Food Quality and Preference 79 (2020) 103755

Contents lists available at ScienceDirect

Food Quality and Preference

journal homepage: www.elsevier.com/locate/foodqual

Consumers' perception of bakery products with insect fat as partial butter replacement

Claudia Delicato[a,c], Joachim J. Schouteten[a,*], Koen Dewettinck[b], Xavier Gellynck[a], Daylan A. Tzompa-Sosa[b]

[a] Department of Agricultural Economics, Ghent University, Coupure Links 653, Gent 9000, Belgium
[b] Department of Food Technology, Safety and Health, Laboratory of Food Technology and Engineering, Ghent University, Coupure Links 653, Gent 9000, Belgium
[c] Department of Medical and Surgical Sciences, University of Foggia, Via A. Gramsci 89/91, Foggia 71122, Italy

ARTICLE INFO

Keywords:
Hermetia illucens
Novel food
Sensory analysis
Emotion
Acceptance
Entomophagy

ABSTRACT

Including insect ingredients into familiar food products could be a step in enabling a higher acceptance of insects in Western countries. This study investigates the potential of bakery products containing black soldier fly larvae fat (BSF LF) as an ingredient. Sensory and emotional profiling, WTP, liking and product preference were examined for cakes, cookies, and waffles by a total of 344 respondents. Each bakery product was formulated with 0%, 25% and 50% BSF LF as butter substitute. Results showed that BSF LF can replace 25% of butter in these bakery products without changing the overall food experience and liking. In waffles, the substitution might even be up to 50% without influencing consumer's acceptance. The attributes related to texture and color were hardly affected indicating that this insect fat provides a similar structure and functionality to bakery products as compared with butter. Future research should explore the use of refined BSF LF to reduce off-flavors perceived in formulations containing a higher percentage of insect fat.

1. Introduction

Growing worldwide population demands more animal-based products. This rise in demand will also increase the environmental impact caused by livestock production. Thus, it is of foremost priority to look for alternatives to animal products that are economically and environmentally more sustainable. On this aspect, insects and insect products are a sustainable alternative to traditional animal-based food sources (Oonincx, van Broekhoven, van Huis, & van Loon, 2015). Current insect production of protein, and lipids as human food is more environmentally favorable as compared to many animal-based food sources and to some extent (water and land usage) also to plant sources (Smetana, Schmitt, & Mathys, 2019). Improvements in the insect industry can further reduce the environmental impact of insect production and the ingredients isolated from them (Smetana et al., 2019). Besides, insects play a major contribution in closing the cycles of agriculture as they can grow in various side streams (Oonincx et al., 2015; Rehman et al., 2017). Thus, the stimulation of the production, and consumption of insects and insects-based products could generate interesting environmental and economic benefits.

Acceptance of insects as food is low in the West due to sensory appeal, unfamiliarity, low availability, high price and poor image (Tan, van den Berg, & Stieger, 2016). However, it could increase if consumers are more exposed to these products (Lensvelt & Steenbekkers, 2014). In western countries taste, price, food quality, trustworthy information and convenience are important factors playing a role in positively influencing the acceptance towards entomophagy (Lensvelt & Steenbekkers, 2014). Studies have shown that acceptance towards food containing insects increases when the visibility of insects decreases and when the products are appealing to the consumers (Gmuer, Nuessli Guth, Hartmann, & Siegrist, 2016; Tan et al., 2015, 2016). This conclusion has been supported by studies conducted on chili paste based on water bugs and butter cookies based on ground beetles (Tan et al., 2015); tortilla made with crickets' flour (Gmuer et al., 2016); beef stew and brownies with not visible mealworms added (Tan et al., 2016) and biscuits containing 10% crickets (Homann, Ayieko, Konyole, & Roos, 2017). However, long-term acceptance is harder to achieve as socio-cultural aspects play a role (Tan et al., 2016). In this regard, food products with insect ingredients with similar sensory perception to the traditional ones could help to increase long-term acceptance.

Black soldier fly (BSF) larvae and its fat has been used mostly in animal feed because of its economic viability and capital investment (Gold, Tomberlin, Diener, Zurbrügg, & Mathys, 2018), yet the chemical and physical characteristics of black soldier fly larvae fat (BSF LF) make

* Corresponding author.
E-mail address: joachim.schouteten@ugent.be (J.J. Schouteten).

https://doi.org/10.1016/j.foodqual.2019.103755
Received 17 March 2019; Received in revised form 8 August 2019; Accepted 8 August 2019
Available online 10 August 2019
0950-3293/

it a useful asset for the baking industry. First of all, BSF LF contains about 70% of saturated FA, being lauric acid the most abundant one (> 40%) (Oonincx et al., 2015) which makes it solid at room temperature (20 °C). Moreover, lauric acid provides positive nutritional attributes to this insect fat since it is more digestible than long chain FA, it prevents the growth of several gram-positive bacteria, fungi and viruses (Dayrit, 2015). Fats are used in bakery because they provide tenderness, flavor compounds emanation, mouthfeel provision, and gluten structure reduction (Marangoni, Goldstein, & Seetharaman, 2014). BSF LF can work on these aspects of baking production for a feasible application in bakery products. Nonetheless, the functionality, sensory perception and acceptance of insect fat as partial butter replacer in bakery products has not yet been explored.

