolidate the existing body of knowledge on the barriers to and potential avenues for the acceptance of edible insects and may also illuminate the next steps appropriate for entomophagy acceptance research.

2. Methods

Selection of relevant studies

A literature search of Web of Science (Core Collection) was conducted in May 2020. The Advanced Search tool was used with the following search string: TI=(insect* OR bug* OR entomophagy) AND TS=(substitute OR alternative OR sustainable OR replac* OR entomophagy OR 'eating insects' OR 'insects as food') AND TS=(consum* OR behav* OR accept* OR perception* OR attitude* OR eat*). The search was restricted to articles published in the English language.

The study selection process is depicted in Figure 1; the inclusion and exclusion criteria are summarised in Table 1. The literature search yielded 1,023 records. In a first step, the titles and abstracts of these records were screened and 968 records that did not meet the inclusion criteria were eliminated. In a second step, the remaining 55 records were read in full, and eight more records were eliminated because they did not meet the inclusion criteria. Most of these eliminated records were excluded because they did not provide effect size(s) specifically related to consumers' WTC insects as food. For example, Barsics *et al.* (2017) investigated the overall liking of insects as food, not WTC. As another example, Ebenebe *et al.* (2017) was not included, because their findings were given in frequencies, not as effect sizes. The identification and screening of the records were performed independently by two parties. Interrater agreement was high ($r=0.90$), and discrepancies between the parties were resolved by a more thorough review of the eligibility of the articles in question. Overall, 47 records met the inclusion criteria.

Because the current review aims to analyse the correlational effect between the WTC and various variables (WTC correlates), these specific correlation coefficients had to be extracted from the 47 records meeting the inclusion

criteria. This occurred in two ways: in 14 records, Pearson's r correlation coefficients relevant to the current meta-analytic objective were reported. These were taken directly into the analysis. For the remaining 33 records, statistical values were not given as Pearson's r correlation coefficients, and the corresponding authors were therefore contacted to obtain the correlation coefficients. Through this method, the relevant correlation coefficients of 23 records were obtained and included in our analysis. Eight records were eliminated because the authors did not respond, and three records were eliminated because the provided data were unusable. One not-yet-published record was identified through personal communication with the author. Ultimately, 37 records were included in the review.

Study information

Table 2 shows the general study characteristics (sample size, country of origin, and data collection method) and more detailed study information. Specifically, it shows the WTC type assessed in the studies (WTT: willingness to try insects as food; WTE: willingness to eat insects as food; WTP: willing to pay for insects as food; WTA: willingness to adopt insects as food), the presentation of the insect food (descriptions, pictures or the real products) and the type of insect food investigated in the studies (specific insect products were mentioned such as 'insect patties'; or there was no specification given concerning the food type and insects were referred to simply as 'edible insects'). Additionally, brief descriptions of the insect food presented in the studies are given.

Selection of relevant effect sizes

From the 37 records included in this review, 195 correlations between WTC and 49 variables (WTC correlates) were extracted. However, we decided to exclude the WTC correlates ($n=15$) measured by only one study because doing so would not have allowed the calculation of a mean effect size. Ultimately, this analysis included 180 correlations between WTC insects and 34 WTC correlates.

These 34 WTC correlates (Table 3) can be divided into the following three subgroups: 'sociodemographic variables and general attitudes' ('gender', 'age', 'education', 'environmental concern', 'health concern') (Figure 2), 'variables related to eating' ('food neophobia', 'meat consumption') (Figure 3) and 'variables related to eating insects' ('disgust at eating insects', 'perceived sustainability of insects as food') (Figure 4).

Figure 1. Summary of the selection process of the included literature.

Table 1. Inclusion and exclusion criteria used for the article selection.

Inclusion criteria	Exclusion criteria
Quantitative study.	Qualitative studies, review articles, opinion papers and outlooks, conference papers and abstracts, concept articles.
Full-text paper in the English language.	Not related to consumer behaviour (e.g. insect-based food technology development, human digestion of insect proteins, environmental impact of insect production systems).
Investigates consumers' willingness to consume insects as food or related measures (such as willingness to try, buy, eat, pay, purchase or adopt insects as food).	Focus on sensory perception of insects as food.
Provides (an) effect size(s) correlating at least one variable to consumers' willingness to consume insects.	Focus on consumer perception of insects primarily as feed.
	Does not provide (an) effect size(s) correlating at least one variable to consumers' willingness to consume insects as food.

Table 2. Overview of included studies.¹

Study	N	Sample country	Data collection ²	WTC-measure ³	Insect food presentation ⁴	Insect food type ⁵	Insect food description	Measured WTC-correlate
Baker <i>et al.</i> (2016)	207	USA	OS	WTP	P	S	insect spice-mix, insect fried-rice	23, 25
Brunner and Nuttavuthisit (2019)	1,042	Switzerland, Thailand	PPS	WTA	D	S	insect patties, insect chips, etc.	1, 2, 3, 5, 6, 7, 17, 20, 21, 23, 24, 27, 28, 29
Chan (2019)	202	Mechanical Turk	OS	WTT	D	S	'insects as meat substitute', deep-fried insects, insect cookies	22, 30
De Boer <i>et al.</i> (2013)	1,083	Netherlands	OS	WTE	D	S	insect snack	1, 2, 3, 7, 9
Dupont and Fiebelkorn (2020)	718	Germany	PPS	WTE	P	S	insect patties	1, 2, 6, 7, 13, 14, 20
Dupont, Hagedorn and Fiebelkorn, pers. comm.	497	Germany	PPS	WTE	P	S	insect patties	1, 2, 3, 6, 7, 8, 13, 14, 19, 20, 21
Elorinne <i>et al.</i> (2019)	567	Finland	OS	WTE	D	NS	'foods of insect origin'	6, 8, 16, 22, 23, 24, 25, 27, 28, 29, 31, 32, 33, 34
Fischer and Steenbekkers (2018)	140	Netherlands	E	WTT	D	NS	whole insects	1, 2, 6, 22
Gere <i>et al.</i> (2017)	400	Hungary	OS	WTE	D	NS	'food containing insect ingredients'	6, 20, 21
Gmuer <i>et al.</i> (2016)	428	Switzerland	OS	WTE	P	S	insect chips, deep-fried insects	1, 2, 6, 7, 21, 22, 23, 26
Grasso <i>et al.</i> (2019)	1,825	EU countries	OS	WTE	D	NS	'foods containing insect-based protein'	1, 2, 3, 9, 10, 11, 12, 15, 16
Hartmann and Siegrist (2016)	104	Switzerland	E	WTE	R	S	insect chips	1, 3, 6, 7, 8, 20, 22, 23, 26
Hartmann <i>et al.</i> (2015)	995	Germany, China	OS	WTE	P	S	'insects as meat substitute', deep-fried insects, insect cookies	1, 2, 3, 6, 9, 11, 12, 15, 17, 20, 21, 23, 24, 30
Jensen and Lieberoth (2019)	189	Denmark	OS	WTE	R	S	roasted insects, insect spring rolls, insect soup	6, 21, 22, 24
Kornher <i>et al.</i> (2019)	311	Germany	E	WTP	P	S	insect patties	1, 2, 3, 6, 7, 9, 10, 11, 12, 22
La Barbera <i>et al.</i> (2018)	160	Western countries	CAS	WTA	D	NS	'insect-based food'	6, 22, 26
Lammers <i>et al.</i> (2019)	516	Germany	OS	WTE	P	S	insect patties, whole insects	1, 2, 3, 4, 6, 7, 8, 13, 14, 19, 20, 21
Legendre <i>et al.</i> (2019)	337	USA	OS	WTP	D	NS	'edible insects'	20, 23
Mancini <i>et al.</i> (2019b)	165	Italy	PPS	WTE	R	S	'insects', insect bread	6, 24
Megido <i>et al.</i> (2014)	189	Belgium	PPS	WTE	R	S	flavoured whole insects	1, 2, 20
Megido <i>et al.</i> (2016)	159	Belgium	E	WTE	R	S	insect patties	1, 20, 21, 23, 33
Menozi <i>et al.</i> (2017)	213	Italy	OS	WTE	D	NS	'products containing insects'	1, 24, 27, 29, 34
Orsi <i>et al.</i> (2019)	293	Germany	OS	WTE	P	S	insect patties, insect protein bars, insect pasta, insect granola	1, 2, 3, 4, 5, 6, 7, 20, 21, 22, 25
Piha <i>et al.</i> (2018)	887	EU countries	OS	WTP	P	S	roasted insects, insect nuggets, insect snack, insect wok, insect seasoning	6, 21
Powell <i>et al.</i> (2019)	510	UK	E	WTP	P	S	various insect foods (e.g. insect patties)	1, 2, 3, 4, 7, 18, 23, 25, 28, 29, 30, 32, 33
Rozin and Ruby (2019)	675	USA, India	OS	WTE	D	S	various whole and roasted insects (e.g. crickets)	28
Ruby and Rozin (2019)	692	India, USA	OS	WTE	P	S	insect tacos, insect dosas, insect lollipops, insect cookies, insect parathas	22, 25, 28
Ruby <i>et al.</i> (2015)	399	USA, India	OS	WTT	P	S	insect tacos, insect dosas, insect lollipops, insect cookies, insect parathas	6, 8, 22, 25, 27, 30, 32
Schäufele <i>et al.</i> (2019)	342	Germany	CAS	WTT	P	S	insect risotto rice	1, 2, 3, 6, 7, 20, 21, 24, 31
Schösler <i>et al.</i> (2012)	1,083	Netherlands	OS	WTT	P	S	insect pizza, chocolate-coated insects, insect salad	1, 2, 3, 7
Sogari <i>et al.</i> (2019b)	88	Italy	PPS	WTE	D	NS	'insect products and insect-based products'	1, 2, 6, 21, 23
Tan <i>et al.</i> (2016)	976	Netherlands	OS	WTP	P	S	insect stew, insect curry, insect brownies, insect cakes	6, 23, 26, 31
Tan <i>et al.</i> (2015)	103	Netherlands	E	WTE	R	S	insect patties	26
Tan <i>et al.</i> (2017)	135	Netherlands	OS	WTP	R	S	whole insects, insect meal balls, insect shakes	26, 34
Verbeke (2015)	368	Belgium	OS	WTA	D	NS	'insects as substitute for meat'	1, 2, 3, 10, 20
Verneau <i>et al.</i> (2016)	282	Denmark, Italy	E	WTE	R	S	insect chocolate bars	20, 27
Videbæk and Grunert (2020)	975	Denmark	E	WTA	D	S	whole insects, pureed insects, insects with fish, insect bread, insect products on the Danish market	6, 8, 18, 22

¹ The measured WTC correlate's enumeration can be found in Table 3 and Figures 2-4.² E = experiment, PPS = paper pencil survey, CAS = computer-administered survey, OS = online survey.³ WTT = willingness to try, WTE = willingness to eat, WTP = willingness to pay, WTA = willingness to adopt.⁴ D = description, P = picture, R = real product.⁵ S = specific insect food product (e.g. insect patties), NS = no specification given regarding the insect as food (e.g. 'insects as food', 'edible insects').

Table 3. Summary of the meta-analyses for the 34 WTC correlates (respectively enumerated).¹

WTC-correlate	k	N	$\bar{r}$	95% CI	80% CR	Q	τ	I ²
Sociodemographic variables and general attitudes								
1 Gender (female)	20	10,323	-0.14	[-0.16, -0.27]	[-0.23, -0.03]	44.42***	0.05	53.68
2 Age	17	9,847	0.00	[-0.05, 0.04]	[-0.19, 0.18]	61.23***	0.09	82.73
3 Education	13	8,919	0.04	[-0.02, 0.10]	[-0.17, 0.25]	99.01***	0.11	87.96
4 Environmental concern	3	1,319	0.05	[-0.01, 0.12]	[-0.05, 0.16]	3.38	0.04	42.37
5 Health concern	2	1,335	-0.03	[-0.14, 0.08]	[-0.20, 0.14]	3.28	0.07	69.47
Variables related to eating in general								
6 Food neophobia	21	8,919	-0.33	[-0.37, -0.26]	[-0.53, -0.07]	179.15***	0.13	88.56
7 Meat consumption	12	6,396	0.08	[0.04, 0.11]	[-0.01, 0.17]	21.61*	0.12	50.16
8 Food sensation and innovation seeking	6	3,058	0.29	[0.25, 0.32]	[0.25, 0.32]	2.59	<0.01	<0.01
9 Importance of taste for food choice	4	4,164	0.01	[-0.09, 0.12]	[-0.22, 0.24]	45.57***	0.11	91.73
10 Importance of sustainability for food choice	3	3,961	0.10	[-0.01, 0.22]	[-0.12, 0.32]	19.17***	0.10	91.99
11 Importance of healthiness for food choice	3	3,081	0.05	[-0.14, 0.23]	[-0.30, 0.39]	50.26***	0.16	95.57
12 Importance of convenience for food choice	3	3,081	0.06	[-0.09, 0.21]	[-0.23, 0.34]	39.61***	0.13	93.52
13 Intention to reduce meat consumption	3	1,200	0.04	[-0.10, 0.18]	[-0.22, 0.30]	12.86*	0.12	83.28
14 Food disgust	3	1,200	-0.44	[-0.50, -0.36]	[-0.54, -0.32]	4.16	0.05	52.00
15 Importance of affordability for food choice	2	2,770	0.07	[-0.14, 0.28]	[-0.29, 0.41]	30.60***	0.15	96.73
16 Food fussiness	2	2,392	-0.21	[-0.26, -0.15]	[-0.28, -0.13]	1.71	0.03	41.64
17 Importance of social acceptability for food choice	2	1,987	0.36	[0.33, 0.40]	[0.33, 0.40]	0.59	<0.01	<0.01
18 Disgust sensitivity	2	1,485	-0.23	[-0.37, -0.07]	[-0.45, 0.02]	8.35*	0.11	88.04
19 Food technology neophobia	2	1,013	-0.27	[-0.32, -0.20]	[-0.32, -0.20]	0.72	<0.01	<0.01
Variables related to eating insects								
20 Familiarity with the concept of eating insects	14	5,899	0.10	[-0.11, 0.31]	[-0.63, 0.74]	883.85***	0.42	98.61
21 Experience with eating insects	12	5,786	0.35	[0.22, 0.46]	[-0.12, 0.69]	276.23***	0.24	96.45
22 Disgust at eating insects	12	4,460	-0.53	[-0.66, -0.36]	[-0.86, 0.13]	543.89***	0.35	97.79
23 Perceived tastiness of insects as food	11	5,363	0.55	[0.33, 0.71]	[-0.31, 0.91]	600.68***	0.46	97.99
24 Perceived social acceptability of insects as food	7	3,463	0.35	[0.24, 0.45]	[0.05, 0.59]	52.69***	0.15	90.68
25 Perceived risk of insects as food	6	2,669	-0.33	[-0.44, -0.21]	[-0.58, -0.02]	44.04***	0.15	90.68
26 Preference for carrier food ²	6	1,906	0.10	[0.05, 0.14]	[0.05, 0.14]	3.17	<0.01	<0.01
27 Perceived sustainability of insects as food	5	2,788	0.57	[0.29, 0.75]	[-0.17, 0.89]	335.37***	0.38	98.69
28 Perceived ethicalness of insects as food	4	2,976	0.27	[-0.01, 0.51]	[-0.35, 0.72]	162.04***	0.30	98.44
29 Perceived healthiness of insects as food	4	2,332	0.42	[0.37, 0.46]	[0.33, 0.49]	5.26	0.04	42.48
30 Perceived nutritiousness of insects as food	4	2,056	0.32	[0.20, 0.42]	[0.08, 0.52]	16.72*	0.11	85.03
31 Preference for visibility of insects in food	3	1,885	0.41	[0.19, 0.58]	[0.02, 0.71]	39.21***	0.20	95.83
32 Perceived naturalness of insects as food	3	1,476	0.41	[0.20, 0.57]	[-0.01, 0.70]	40.34***	0.19	94.79
33 Perceived visual appeal of insects as food	3	1,236	0.27	[0.00, 0.50]	[0.26, 0.68]	40.16***	0.24	95.54
34 Familiarity with carrier food ²	3	915	0.35	[-0.14, 0.69]	[-0.56, 0.87]	127.17***	0.44	97.93