Due the challenges for insect product acceptance and the technological characteristics of BSF LF, the research presented here focuses on BSF LF as ingredient in three different types of bakery products, namely waffles, cookies and cakes. The choice has fallen on bakery products since it has been suggested that developing products close to Western dietary patterns could lift one of the barriers preventing the intention to eating food products containing insects (Menozzi, Sogari, Veneziani, Simoni, & Mora, 2017). Next to the acceptance, we examine to which extent replacing regular bakery fat by insect fat could influence the emotional associations and sensory properties of food products. Previous research indicated that some consumers tend to have negative emotional associations with food products containing insect ingredients, warranting the inclusion of emotions in food product development research (Gmuer et al., 2016; Schouteten et al., 2016). Besides, such emotional measurements could provide additional information between similar liked food products (Lagast, Gellynck, Schouteten, De Herdt, & De Steur, 2017) and improve food choice prediction (Dalenberg et al., 2014). Given that it is key in Western countries to let people try insect food products, it is also important that the sensory properties of products containing insect ingredients are similar to those of regular products so that the samples meet the expectations of the Western consumers (Tan et al., 2015).

2. Materials and methods

2.1. Experimental design

Consumer tests for bakery products were conducted for cakes, waffles, and cookies using different products blends containing BSF LF. Pretests performed by the researchers indicated that substitution over 50% noticeably influenced the sensory properties of the samples, which led to the decision to let consumers evaluate samples containing 0%, 25% and 50% butter substitution given the aim of the research. Each participant evaluated blindly the three formulations of one bakery product but was informed that these products might have contained an insect ingredient. This study was approved by the ethical committee of Ghent University Hospital.

2.2. Bakery products and presentation mode

The three bakery products with partial substitution of butter by BSF LF were formulated as indicated in Table 1. The following recipes correspond to cakes (C0, C25, C50), cookies (Co0, Co25, Co50), and waffles (W0, W25, W50) of which the number in the abbreviation resembles the percentage of BSF LF. Water was added on all the products when butter was substituted with BSF LF during batter preparation. Addition of water was necessary to adjust the humidity in the products since butter is made of ~82% of fat, ~15% of moisture and ~2% of solids-non-fat (Evers, Crawford, & Kissling, 2003; Walstra, Geurts, & Noomen, 1999), whereas BSF LF is anhydrous. As this difference might affect the products (Wassell, 2014), the addition of water guaranteed the obtainment of the same moisture content.

Cakes were baked in aluminum containers of the size of 18 * 13 * 4 cm. The cookies were baked in an oven tray on baking paper, each cookie weighted 20 g approximately. These products were baked in a convection oven (SMEG SFP140, Italy) with air circulation at 180 °C. Cakes were cooked for one hour whereas cookies for 10 min. Waffles were baked in a waffle maker (Tefal Snack collection SW02-M, France). They were baked in the machine until the dough was baked and crust was brown (about 5 min). All the ingredients for the three products were purchased in local supermarkets. BSF LF, commercially available as LipidX™, was kindly provided by Protix B.V. (Dongen, the Netherlands).

Table 1
Formulation of three bakery products with different fat sources.

Ingredient	Cake			Cookie			Waffle		
	C0	C25	C50	Co0	Co25	Co50	W0	W25	W50
Wheat flour (g)	125	125	125	93	93	93	100	100	100
Butter (g)	125	93.5	62.5	83	62.25	41.5	75	56.3	37.5
BSF fat (g)	–	31.5	62.5	–	20.75	41.5	–	15.4	30.8
White sugar (g)	125	125	125	–	–	–	75	75	75
Brown sugar (g)	–	–	–	87	87	87	–	–	–
Eggs (units)	2	2	2	2	2	2	1 ½	1 ½	1 ½
Baking powder (g)	5	5	5	5	5	5	3.2	3.2	3.2
Salt (g)	–	–	–	1.2	1.2	1.2	–	–	–
Vanilla extract (g)	–	–	–	6	6	6	1.6	1.6	1.6
Water (g)	–	3	5	–	2.5	5	–	3.4	6.7

All bakery products were prepared the day before the consumers' tests took place. Respondents were served only samples of the same bakery product but prepared with the different fat blends, thus a participant evaluated three samples in total. Each sample was given a three-digit code and presented in a transparent odorless cup. Samples were presented according to an experimental design that was balanced for order and carry-over effects (Williams' Latin Square design). Furthermore, participants also received a cup of water at room temperature to rinse their mouth. Samples for each product were given in equal size, having the following measures: cakes, 3 cm width * 6 cm length * 4 cm height, the crust on the shorter sides removed. The cookies sample were squared pieces measuring approximately 5 cm. Lastly, each waffle sample was a square measuring 4 * 4cm.

2.3. Participants

The 344 participants were young adults and university staff volunteers recruited at an university campus in Ghent (Belgium) through flyers during November 2017. They evaluated the three formulations of the same product category, leading to the evaluation of cakes by 102 participants (mean age 27 years, 61% female), cookies by 110 participants (mean age 24 years, 56% female) and waffles by 132 participants (mean age 24 years, 55% female). Participants were free to choose which product category they wanted to evaluate. This study focused on young adults, as these are the readiest to adopt insects as food products (Verbeke, 2015). Prior to their participation, each participant signed an informed consent where they were noticed about the use of insect ingredients in some products. Only persons who regularly consume bakery products (yes/no question 'do you regularly consume bakery products) were allowed to participate in this study. Persons with gluten, egg, milk or house mite allergies were not allowed to participate in this trial.

2.4. Experimental procedure

A similar questionnaire was used for all product categories (waffles, cake and cookies). The first part of the tasting enquired the assessment of the overall liking score on a 9-point hedonic scale from 1 – "Dislike extremely" to 9 – "Like extremely".