¹ Sorted by k and N (within each subgroup). Significant $\bar{r}$ in bold. k = number of studies contributing to meta-analysis; N = total sample size; $\bar{r}$ = mean observed correlation; CI = confidence interval around $\bar{r}$; CR = credibility interval around $\bar{r}$; Q = test for homogeneity; τ = estimated standard deviation of the distribution of the true effects across studies; I² = proportion of heterogeneity due to between-study differences. *P<0.05, ***P<0.001.

² Carrier food refers to the food product that contains the edible insect (e.g. a burger patty or a chocolate bar).

Figure 2. Forest plot showing the mean effect sizes between the willingness to eat insects as food insects and the willingness to consume correlates 1". Error bars represent the 80% CR credibility intervals of the effect size. Grey circles represent the effect size for included studies. The size of the circle indicates the study sample size. Sorted by k (number of studies contributing to mean effect size).

Data analysis

The current analysis reports all effect sizes as Pearson's r correlation coefficients. Some articles ($n=5$) reported more than one correlation for the same relationship between WTC and a certain WTC correlate. For example, some studies reported the correlation between WTC and a certain WTC correlate for a vegetarian and a non-vegetarian group (e.g. Elorinne *et al.*, 2019). For these cases, a composite correlation coefficient was calculated based on the data provided by the authors (Hunter and Schmidt, 2004). Some articles ($n=2$) contained multiple studies (e.g. Chan, 2019). If only one study within a multi-study article was relevant, only the study information and results of the relevant study were included. If multiple studies within one multi-study article were relevant, composite correlation coefficients (Hunter and Schmidt, 2004) and the average sample size across the studies were calculated.

To estimate mean effect sizes and their variability in the metanalysis, the random effects method (Hedges and Olkin, 2014) was applied because random differences across studies were likely (significant Q statistic; Table 3). This methodology incorporates the influence of sample size and weighs effect sizes accordingly. Baujat plots and corresponding diagnostics were inspected to check for potential outliers and influential cases. Funnel plots, Egger's regression tests and the Rank correlation tests indicated that publication bias was not influential. The resulting mean effect sizes (Table 3) were interpreted according to

Figure 3. Forest plot of the willingness to consume correlates 'variables related to eating in general'. For a description of the figure elements, view the description of Figure 2.

Figure 4. Forest plot of the willingness to consume correlates ‘variables related to eating insects’. For a description of the figure elements, view the description of Figure 2.

Funder and Ozer (2019), whereby $\bar{r}=0.10$ represents a small effect, $\bar{r}=0.20$ a medium effect and $\bar{r}=0.30$ a large effect. Corresponding confidence and credibility intervals were given to communicate the precision (or uncertainty) of the summary estimate. Table 3 also depicts heterogeneity analyses. A significant Q statistic was interpreted as evidence that heterogeneity is present across the reported results of the studies. I^2 was reported as a quantification of these inconsistencies across studies and interpreted according to Deeks *et al.* (2011), whereby an I^2 of 0-40% indicates unimportant heterogeneity, an I^2 of 30-60% indicates moderate heterogeneity, an I^2 of 50-90% indicates substantial heterogeneity and an I^2 of 75-100% indicates considerable heterogeneity. Similarly, τ was reported to indicate the extent of variation, or heterogeneity, among the reported results of the studies. Forest plots are presented to display the (composite) correlation coefficients of the WTC correlates for each of the three subgroups (Figures 2-4). Lastly, meta-regressions were conducted to test whether certain study characteristics had explanatory value concerning heterogeneity.

All data analyses were conducted in R (R Core Team, 2010; SPSS Version 24.0, IBM Corp, Armonk, NY, USA) with the ‘metafor’ (Viechtbauer, 2010) and ‘robumeta’ (Fisher and Tipton, 2015) packages, while Figures 2-4 were created using Tableau (Tableau Software Inc., 2003).

3. Results

Descriptive study characteristics

Table 2 shows the most important study characteristics. Most studies were surveys (online, paper-pencil or computer-administered) conducted with participants from European countries. Only eight studies involved an experiment, and only six studies involved participants not from Europe (e.g. the USA, India, China or Thailand). As the WTC measure, the majority ($n=21$) of the studies assessed WTE, while seven studies assessed WTP, five studies assessed WTT and four studies assessed WTA. To assess these measures, mostly descriptions ($n=14$) or pictures ($n=15$) of the insect foods in question were presented, while in eight studies, the real insect food product was presented to participants. For most studies ($n=29$) participants were asked to indicate their willingness to consume specific insect-based food products (e.g. mealworm patties, insect-flour protein bars or deep-fried crickets). In the other eight studies, a specific type of insect food was not given. Participants were asked to indicate their willingness to consume ‘foods of insect origin’ or ‘insect-based foods’.

Results of the meta-analysis

Heterogeneity analyses

For 25 of the 34 WTC correlates, the Q statistic provided evidence for significant heterogeneity across studies. Correspondingly, the I^2 and τ results for these WTC correlates were high (with I^2 values ranging from 53 to 96%), indicating that the effect sizes extracted from the studies varied greatly. For nine of the 34 WTC correlates, there was no evidence for significant heterogeneity across studies. However, because most of these low-heterogeneity WTC correlates had a low number of contributing studies ($k < 6$), there is a high level of uncertainty regarding these results (Deeks *et al.*, 2011).

Mean estimated effect sizes

■ Sociodemographic variables and general attitudes

This subgroup consists of WTC correlates 1-5 (Figure 2). There was relatively large heterogeneity concerning the reported effect sizes for the sociodemographic variables and 'education', as well as the attitudes 'environmental concern' and 'health'. This heterogeneity was especially pronounced for 'education'. Considering the fact that the composite effect sizes for these four WTC correlates were also close to 0, these results suggest no correlation between these variables and WTC insects. The number of contributing studies should be taken into account when considering these results however: While the inconsistent effects of 'age' and 'education' were found across a large number of studies, the composite effects of the attitudes (i.e. 'environmental concern' and 'health concern') were calculated from only two to three studies. It is therefore uncertain whether the inconsistent effect of the attitudes would persist if there were more data from more studies to draw from.

Within this subgroup, 'gender' was the only variable with any correlation to WTC. For this variable, the heterogeneity across a large number of studies was relatively low, and a small composite effect size was calculated. The female participants in the identified literature, therefore, were consistently less willing to consume insects than the male participants; however, this effect was small.

■ Variables related to eating in general

This subgroup consists of WTC correlates 6-19 (Figure 3). Most of the food choice motives ('importance of taste', 'healthiness', 'sustainability', 'convenience', and 'affordability for food choice') had composite effect sizes close to 0, suggesting no link between these variables and consumers' WTC insects. Interestingly, the 'importance of social acceptability for food choice' was the only food choice motive strongly correlated with WTC. Again, however, it

should be taken into account that all of these food choice motive composite effect sizes only included two or three studies. Thus, there is little certainty that the calculated mean effect sizes represent the 'true' mean effect sizes for these variables.

In contrast to the food choice motives, we have 'food neophobia' and 'food sensation and innovation seeking'. The composite effect of these WTC correlates can be considered large, and it included a relatively large number of homogeneous correlation coefficients, indicating a high level of certainty that these factors are closely linked to WTC insects. Such large composite effect sizes were also found for the related constructs 'food technology neophobia' and 'food fussiness'. However, the number of contributing studies for these factors was small, limiting the credibility of these results. Also, WTC correlates related to disgust ('food disgust' and 'disgust sensitivity') had large negative composite effect sizes. Again, however, the number of contributing studies for these variables was small.

Overall, therefore, it appears that more general food choice motives ('importance of taste', 'sustainability', 'healthiness', 'nutritiousness', and 'convenience for food choice') are weakly linked to WTC insects. Variables, however, which are related to the newness and acceptability of food ('food neophobia', 'food sensation and innovation seeking', 'food technology neophobia', 'food fussiness' and the 'social acceptability of food'), as well as affect ('food disgust' and 'disgust sensitivity'), are more strongly linked to WTC insects.

■ Variables related to eating insects

In this subgroup (Figure 4), the WTC correlates with the largest composite effect sizes were the 'perceived sustainability of insects as food' ($\bar{r}=0.57$), the 'perceived tastiness of insects as food' ($\bar{r}=0.55$) and 'disgust at eating insects as food' ($\bar{r}=-0.53$). While the disgust factor is unsurprisingly the greatest barrier to the acceptance of entomophagy, an awareness of its environmental benefits – more so than the awareness of health and nutrition related benefit – appears to be the most important driver of the acceptance of insects as food. Furthermore, the results suggest that making insect food appear tasty to consumers could be highly important for consumers' WTC insects.

Interestingly, the reported effect sizes of 'familiarity with the concept of eating insects' were very heterogeneous ($\bar{r}=0.10$) across the identified literature, which may be a reason for the small mean effect size that was obtained for this WTC correlate.

Other WTC correlates that were strongly correlated to WTC and also had a relatively large number of contributing studies were 'experience with eating insects' ($\bar{r}=0.35$, $k=12$)

and the 'perceived social acceptability of insects as food' ($\bar{r}=0.35$, $k=7$). The other variables from this subgroup (i.e. WTC correlates 31-34) only include two or three studies; the credibility of the calculated composite effect for these variables is therefore highly limited.

Meta-regressions

Meta-regressions were conducted to determine whether the study characteristics described in Table 2 can explain the high levels of heterogeneity shown for many WTC correlates (Table 3). Specifically, the moderating effects of the type of data collection (experiment, paper pencil survey, computer-administered survey or online survey), the type of WTC measure (WTT, WTE, WTP or WTA), the insect food presentation (description, picture or real product) and the insect food type (specific insect food product or non-specific type of insect food) were tested. These meta-regressions were conducted for WTC correlates fulfilling two specifications, as recommended by Deeks *et al.* (2011): a meta-regression was only performed for WTC correlates that had considerably high heterogeneity (i.e. $I^2>75\%$) and also included ten or more studies (i.e. $k>10$). Thus, the WTC correlates examined through this procedure were 'gender', 'age', 'education', 'food neophobia', 'familiarity with the concept of eating insects', 'experience with eating insects', 'disgust at eating insects', and the 'perceived tastiness of eating insects'.

As can be seen in Table 4, moderating effects were found for two WTC correlates. Firstly, the correlation between WTC and 'familiarity with the concept of eating insects' was moderated by insect food presentation, explaining 27.5% of variance. Specifically, presenting participants with pictures of the insect food and the real insect food product negatively affected the link between the correlate and WTC (as opposed to presenting only a description). Secondly, the correlation between WTC and the 'experience with eating

insects' was moderated by insect food type, explaining 40.6% of variance. Specifically, asking participants about specific insect foods negatively affected the link between the correlate and the WTC (as opposed to not mentioning any specific type of insect food).

4. Discussion

Main findings and implications

To better understand the generally low WTC insects, we synthesised the effect sizes of various WTC correlates reported in previous studies. We present not only an overview of factors related to entomophagy acceptance – as previous qualitative reviews have already done – but also estimates of their effect sizes. Although there was a high level of heterogeneity for some WTC correlates, our results provide an approximate quantification of the importance of various WTC correlates (both as individual factors and in comparison with one another) and certain study characteristics of past entomophagy acceptance research (in terms of moderating effects).

Our main conclusion is that affect-based factors are most relevant to WTC insects. For instance, the 'classical' food choice motives (Stephens *et al.*, 1995) (i.e. *the importance of sustainability, healthiness, convenience and affordability for food choice*), which are not necessarily related to affect but rather to more general food quality measures, were hardly correlated to WTC ($\bar{r}=0.01-0.10$). Instead, across all 37 included studies, the factors with consistently large effect sizes ($\bar{r}=-0.33-0.55$) were factors strongly related to affect. Specifically, factors related to the fear of the unfamiliar, disgust, pleasure and social acceptability (i.e. *food neophobia, food technology neophobia, food disgust, food disgust sensitivity, food fussiness, disgust at eating insects, the perceived risk of insects as food, the perceived*

Table 4. Results of meta-regressions.¹

WTC correlate	Moderator	k	β	SE	z	95% CI	R ²
Familiarity with the concept of eating insects	Insect food presentation	14					
	Picture (vs description)		-0.55*	0.22	-2.44	[-1.10, -0.02]	27.5%
	Real product (vs description)		-0.56*	0.28	-2.44	[-0.99, -0.11]	27.5%
Previous insect consumption	Insect food type	12					
	Specific (vs no specification given) ²		-0.47*	0.14	3.27	[-0.76, -0.18]	40.6%

¹ k = number of studies contributing to meta-regression; β = regression estimate; SE = standard error; z = z-value; 95% CI = confidence interval around β ; R² = percentage of explained variance. * $P<0.05$.