Next, participants were asked to perform the sensory and emotional

profiling task of the sample using the rate-all-that-apply (RATA) approach with a 5-point scale (1 = slightly – 5 = very) (Ares et al., 2014). Participants first needed to check the applicable attributes/emotional terms after which the 5-point scale appeared to rate the intensity of the applicable term. Sensory and emotional terms were generated for the bakery products during one afternoon using a focus group, category, following largely the procedure described in Schouteten et al. (2015). In short, a group of 15 non-trained consumers evaluated a list of potential sensory/emotional terms (based upon pilot work and prior research) for a product category using the check-all-that-apply (CATA) method. After the initial selection, the participants discussed the terms and were free to include other terms for a specific product category. Researchers generated then a list with sensory and emotional terms based upon the input of the focus group for that specific product category. Selection of the terms was based on term usage frequencies, discriminatory ability and sensory modalities (sensory terms)/valence (emotional terms). The list, generated by the researchers, for the sensory and emotional terms of that specific product category was then discussed by the focus group. This led to a final list containing sensory and emotional terms for a specific product category. After the first final list was established, a small break (15 min) was held, before the whole procedure started again for the second product category. Followed by another break (15 min) before the participants started the generation of the list with sensory and emotional terms for the last product category. When all lists were made, it was clear that the lists containing emotional terms were highly similar. Hence, the researchers decided, in consultation with the focus group, to generate one list which could be used for all three product categories. The sensory terms covered different sensory modalities such as appearance, aroma, flavor, texture and aftertaste. For cake, the terms were bad aftertaste, beige dough, bright crust, brown crust, buttery aroma, buttery flavor, crumbly, dry, good aftertaste, long aftertaste, off-flavor, rancid aroma, rancid flavor, salty, spongy, sticky, sweet and thick. For cookies, the following terms were used: bad aftertaste, baked aroma, baked flavor, buttery flavor, crumbly, crunchy, dark color, dry, good aftertaste, flatness, hard, long aftertaste, off-flavor, rancid aroma, rough surface, salty, sweet, uniform color, vanilla aroma, and vanilla flavor. Lastly, the sensory terms for the waffles were airiness, bad aftertaste, bright crust, brown color, buttery flavor, crumbly, elasticity, dry, good aftertaste, granular, long aftertaste, off-flavor, rancid aroma, rancid flavor, salty, shiny surface, sweet, vanilla aroma. For the emotional terms, a total of 19 emotional terms were included: calm, contented, desire, disappointed, discontented, disgusted, dissatisfied, distrustful, energetic, enthusiastic, fearful, glad, good, guilty, happy, pleasant, pleasantly surprised, satisfied, worried.

Next, willingness to pay (WTP) for the blend was asked as an open-ended question (no reference price was included). This question referred to the status in which such products could be found in stores: for cakes, a package of 400 gr of product was proposed; for cookies, a package of 8 units; for waffles, a package of 6 units. After the evaluation of all three blends, respondents were asked to indicate their preferred blend. Further, participants were asked 4 yes/no questions regarding their consumption pattern namely 'do you regularly consume insects', 'have you consumed insects in the past', 'do you regularly consume products containing insect ingredients' and 'have you consumed products containing insect ingredients in the past'.

Testing took place in a sensory laboratory under artificial daylight and temperature control (21 °C). Data was collected using EyeQuestion v4.9.4 (Logic8 B.V., The Netherlands).

2.5. Data analysis

All data analyses were performed on the three blends of the same bakery product. The same analysis was performed for each bakery product. Analysis of variance (ANOVA) was carried out on overall liking and WTP data, considering sample as a fixed source of variation and consumers as a random source of variation. When differences among samples were found, Tukey's test was used for post-hoc comparison of means. Chi square test was performed to examine if there were significant differences regarding consumers' preferences of the blends.

The emotional associations and sensory attributes were measured using RATA scales. Research of Meyners, Jaeger, and Ares (2016) showed that the missing check can be considered as a 0, so the data can be seen as measured on a 6-point scale (0–5). The RATA data was analyzed using ANOVA considering sample as a fixed source and consumer as a random effect. Tukey's test was performed for post-hoc comparison of means. Paired t-tests were carried out to examine if the intensities of the bad aftertaste differed significantly with the good aftertaste for the same product. Furthermore, Principal Component Analysis (PCA) was performed using Dravniek's scores (Dravnieks, 1982) for the emotional/sensory attributes separately to graphical visualize the emotional/sensory space of each bakery product (Meyners et al., 2016). It was opted to work with Dravniek's scores in order to balance the elicitation rate and average rating scores of the emotions/attributes.

A significance level of 5% was considered for all statistical tests. All analyses were performed using SPSS 25 (IBMCorp, 2017), except for the PCA which was carried out using XLSTAT version 2018.4 ((Addinsoft, 2019)).

3. Results

3.1. Liking, preference and WTP

In general, around half of the participants of the three studies have tried eating insects while less participants have tried food products prepared with insects before. An overview of the characteristics of the participants for the three types of bakery products is listed in Table 2.

Mean liking scores, preference and WTP for the bakery products are summarized in Table 3. No significant differences regarding the preference between the cake ($\chi^2(2,\ n = 102) = 2.294,\ p = 0.318$) and cookie blends ($\chi^2(2,\ n = 110) = 5.473,\ p = 0.065$) were found. In cakes and cookies, a 25% of butter substitution by BSF LF did not change liking and WTP. However, a 50% of substitution significantly reduced the liking and WTP. The preference for the product with 50% of butter substitution by BSF LF was 26.5% for cake and 24.5% for cookies. Lastly, in waffle formulations, butter substitution by BSF LF did not change liking even at a substitution level of 50%. But it should be noted that the preference for the different waffles blends differed significantly ($\chi^2(2,\ n = 132) = 9.591,\ p = 0.008$). Preference was the highest for W0 (43.9%) followed by W25 (34.1%) and W50 (22.0%). WTP was similar for W0 and W25, which was significantly higher than W50.

Table 2
Characteristics of the participants for the sample testing.

	Cake (n = 102)	Cookie (n = 110)	Waffle (n = 132)
Consume insects regularly (%)	4.9	0.9	0.8
Have tried insects (%)	60.8	42.7	52.3
Consume products made with insects regularly (%)	4.9	1.8	1.5
Have tried products made with insects (%)	48.0	36.4	48.5

Table 3
Mean (S.D.) liking scores ,mean (S.D.) WTP and preference for the bakery products.

	Cake (n = 102)			Cookie (n = 110)			Waffle (n = 132)		
	C0	C25	C50	Co0	Co25	Co50	W0	W25	W50
Liking score[1,2]	6.6_a (1.3)	6.7_a (1.4)	6.1_b (1.6)	6.3_a (1.4)	6.3_a (1.5)	5.5_b (1.9)	6.1 (1.5)	6.2 (1.6)	6.1 (1.4)
WTP[1,3]	2.5_a (1.8)	2.4_{ab} (1.9)	2.1_b (1.6)	1.8_a (1.3)	1.9_a (1.4)	1.5_b (1.3)	2.3_a (1.5)	2.1_a (1.6)	1.9_b (1.4)
Preference[4]	38.2	35.3	26.5	42.7	32.7	24.5	43.9	34.1	22.0

[1] In each row and for each product, values with different superscript letters are significantly different ($p < 0.05$).
[2] Data is expressed as average score on Likert scale 1–9.
[3] Data is expressed as average WTP in €.
[4] Data is expressed as percentage of participants preferring that blend.

3.2. Sensory profiling

Overall, participants found that 21.7% of the sensory terms for the cookies were applicable. For the cake, 30.4% of the terms were checked and for the waffle samples 24.2% of the terms.

Significant differences were found for the sensory attributes related to appearance for the cakes (Table 4). The beigeness of the dough was perceived as less intense for C50 compared to C0. Further, the brightness of the crust was rated as more intense for the C25 than C0 and C50. Also, the brownness of the crust of C25 was lower than C0 and C50. Regarding flavor and aroma, as the percentage of BSF LF increased in the cake formulation to 50%, sweet perception was reduced, and dryness sensation significantly increased. The intensity of buttery flavor was significantly reduced in C50 compared to C25 albeit that no significant differences were found for the buttery flavor between samples C0 and C50. Further, the intensity of a bad aftertaste was significantly higher for 50% BSF LF compared to 25% BSF LF and 0% BSF LF. Substitution of butter by 50% BSF LF significantly reduced the stickiness and thickness perception in cakes. However, the sponginess and crumbliness were not affected.

The blend Co50 showed a significantly higher score for bad aftertaste (1.04), long aftertaste (1.2), off-flavor (0.74) and rancid aroma (0.25). Moreover, good aftertaste (0.94) was significantly lower for Co50. When comparing the good and bad aftertaste of each sample, it was found that the perceived intensity of the good aftertaste was for all cookie samples stronger than the bad aftertaste (Co0: $p = 0.013$ – Co25 : $p = 0.020$ – Cp50: $p < 0.001$). Addition of BSF LF significantly reduced the vanilla flavor perception, both for Co25 and Co50 compared to Co0. Addition of BSF LF did not influence the perception of baked aroma and flavor, buttery flavor, dry, salty, sweet, vanilla aroma. It neither influenced consumer's perception of appearance nor texture attributes.

Consumer's perception of waffles was hardly affected by substitution of butter by BSF LF. A lower intensity of the brown color was

Table 4
RATA for the intensity of sensory attributes related to the bakery products formulations, from 0 – attribute not applicable at all to 5 – attribute very applicable.