² Specific insect food products: e.g. insect patties or insect chocolate bars; No specification given concerning the type of food product: e.g. 'insects as food' or 'edible insects'.

social acceptability of insects as food and the *perceived tastiness of insects as food*). Evolutionarily, these factors stem from human protection mechanisms to prevent the consumption of potentially harmful substances (Chapman and Anderson, 2012; Martins and Pliner, 2006; Tuorila *et al.*, 1994). Naturally, these can also be barriers to other novel foods, such as genetically-modified foods (Costa-Font *et al.*, 2008), cultured meat (Siegrist and Hartmann, 2020) or other novel meat substitutes, e.g. mycoprotein (Hartmann and Siegrist, 2017a). Compared to most of these foods, however, consumers appear to be more averse toward insects (Dupont and Fiebelkorn, 2020; Grasso *et al.*, 2019).

Approaches to increasing entomophagy acceptance

Pliner and Salvy (2006) propose various approaches to increase the acceptance of novel foods. In combination with our findings, these could be applicable to entomophagy, potentially to varying degrees of effectivity.

The first and perhaps most effective approach is the reduction of the main barriers to entomophagy acceptance – ‘food neophobia’ ($\bar{r}=-0.33$), ‘disgust’ ($\bar{r}=-0.53$, $\bar{r}=-0.44$) and the ‘expected (unpleasant) taste of insects’ ($\bar{r}=-0.55$). In general, ‘food neophobia’ and ‘disgust’ are decreased through gradual and/or early exposure to unfamiliar food (Birch *et al.*, 1987; Loewen and Pliner, 1999; Pliner, 1982; Sullivan and Birch, 1990; Wardle *et al.*, 2003). The emergence of insect food products in supermarkets, ‘bug banquets’ (Looy and Wood, 2006) and the media (Legendre *et al.*, 2019) have all contributed to the public’s steady familiarisation with entomophagy. Indeed, we found that ‘familiarity with the concept of entomophagy’ ($\bar{r}=0.10$) and ‘previous insect consumption’ ($\bar{r}=0.35$) both positively impact WTC (Gere *et al.*, 2017; Hartmann *et al.*, 2015; Legendre *et al.*, 2019). As a next step, entomophagy should be promoted specifically to children. Dupont and Fiebelkorn (2020), who conducted one of the first entomophagy acceptance studies with a sample of children and adolescents, recommend tasting sessions, teaching units and methods for including edible insects in class, e.g. in biology or geography class (Fiebelkorn and Kuckuck, 2019; Fiebelkorn and Puchert, 2018). As an emotion connected to the oral sense, disgust is linked to taste (Rozin *et al.*, 2009). Pelchat and Pliner (1995) found that providing individuals with the verbal information that a novel food tasted good increased their willingness to try it. Thus, to combat the ‘perceived (unpleasant) taste of insects as food’, insect food advertisements and packaging could explicitly create positive expectations. Future studies should examine how familiarisation with and positive expectations regarding edible insects can be fostered more concretely.

As a second approach, the benefits of insects as food should be emphasised. We found that the ‘perceived sustainability of insects as food’ ($\bar{r}=0.55$) appears to be their most compelling benefit. In second and third places,

consumers are also compelled by the ‘perceived healthiness’ ($\bar{r}=0.42$) and ‘nutritiousness’ ($\bar{r}=0.32$) of insects as food. Insects may therefore have the most success in the ‘green consumer’ market (e.g. as insect-based meat substitutes for environmentally motivated consumers) and, alternatively, among fitness and health-oriented consumers (e.g. insect protein bars and shakes; insects as a ‘healthier’ meat alternative). Indeed, informing consumers about either the individual or societal benefits of edible insects differentially impacts WTC (La Barbera *et al.*, 2018; Verneau *et al.*, 2016). More research on this topic is needed to better understand the various insect consumer segments (Brunner and Nuttavuthisit, 2019). However, strong emotional aversions may block information effects (Martins *et al.*, 1997; Pliner and Salvy, 2006). Thus, as Pliner and Salvy (2006) have concluded, cognitive interventions tend to have limited impact on affect-based food aversions. In the case of entomophagy, therefore, emphasising the positives of edible insects (‘Approach 2’) may be less effective than directly combatting the negative affective factors (‘Approach 1’).

Lastly regarding Approach 3, humans not only exhibit aversion but also curiosity regarding novel foods (Rozin and Rozin, 1981). Indeed, we found that consumers who are ‘food sensation and innovation seeking’ were likely to have a higher WTC ($\bar{r}=0.29$), a result in line with the finding that ‘food neophobia’, ‘food technology neophobia’ and the ‘importance of social acceptability for food choice’ are all negatively correlated with WTC. Brunner and Nuttavuthisit (2019) propose that insect food products could be marketed as something unique and exciting, e.g. at special ‘insect bars’ similar to sushi bars.

Other findings and implications

In accordance with past research (e.g. Lammers *et al.*, 2019), we found certain sociodemographic variables to be unrelated to entomophagy aversions: the effects of ‘age’ ($\bar{r}=0.00$) and ‘education’ ($\bar{r}=0.04$) were highly inconsistent across studies, with mean effects sizes close to 0. There was a negative mean effect for ‘gender’, i.e. being female ($\bar{r}=-0.14$); however, this effect was small and could have been influenced by the tendency of women to generally have higher disgust sensitivity than men (Egolf *et al.*, 2018). Entomophagy acceptance, however, varies cross-culturally (Gómez-Luciano *et al.*, 2019; Verneau *et al.*, 2016), especially when comparing Western with Asian countries (Brunner and Nuttavuthisit, 2019; Hartmann *et al.*, 2015; Ruby and Rozin, 2019; Ruby *et al.*, 2015). We were not able to investigate national differences, because many studies with non-Western participants had to be eliminated during the literature search and, as a result, most of the included studies consisted of primarily Western samples. A sociocultural perspective should be incorporated in future syntheses of entomophagy acceptance research.

In addition to sociodemographic variables, an individual's dietary behaviour may also predict the WTC insects. Indeed, 'meat consumption' was positively associated with WTC. This estimated effect, however, included studies with vegans and vegetarians. Naturally, most vegans and vegetarians are less willing to eat insects (Elorinne *et al.*, 2019), and their inclusion influenced our estimated effect size. Therefore, our findings do not represent how omnivore's WTC insects correlates with their meat consumption and – more importantly – 'their intention to reduce' meat consumption. Dupont *et al.* (pers. comm.) and Verbeke (2015), for example, found that individuals who intended to or had already reduced their meat consumption were more WTC insects, perhaps because they saw them as a sustainable meat replacement. Despite this, Lammers *et al.* (2019) showed that omnivores would prefer to merely try insects as opposed to adopting them as meat-substitutes. More studies focused on insects specifically as meat-substitutes are needed because it may be easier to encourage the 'switch' from meat to insects than persuade consumers to adopt insects into their diet without any further framing.