Sensory attributes		Cake (n = 102)			Cookie (n = 110)			Waffle (n = 132)		
		C0	C25	C50	Co0	Co25	Co50	W0	W25	W50
Texture	Airiness							0.65	0.73	0.78
	Crumbly	1.02	1.48	1.29	1.02	1.06	0.96	0.97	0.90	1.08
	Crunchy				0.10	0.15	0.15			
	Elasticity							0.38	0.38	0.25
	Granular							0.51	0.68	0.79
	Hard				0.09	0.09	0.02			
	Rough surface				0.37	0.28	0.25			
	Spongy	1.56	1.82	1.52						
	Sticky	1.33_a	0.75_b	0.39_b						
	Thick	1.06_a	0.88_{ab}	0.58_b						
Flavor and aroma	Bad aftertaste	0.27_b	0.23_b	0.69_a	0.26_b	0.28_b	1.04_a	0.48	0.39	0.41
	Baked aroma				0.89	0.99	0.91			
	Baked flavor				0.89	0.89	0.81			
	Buttery aroma	1.71	2.03	1.58						
	Buttery flavor	2.31_{ab}	2.41_a	1.76_b	1.92	2.16	2.18	1.73	2.00	1.69
	Dry	0.51_a	0.72_a	1.41_b	0.75	0.82	0.62	1.94	1.81	2.02
	Good aftertaste	1.91	1.85	1.47	1.53_a	1.47_a	0.94_b	1.35	1.54	1.29
	Long aftertaste	0.75	0.95	1.18	0.64_b	0.65_b	1.20_a	0.66	0.56	0.67
	Off-flavor	0.18	0.27	0.45	0.14_b	0.22_b	0.74_a	0.27	0.18	0.33
	Rancid Aroma	0.09	0.15	0.27	0.08_b	0.05_b	0.25_a	0.06	0.09	0.14
	Rancid flavor	0.15	0.15	0.37				0.05	0.14	0.20
	Salty	0.35	0.38	0.30	0.21	0.42	0.36	0.10	0.08	0.11
	Sweet	2.60_a	2.51_{ab}	2.02_b	1.82	2.10	1.94	1.79_{ab}	2.17_a	1.70_b
	Vanilla aroma				0.65	0.57	0.65	0.87	1.06	1.02
	Vanilla flavor				1.06_a	0.60_b	0.54_b			
Appearance	Beige dough	0.89_a	0.77_{ab}	0.55_b						
	Bright crust	0.48_b	0.79_a	0.29_b				1.37_{ab}	1.55_a	1.23_b
	Brown color							0.42_a	0.35_{ab}	0.18_b
	Brown crust	1.33_{ab}	1.05_a	1.52_b						
	Dark color				0.19	0.15	0.26			
	Flatness				0.39	0.18	0.34			
	Shiny surface							0.20	0.23	0.21
	Uniform color				1.47	1.17	1.48			

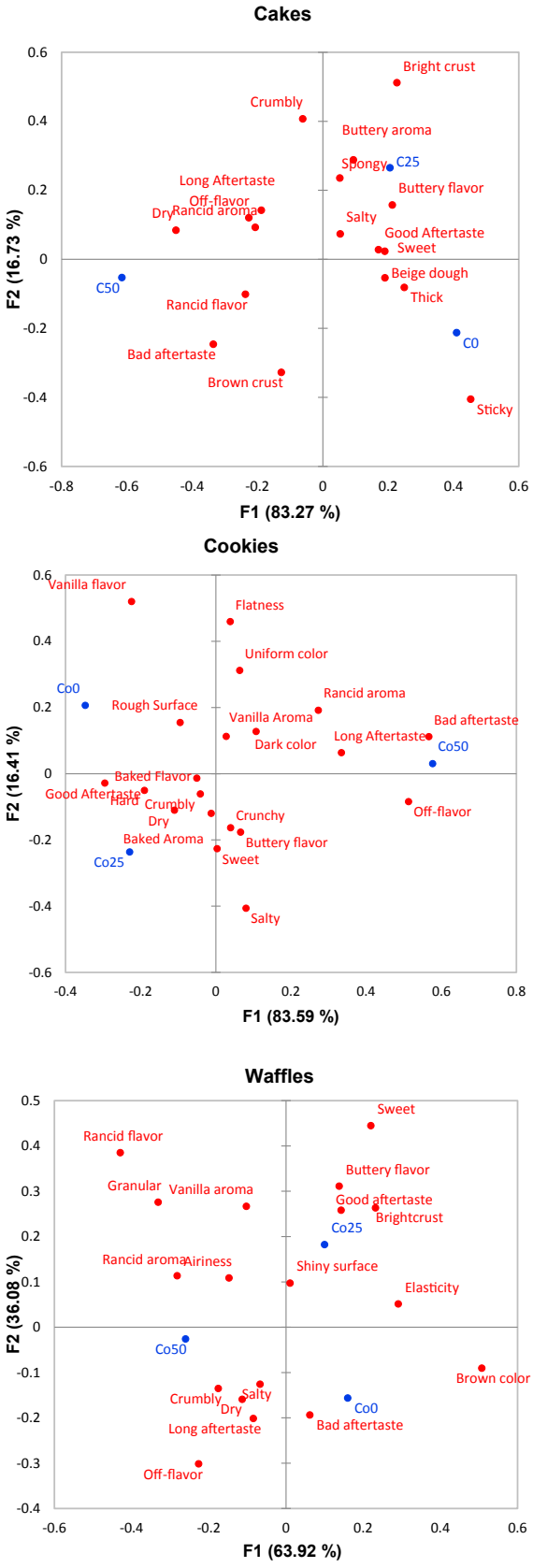

Fig. 1. PCA scores and loading plots for sensorial attributes perceived by consumers after eating cakes (C), Cookies (Co) and waffles (W) with 100% butter (0) or with a 25% (25) or 50% (50) substitution of butter by black soldier fly larvae fat.

perceived when butter was replaced by 50% BSF LF. The brightness of the crust was perceived different between the formulations, with a more bright crust for W25 than W50. The only flavor attribute showing a significant difference was sweetness, with W25 perceived as sweeter compared to W50.

The Dravniek's PCA's (Fig. 1) show the consumers' sensorial understandings of the different products. In cakes and cookie formulations, the first dimension of the PCA explained > 80% of variability, whereas in waffles about 63.9% of the variability was explained. In the PCA plots, it is shown than the bakery products with 25% of butter substitution with BSF LF is similar to the products formulated with 100% butter since they are close together in the first dimension. The bakery products with 25% butter substitution by BSF LF were more discriminating with the regular bakery products in the second dimension, albeit that this second dimension is of less importance for the cake and cookies samples. For all products, it is seen that off-flavor, rancid aroma, rancid taste and bad aftertaste were more closely related to the formulation with 50% BSF LF.

3.3. Emotional profiling

Consumers checked 14.5% of the emotional terms for the cookie samples while 18.0% and 15.2% of the terms were found applicable for respectively the cake and waffle samples.

The cake prepared with butter and the cake with 25% BSF LF evoked a higher intensity of pleasantness compared to the cake made with 50% BSF LF (Table 5). A higher intensity of happiness and satisfaction was mentioned for C0 compared to C50 while participants were to a higher extent enthusiastic for C25 compared to C50. Regarding the negative emotional associations, the intensity of disappointment was higher for C25 and C50 compared to C0. Further, the intensity of the emotional associations disgust and distrust was significantly higher for C50 than C0 while the intensity for dissatisfied was higher for C50 than C25.

Regarding cookies, feelings of content, goodness, pleasantness, satisfaction were significantly higher in Co0 and Co25 than Co50. Also Co0 and Co25 scored significantly lower than Co50 in the negative emotions disgust, discontent, and disappointment. Further, the intensity of dissatisfaction was significantly lower in Co25 than Co50, but neither of those two blends scored significantly different from Co0.

Only one emotional association was significantly different for the waffles namely enthusiasm. W0 scored significantly higher than W25 on enthusiasm while W50 was not significantly different from either.

Dravniek's PCA's indicated that the emotions across all the blends were less clustered than the sensory attributes. Similar to the PCA of the sensory attributes, the PCA for cakes and cookies was predominantly determined by the first dimension, which explained over 80% of the total variance. In contrast, the first dimension of the PCA for the emotional associations of the waffles explained only over 64% of the total variance. The first axis for the cake and cookie samples was associated with the valence of the emotions, with positive emotions situated on the left side and negative emotions on the right side. The samples prepared with only butter (C0/Co0) and 25% substitution of the butter by BSF LF (C25/C025) were located on the left side with positive emotions while the samples with 50% substitution (C50/Co50), linked to the negative emotions, were situated on the right for the cake and cookie products. The PCA of the waffles, were the three products had a similar overall liking score, showed a more diffuse image which makes it hard to label the axis. W0 was closely linked to the emotion glad and energetic. W25 and W50 were close to each other in the first dimension but clearly distinguished by the second dimension which accounted for over 35% of the variance. W25 was associated with pleasantness and content while W50 was related with discontented, good and calm (see Fig. 2).

Table 5
RATA for the intensity of emotional terms related to the bakery products formulations, from 0 – attribute not applicable at all to 5 – emotion very applicable.

	Emotion	Cake (n = 102)			Cookie (n = 110)			Waffle (n = 132)		
		C0	C25	C50	Co0	Co25	Co50	W0	W25	W50
Positive	Calm	1.06	1.43	1.28	1.26	1.23	0.95	1.26	1.27	1.45
	Contented	0.66	0.80	0.53	1.05_{a}	0.76_{a}	0.41_{b}	0.77	0.84	0.79
	Desire	0.55	0.46	0.37	0.24	0.28	0.18	0.14	0.23	0.12
	Energetic	0.46	0.39	0.43	0.08	0.17	0.05	0.18	0.11	0.15
	Enthusiastic	0.51_{ab}	0.68_{a}	0.23_{b}	0.45	0.21	0.32	0.52_{a}	0.24_{b}	0.40_{ab}
	Glad	0.81	0.94	0.72	0.59	0.45	0.34	0.63	0.57	0.51
	Good	2.14	2.20	1.89	1.90_{a}	1.91_{a}	1.25_{b}	1.69	1.60	1.77
	Happy	1.54_{a}	1.35_{ab}	0.92_{b}	0.74	1.10	0.81	1.20	1.20	1.05
	Pleasant	1.51_{a}	1.52_{a}	1.05_{b}	1.05_{a}	1.14_{a}	0.68_{b}	0.95	1.08	0.95
	Pleasantly surprised	0.88	0.85	0.59	0.89	0.77	0.72	0.60	0.63	0.62
	Satisfied	1.87_{a}	1.50_{ab}	1.14_{b}	1.31_{a}	1.28_{a}	0.87_{b}	0.96	1.27	1.19
Negative	Disappointed	0.04_{b}	0.27_{a}	0.58_{a}	0.32_{b}	0.19_{b}	0.75_{a}	0.38	0.48	0.47
	Discontented	0.21	0.22	0.28	0.08_{b}	0.13_{b}	0.62_{a}	0.14	0.14	0.18
	Disgusted	0.01_{b}	0.05_{ab}	0.22_{a}	0.10_{b}	0.08_{b}	0.59_{a}	0.14	0.15	0.11
	Dissatisfied	0.21_{ab}	0.17_{b}	0.49_{a}	0.19_{ab}	0.15_{b}	0.42_{a}	0.39	0.36	0.27
	Distrustful	0.04_{b}	0.17_{ab}	0.23_{a}	0.04	0.09	0.25	0.08	0.06	0.02
	Fearful	0.01	0.05	0.14	0.02	0.00	0.00	0.05	0.02	0.04
	Guilty	0.14	0.10	0.19	0.04	0.08	0.07	0.00	0.05	0.02
	Worried	0.12	0.06	0.22	0.07	0.3	0.05	0.08	0.03	0.01

4. Discussion

For the cakes and cookies, liking was higher for bakery products with 100% butter and 25% butter substitution by BSF LF than the 50% substitution. Although significantly lower, the liking score for the cakes and cookies with 50% BSF LF did only decrease with 0.5–0.8. Regarding the sensory and emotional profiling, similar profiles were also observed for the cakes and cookies with 100% butter and 25% substitution. The substitution of butter by up to 50% BSF LF had a rather limited impact on consumer's perception regarding the sensory attributes and emotional associations of the waffles. The butter replacement did not affect the overall liking scores of waffles but led to a lower WTP.