Multiple studies show that consumers prefer edible insects to be invisible and processed rather than visible and whole (Gmuer *et al.*, 2016; Hartmann and Siegrist, 2016; Orsi *et al.*, 2019). Unfortunately, the experimental design of most of these studies did not allow us to calculate an effect size estimating how 'the degree of processing' impacts WTC insects. Still, we found that the 'preference for the visibility of insects in food' ($\bar{r}=0.41$) was positively correlated with WTC.

Both the 'preference for' ($\bar{r}=0.10$) and 'familiarity of the carrier food' ($\bar{r}=0.35$) – the 'main' food product carrying the insect ingredient – were positively correlated with WTC. However, only a few studies (Elorinne *et al.*, 2019; Hartmann and Siegrist, 2016; La Barbera *et al.*, 2018; Menozzi *et al.*, 2017; Tan *et al.*, 2015, 2016, 2017) contributed to these findings. Thus, carrier food variables should be investigated more in depth, for example, the product type, e.g. pasta vs chocolate bar (Lombardi *et al.*, 2019; Orsi *et al.*, 2019); the flavour, e.g. savoury vs sweet (Schäufele *et al.*, 2019; Tan *et al.*, 2016), or the serving context, e.g. snack vs meal vs dessert (Brunner and Nuttavuthisit, 2019; Elorinne *et al.*, 2019).

In the same vein, other variables related to marketing and product development must be explored in more depth, such as price (Lombardi *et al.*, 2019), convenience (Brunner and Nuttavuthisit, 2019; Elorinne *et al.*, 2019), insect species (Fischer and Steenbekkers, 2018; Rozin and Ruby, 2019) and the packaging (Baker *et al.*, 2016). The 'classical' variables of entomophagy, as Lammers *et al.* (2019) call them, such as 'food neophobia' or 'disgust', have been explored sufficiently, and future research should be more market oriented.

Meta-regression results

The meta-regressions showed that study characteristics such as insect food presentation may have moderating effects. Specifically, the positive effects of 'familiarity with entomophagy' and 'previous insect consumption' on WTC insects were stifled when participants were shown specific products as compared to non-specific products ($\beta=-0.47$) or actual products ($\beta=-0.56$) and pictures of the product ($\beta=-0.55$) as compared to mere verbal descriptions. Baker *et al.* (2016) found similar study characteristics to be influential because they showed that providing images of processed (vs whole) insects positively influenced perceptions in retail settings, while providing vague (vs explicit) descriptions did so in restaurant settings. In our analysis, moderating effects were not found for the other study characteristics. However, because meta-regressions were conducted for only a small number of WTC correlates due to methodological restrictions, other study characteristics – such as offering tasting samples (Mancini *et al.*, 2019b; Megido *et al.*, 2016; Tan *et al.*, 2015) or asking participants to try vs buy insects as food (Tan *et al.*, 2016) – may actually have moderating effects as well.

Limitations

Regarding the main limitation, many studies and effect sizes concerning entomophagy acceptance could not be included in this analysis due to the inclusion criteria. Our findings therefore do not include the entirety of the existing literature on this topic. Specifically, we only included studies that measured WTC edible insects (and not, for example, the sensory liking of edible insects) and studies for which we were able to obtain these effects as Pearson's r . Furthermore, we only included WTC correlates measured in at least two papers. For example, variables such as consumers' attitudes toward organic production methods (Kornher *et al.*, 2019), purchase activism (Legendre *et al.*, 2019) and nutritional knowledge (Brunner and Nuttavuthisit, 2019), in relation to WTC, had only been measured by single studies and were therefore not included in this analysis. These may be interesting variables for future research to consider.

Furthermore, many other study characteristics which we have not tested for could have potential moderating effects. For example, the sample age group (i.e. if the sample consisted of students/general population, or young adults/adults/senior citizens), or the date of data collection (as opposed to the date of publication) could be of relevance.

5. Conclusions

Aversions to edible insects appear to be most strongly linked to affect-based factors, which are best reduced through gradual and/or early exposure to entomophagy. Unsurprisingly, therefore, steady familiarisation over

a longer period of time is the safest bet to foster the acceptance of entomophagy in the long term. Concerning interventions that may already show effects in the short term, information-based approaches (e.g. emphasising the benefits of insects as food) may convince consumers to at least try edible insects. However, the influence of these cognitive factors may be blocked by the strong emotional insect aversions, limiting the success of insects with consumers compelled 'merely' by their sustainability and health related benefits. As an alternative approach, human curiosity appears to be decisive for WTC insects. It is likely therefore that food sensation and innovation seekers could be among the first adopters of entomophagy.

Many general psychological factors have been investigated comprehensively in the context of entomophagy acceptance. Future research should focus on the nuances of how to concretely bring insects to consumers. With this, it becomes even more important that researchers consider the influence of certain study characteristics (e.g. the utilised stimuli) to ensure unbiased results. Furthermore, future research should include product development and the marketing of more specific insect food products.

Acknowledgements

We thank all the authors who upon request provided us with the necessary data to conduct the meta-analysis. We also thank Luana Giacone for her valuable help during the study identification and screening process as well as Victoria Cologne for her help with the construction of the figures using the Tableau Software.

Conflict of interest

The authors declare no conflict of interest.

References

- Baker, M.A., Shin, J.T. and Kim, Y.W., 2016. An exploration and investigation of edible insect consumption: the impacts of image and description on risk perceptions and purchase intent. *Psychology & Marketing* 33: 94-112.
- Barsics, F., Megido, R.C., Brostaux, Y., Barsics, C., Blecker, C., Haubruge, E. and Francis, F., 2017. Could new information influence attitudes to foods supplemented with edible insects? *British Food Journal* 119: 2027-2039.
- Belluco, S., Losasso, C., Maggioletti, M., Alonzi, C.C., Paoletti, M.G. and Ricci, A., 2013. Edible insects in a food safety and nutritional perspective: a critical review. *Comprehensive Reviews in Food Science and Food Safety* 12: 296-313.
- Birch, L.L., McPhee, L., Shoba, B., Steinberg, L. and Krehbiel, R., 1987. 'Clean up your plate': effects of child feeding practices on the conditioning of meal size. *Learning and Motivation* 18: 301-317.
- Boland, M.J., Rae, A.N., Vereijken, J.M., Meuwissen, M.P., Fischer, A.R., Van Boekel, M.A., Rutherford, S.M., Gruppen, H., Moughan, P.J. and Hendriks, W.H., 2013. The future supply of animal-derived protein for human consumption. *Trends in Food Science & Technology* 29: 62-73.
- Brunner, T.A. and Nuttavuthisit, K., 2019. A consumer-oriented segmentation study on edible insects in Switzerland and Thailand. *British Food Journal* 122: 482-488.
- Chan, E.Y., 2019. Mindfulness and willingness to try insects as food: the role of disgust. *Food Quality and Preference* 71: 375-383.
- Chapman, H.A. and Anderson, A.K., 2012. Understanding disgust. *Annals of the New York Academy of Sciences* 1251: 62-76.
- Costa-Font, M., Gil, J.M. and Traill, W.B., 2008. Consumer acceptance, valuation of and attitudes towards genetically modified food: review and implications for food policy. *Food Policy* 33: 99-111.
- De Boer, J., Schösler, H. and Boersema, J.J., 2013. Motivational differences in food orientation and the choice of snacks made from lentils, locusts, seaweed or 'hybrid' meat. *Food Quality and Preference* 28: 32-35.
- Deeks, J.J., Higgins, J., Altman, D.G. and Green, S., 2011. *Cochrane handbook for systematic reviews of interventions version 5.1*. Cochrane, London, UK.
- Dupont, J. and Fiebelkorn, F., 2020. Attitudes and acceptance of young people toward the consumption of insects and cultured meat in Germany. *Food Quality and Preference* 85: 103983.
- Ebenebe, C.I., Amobi, M.I., Udegba, C., Ufele, A.N. and Nweze, B.O., 2017. Survey of edible insect consumption in south-eastern Nigeria. *Journal of Insects as Food and Feed* 3: 241-252. <https://doi.org/10.3920/JIFF2017.0002>
- Egolf, A., Siegrist, M. and Hartmann, C., 2018. How people's food disgust sensitivity shapes their eating and food behaviour. *Appetite* 127: 28-36.
- Elorinne, A.-L., Niva, M., Vartiainen, O. and Väisänen, P., 2019. Insect consumption attitudes among vegans, non-vegan vegetarians, and omnivores. *Nutrients* 11: 292.
- Fiebelkorn, F. and Kuckuck, M., 2019. Insekten oder *in-vitro*-Fleisch - Was ist nachhaltiger? Eine Beurteilung mithilfe der Methode des „Expliziten Bewertens“. *Praxis Geographie* 6: 14-21.
- Fiebelkorn, F. and Puchert, N., 2018. Aufgetischt: Mehlwurm statt Rindfleisch. *Unterricht Biologie* 42: 12-16.
- Fischer, A.R. and Steenbekkers, L.B., 2018. All insects are equal, but some insects are more equal than others. *British Food Journal* 120: 852-863.
- Fisher, Z. and Tipton, E., 2015. Robumeta: an R-package for robust variance estimation in meta-analysis. Available at: <https://arxiv.org/abs/1503.02220>
- Funder, D.C. and Ozer, D.J., 2019. Evaluating effect size in psychological research: sense and nonsense. *Advances in Methods and Practices in Psychological Science* 2: 156-168.
- Gere, A., Székely, G., Kovács, S., Kókai, Z. and Sipos, L., 2017. Readiness to adopt insects in Hungary: a case study. *Food Quality and Preference* 59: 81-86.
- Gmuer, A., Guth, J.N., Hartmann, C. and Siegrist, M., 2016. Effects of the degree of processing of insect ingredients in snacks on expected emotional experiences and willingness to eat. *Food Quality and Preference* 54: 117-127.

- Gómez-Luciano, C.A., De Aguiar, L.K., Vriesekoop, F. and Urbano, B., 2019. Consumers' willingness to purchase three alternatives to meat proteins in the United Kingdom, Spain, Brazil and the Dominican Republic. *Food Quality and Preference* 78: 103732.
- Grasso, A.C., Hung, Y., Olthof, M.R., Verbeke, W. and Brouwer, I.A., 2019. Older consumers' readiness to accept alternative, more sustainable protein sources in the European Union. *Nutrients* 11: 1904.
- Halloran, A., Roos, N., Eilenberg, J., Cerutti, A. and Bruun, S., 2016. Life cycle assessment of edible insects for food protein: a review. *Agronomy for Sustainable Development* 36: 57.
- Hartmann, C., Shi, J., Giusto, A. and Siegrist, M., 2015. The psychology of eating insects: a cross-cultural comparison between Germany and China. *Food Quality and Preference* 44: 148-156.
- Hartmann, C. and Siegrist, M., 2016. Becoming an insectivore: results of an experiment. *Food Quality and Preference* 51: 118-122.
- Hartmann, C. and Siegrist, M., 2017a. Consumer perception and behaviour regarding sustainable protein consumption: a systematic review. *Trends in Food Science & Technology* 61: 11-25.
- Hartmann, C. and Siegrist, M., 2017b. Insects as food: perception and acceptance. Findings from current research. *Ernährungs Umschau* 64: 44-50.
- Hedges, L. and Olkin, I., 2014. *Statistical methods for meta-analysis*. Academic press, Cambridge, MA, USA.
- Hunter, J.E. and Schmidt, F.L., 2004. *Methods of meta-analysis: correcting error and bias in research findings*. Sage, Thousand Oaks, CA, USA.
- Jensen, N.H. and Lieberoth, A., 2019. We will eat disgusting foods together – evidence of the normative basis of Western entomophagy-disgust from an insect tasting. *Food Quality and Preference* 72: 109-115.
- Kim, T.-K., Yong, H.I., Kim, Y.-B., Kim, H.-W. and Choi, Y.-S., 2019. Edible insects as a protein source: a review of public perception, processing technology, and research trends. *Food Science of Animal Resources* 39: 521.
- Kornher, L., Schellhorn, M. and Vetter, S., 2019. Disgusting or innovative-consumer willingness to pay for insect based burger patties in Germany. *Sustainability* 11: 1878.
- La Barbera, F., Verneau, F., Amato, M. and Grunert, K., 2018. Understanding Westerners' disgust for the eating of insects: the role of food neophobia and implicit associations. *Food Quality and Preference* 64: 120-125.
- Lammers, P., Ullmann, L.M. and Fiebelkorn, F., 2019. Acceptance of insects as food in Germany: is it about sensation seeking, sustainability consciousness, or food disgust? *Food Quality and Preference* 77: 78-88.
- Legendre, T.S., Jo, Y.H., Han, Y.S., Kim, Y.W., Ryu, J.P., Jang, S.J. and Kim, J., 2019. The impact of consumer familiarity on edible insect food product purchase and expected liking: the role of media trust and purchase activism. *Entomological Research* 49: 158-164.
- Loewen, R. and Pliner, P., 1999. Effects of prior exposure to palatable and unpalatable novel foods on children's willingness to taste other novel foods. *Appetite* 32: 351-366.
- Lombardi, A., Vecchio, R., Borrello, M., Caracciolo, F. and Cembalo, L., 2019. Willingness to pay for insect-based food: the role of information and carrier. *Food Quality and Preference* 72: 177-187.
- Looy, H. and Wood, J.R., 2006. Attitudes toward invertebrates: are educational' bug banquets' effective? *The Journal of Environmental Education* 37: 37-48.
- Mancini, S., Moruzzo, R., Riccioli, F. and Paci, G., 2019a. European consumers' readiness to adopt insects as food. A review. *Food Research International* 122: 661-678.
- Mancini, S., Sogari, G., Menozzi, D., Nuvoloni, R., Torracca, B., Moruzzo, R. and Paci, G., 2019b. Factors predicting the intention of eating an insect-based product. *Foods* 8: 270.
- Martins, Y., Pelchat, M.L. and Pliner, P., 1997. 'Try it; it's good and it's good for you': effects of taste and nutrition information on willingness to try novel foods. *Appetite* 28: 89-102.
- Martins, Y. and Pliner, P., 2006. 'Ugh! That's disgusting!': identification of the characteristics of foods underlying rejections based on disgust. *Appetite* 46: 75-85.
- Megido, R.C., Gierts, C., Blecker, C., Brostaux, Y., Haubruge, É., Alabi, T. and Francis, F., 2016. Consumer acceptance of insect-based alternative meat products in Western countries. *Food Quality and Preference* 52: 237-243.
- Megido, R.C., Sablon, L., Geuens, M., Brostaux, Y., Alabi, T., Blecker, C., Drugmand, D., Haubruge, É. and Francis, F., 2014. Edible insects acceptance by Belgian consumers: promising attitude for entomophagy development. *Journal of Sensory Studies* 29: 14-20.
- Menozzi, D., Sogari, G., Veneziani, M., Simoni, E. and Mora, C., 2017. Eating novel foods: an application of the theory of planned behaviour to predict the consumption of an insect-based product. *Food Quality and Preference* 59: 27-34.
- Nowak, V., Persijn, D., Rittenschober, D. and Charrondiere, U.R., 2016. Review of food composition data for edible insects. *Food Chemistry* 193: 39-46.
- Oonincx, D.G.A.B., Van Itterbeeck, J., Heetkamp, M.J., Van den Brand, H., Van Loon, J.J.A. and Van Huis, A., 2010. An exploration on greenhouse gas and ammonia production by insect species suitable for animal or human consumption. *PLoS ONE* 5: e14445.
- Orsi, L., Voegelé, L.L. and Stranieri, S., 2019. Eating edible insects as sustainable food? Exploring the determinants of consumer acceptance in Germany. *Food Research International* 125: 108573.
- Payne, C.L., Scarborough, P., Rayner, M. and Nonaka, K., 2016. A systematic review of nutrient composition data available for twelve commercially available edible insects, and comparison with reference values. *Trends in Food Science & Technology* 47: 69-77.
- Pelchat, M.L. and Pliner, P., 1995. 'Try it. You'll like it! Effects of information on willingness to try novel foods. *Appetite* 24: 153-165.
- Piha, S., Pohjanheimo, T., Lähdenmäki-Uutela, A., Křečková, Z. and Otterbring, T., 2018. The effects of consumer knowledge on the willingness to buy insect food: an exploratory cross-regional study in Northern and Central Europe. *Food Quality and Preference* 70: 1-10.
- Pliner, P., 1982. The effects of mere exposure on liking for edible substances. *Appetite* 3: 283-290.
- Pliner, P. and Salvy, S., 2006. Food neophobia in humans. *Frontiers in Nutritional Science* 3: 75.
- Powell, P.A., Jones, C.R. and Consedine, N.S., 2019. It's not queasy being green: the role of disgust in willingness-to-pay for more sustainable product alternatives. *Food Quality and Preference* 78: 103737.
- R Core Team, 2010. *R: a language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna, Austria.