The main sensory difference between the cake samples was the perception of the brown color. So it could be that although this color perception does not impact the overall liking, people are less willing to pay for cakes which are more brown. Lombardi, Vecchio, Borrello, Caracciolo, and Cembalo (2019) found that consumers are WTP equally or slightly less for insect-based products compared to conventional products depending on the type of product. Our results support this finding, with an equal WTP for the cookies and waffles. For the cake samples, the WTP of the blend with 50% insect fat was slightly less. However, Lombardi et al. (2019) also indicated that providing information about the benefits of insect-based products could increase the WTP. Therefore, including such information might lead to a similar WTP for the insect-based cakes.

Differences in the sensory profiling was found for all three products, albeit that the differences for the waffle samples were rather limited. This illustrates that the RATA-method can be used with consumers, even in the context with food products which are not available on the market (Ares et al., 2014). It is interesting to mention that the butter sensorial attributes were in fact higher, and sometimes also significantly different, from 0% BSF LF. This suggests that BSF LF could change towards a better flavor perception of the bakery products when used at concentrations of about 25%. Further, the significant differences for cookies were mainly related to the aftertaste and off-flavor. Such off-flavors are closely associated with *a priori* conceptualization of insect foods (Verneau et al., 2016). Some consumers perceived the aftertaste as bad while others classified it as good. Overall, good aftertaste was scored higher than bad aftertaste suggesting that even though an aftertaste was present, most people perceived it as a positive attribute rather than as negative. It is true nonetheless, that substitution of butter by BSF LF in cookies significantly affected the flavor and aroma perception at 50% BSF LF substitution. Moreover, the texture of the products was not changed even at 50% of BSF LF content for the cookies and waffles, meaning that this fat conveys functionality to bakery products. Our study showed that substitution of BSF LF change the perception of bakery products in several attributes. This is the first time that this change is shown using an insect fat, and it is an interesting feature, as such. More research is necessary to understand how BSF LF changes the organoleptic properties of the products, as well as the potential interactions between flavor compounds and food microstructure in these bakery products. This problem can be approached by combining instrumental techniques (e.g. volatile analysis) and sensory testing.

The emotional profiles of the cakes and cookies substituted with 25% BSF LF were rather similar to those of the blends without BSF LF. For waffles, there was even only one emotional association (enthusiastic) significant between the different blends. These results are of interest in the light of previous research which mentioned that negative emotions, such as disgust, are major obstacles for the consumption of food products containing insect ingredients in western countries (La Barbera, Verneau, Amato, & Grunert, 2018). It is likely that the emotions were unchanged because the consumers were unable to detect the product with insect ingredients since the appearance of the products was similar among them. In addition, the resemblance between the emotional associations of the samples prepared with butter and those with 25% BSF LF for all samples is in line with the results of the sensory profiles showing rather limited significant differences. This supports earlier literature stating that the emotional associations are mainly sensory-driven (Ng, Chaya, & Hort, 2013; Schouteten et al., 2016; Spinelli, Masi, Zoboli, Prescott, & Monteleone, 2015).

The results indicate that the butter substitutions by cakes and cookies were perceived different from waffles. This might indicate either that the flavor release in this product differs from cakes and cookies or that the baking process influences the flavor of the waffles. It has been shown that the mode of heat transfer affects the flavor of bakery products (Venkateshmurthy & Raghavarao, 2015). Cakes and cookies were prepared in a convection oven whereas the waffles were prepared in a waffle maker. The way in which the batter is exposed to the heat differs in both equipments. In convection ovens, hot air (180 °C) transfers heat to the batter. Whereas in waffle makers, the heat plates (200–240 °C) come in contact with the batter cooking it directly. The heat transfer is different in both systems being more efficient in the heat plates. Thermal conductivity is dependent on each product, but it