- Rozin, E. and Rozin, P., 1981. Culinary themes and variations. *Natural History* 90: 6-14.
- Rozin, P., Haidt, J. and Fincher, K., 2009. From oral to moral. *Science* 323(5918): 1179-1180.
- Rozin, P. and Ruby, M.B., 2019. Bugs are blech, butterflies are beautiful, but both are bad to bite: admired animals are disgusting to eat but are themselves neither disgusting nor contaminating. *Emotion* 20: 854-865.
- Ruby, M.B. and Rozin, P., 2019. Disgust, sushi consumption, and other predictors of acceptance of insects as food by Americans and Indians. *Food Quality and Preference* 74: 155-162.
- Ruby, M.B., Rozin, P. and Chan, C., 2015. Determinants of willingness to eat insects in the USA and India. *Journal of Insects as Food and Feed* 1: 215-225.
- Schäufele, I., Albores, E.B. and Hamm, U., 2019. The role of species for the acceptance of edible insects: evidence from a consumer survey. *British Food Journal* 121: 2190-2204.
- Schösler, H., De Boer, J. and Boersema, J.J., 2012. Can we cut out the meat of the dish? Constructing consumer-oriented pathways towards meat substitution. *Appetite* 58: 39-47.
- Siegrist, M. and Hartmann, C., 2020. Perceived naturalness, disgust, trust and food neophobia as predictors of cultured meat acceptance in ten countries. *Appetite* 155: 104814.
- Smetana, S., Mathys, A., Knoch, A. and Heinz, V., 2015. Meat alternatives: life cycle assessment of most known meat substitutes. *The International Journal of Life Cycle Assessment* 20: 1254-1267.
- Sogari, G., Menozzi, D., Hartmann, C. and Mora, C., 2019a. How to measure consumers acceptance towards edible insects? A scoping review about methodological approaches. In: Sogari, G., Mora, C. and Menozzi, D. (eds.) *Edible insects in the food sector*. Springer, Berlin, Germany, pp. 27-44.
- Sogari, G., Menozzi, D. and Mora, C., 2019b. The food neophobia scale and young adults' intention to eat insect products. *International Journal of Consumer Studies* 43: 68-76.
- Steptoe, A., Pollard, T.M. and Wardle, J., 1995. Development of a measure of the motives underlying the selection of food: the food choice questionnaire. *Appetite* 25: 267-284.
- Sullivan, S.A. and Birch, L.L., 1990. Pass the sugar, pass the salt: experience dictates preference. *Developmental Psychology* 26: 546.
- Tableau Software Inc, 2003. Tableau desktop (version 2018.1.10). Mountain view. Tableau Software Inc., Palo Alto, CA, USA. Available at: <https://www.tableau.com/products/desktop>.
- Tan, H.S.G., Fischer, A.R., Van Trijp, H.C. and Stieger, M., 2015. Tasty but nasty? Exploring the role of sensory-liking and food appropriateness in the willingness to eat unusual novel foods like insects. *Food Quality and Preference* 48: 293-302.
- Tan, H.S.G., Van den Berg, E. and Stieger, M., 2016. The influence of product preparation, familiarity and individual traits on the consumer acceptance of insects as food. *Food Quality and Preference* 52: 222-231.
- Tan, H.S.G., Verbaan, Y.T. and Stieger, M., 2017. How will better products improve the sensory-liking and willingness to buy insect-based foods? *Food Research International* 92: 95-105.
- Tuorila, H., Meiselman, H.L., Bell, R., Cardello, A.V. and Johnson, W., 1994. Role of sensory and cognitive information in the enhancement of certainty and linking for novel and familiar foods. *Appetite* 23: 231-246.
- Van Huis, A., Van Itterbeeck, J., Klunder, H., Mertens, E., Halloran, A., Muir, G. and Vantomme, P., 2013. *Edible insects: future prospects for food and feed security*. Food and Agriculture Organization of the United Nations, Rome, Italy.
- Verbeke, W., 2015. Profiling consumers who are ready to adopt insects as a meat substitute in a Western society. *Food Quality and Preference* 39: 147-155.
- Verneau, F., La Barbera, F., Kolle, S., Amato, M., Del Giudice, T. and Grunert, K., 2016. The effect of communication and implicit associations on consuming insects: an experiment in Denmark and Italy. *Appetite* 106: 30-36.
- Videbæk, P.N. and Grunert, K.G., 2020. Disgusting or delicious? Examining attitudinal ambivalence towards entomophagy among Danish consumers. *Food Quality and Preference* 83: 103913.
- Viechtbauer, W., 2010. Conducting meta-analyses in R with the metafor package. *Journal of Statistical Software* 36: 1-48.
- Wardle, J., Cooke, L.J., Gibson, E.L., Sapochnik, M., Sheiham, A. and Lawson, M., 2003. Increasing children's acceptance of vegetables; a randomized trial of parent-led exposure. *Appetite* 40: 155-162.