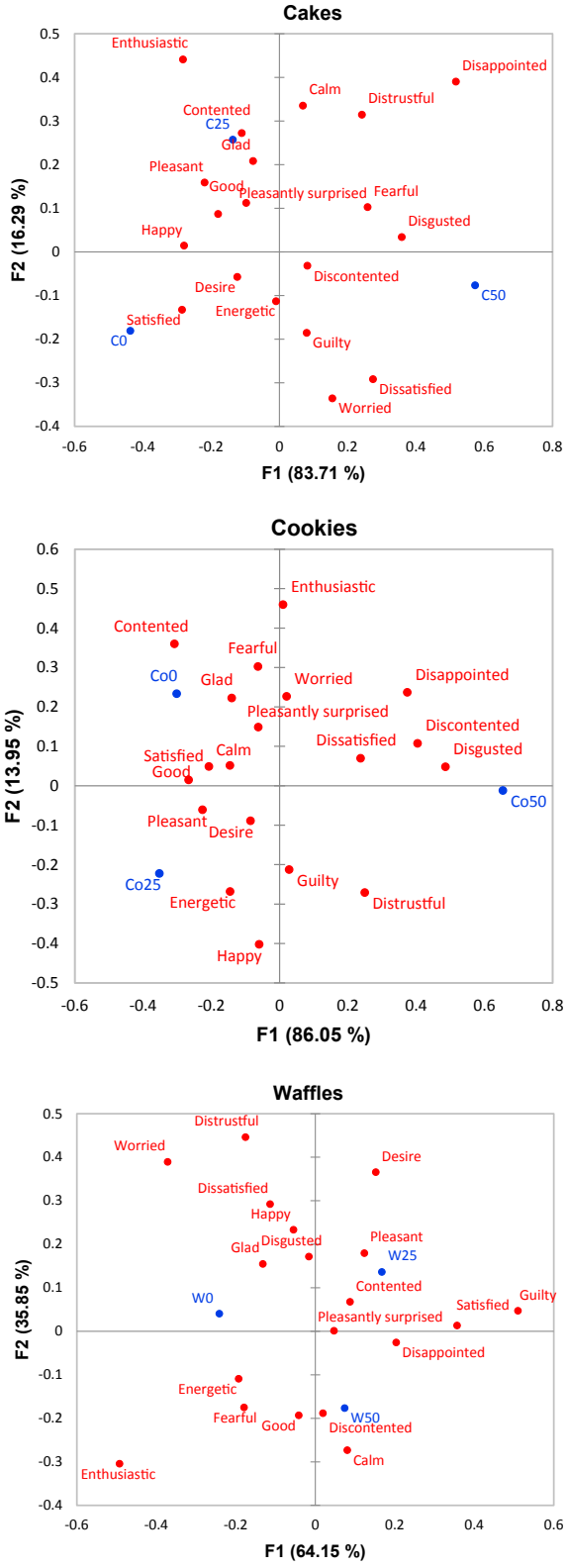

Fig. 2. PCA scores and loading plots for emotional attributes perceived by consumers after eating cakes (C), Cookies (Co) and waffles (W) with 100% butter (0) or with a 25% (25) or 50% (50) substitution of butter by black soldier fly larvae fat.

is usually higher in heat plates than in convection ovens (Cevoli, Fabbri, Marai, Ferrari, & Guarnieri, 2014; Venkateshmurthy & Raghavarao, 2015). We suggest that a higher baking temperature and a higher heat transfer rate to the batter might have affected the flavor of the waffles either by producing more Maillard reaction products or by releasing more volatile compounds from the batter.

In the present study crude insect fat was used. This fat had a strong and characteristic aroma. Crude edible oils and fats contain all the aromas and flavors proper to the source where it is extracted. Since most of these flavors are too strong or not pleasant for human consumption, most oils and fats are deodorized prior to human consumption. We suggest that deodorization of BSF LF can help to reduce the off-flavors in the fat allowing a higher substitution in these bakery products. Moreover, deodorization can help to reduce the rancid flavors and aromas revealed in this study. The compounds relating to rancidity described in this study are not likely to be related to oxidation compounds since the fat used in this study was not oxidized (PV = 0.99 mEq O_2/kg fat, p-anisidine = 0.1). Oil refining is an energy-intense process that can reduce the sustainability of insect oils. We suggest that future life-cycle-assessments studies of insect production should include oil refining as last processing step.

In future studies butter oil should be used instead of butter to eliminate any possible difference related to the fat itself. Butter is an oil in water emulsion with milk fat proteins and whey proteins in the water phase (Walstra et al., 1999), whereas BSF LF was in the anhydrous state. In this research we assume that the fat did not cause any of the differences found in the perception of the bakery products since egg was an ingredient. Egg protein could also provide the emulsification functionality in the batters.

Strength of this research lies in the application of an insect fat without being bound to the physical characteristics of those, which would have been more complex, or even unattainable. As Shelomi (2015) observed, food technology has not allowed us yet to create a “cricket brisket”. We showed that integration of insect ingredients into more traditional and widely consumed bakery products do not change the liking or preference of the consumers as long as the taste is not affected. As previously suggested by Menozzi et al. (2017), integration of insect ingredients into common food might be a more successful approach than exposing consumers to completely new food product since it helps to lower the barriers for consumers to consume an insect-based food.

Working nonetheless on the organoleptic characteristics of such products is extremely important for their success. It is in fact unlikely that most consumers will opt for entomophagy for environmental or ethical reasons only (Verbeke, 2015). Hence, research of techniques to deodorize BSF fat stock or dissimulate off - and long flavors should be looked at closely. Deodorization is a well-developed technology in the oil industry with competitive costs in an industrial scale. Application of this technology to this insect fat should not be an issue. Furthermore, it is important to work on the price to keep it competitive to other similar products though food manufacturers need to reassure consumers that food products containing insects are of a similar quality as conventional products.

Lastly, some limitations and directions for further research deserve attention. The majority of participants of this research were young adults, given that previous research in Belgium showed that this group has the highest potential for adopting insects (Verbeke, 2015). Further research is recommended to examine if similar results would be obtained with a broader consumer sample. Participants were informed a priori that products might contain insect ingredients, in line with the requirements of the ethical committee, which might have resulted in participants who are more open and readier to consume such products. This is reflected in the fact that about half of the sample has tasted insect products before which is more compared to numbers reported in previous research in Belgium (Thielen, Vermuyten, Storms, Rumpold, & Campenhout, 2019). One should note that in Belgium, the federal agency for safety of the food chain (FAVV) approved 10 types of insects for human consumption in 2014 of which 3 remained approved since new European legislation is in force (Federaal Agentschap voor de Veiligheid van de Voedselketen, 2019). In addition, the samples were

evaluated in a blind condition, as the purpose was to have the focus on the sensory attributes. Further research could examine to which extent content information might influence the expected and informed evaluation of bakery products prepared with insect ingredients. One also need to consider that the usage frequencies of the sensory and emotional terms were not high. Previous research using RATA questions in the same country found mainly higher usage frequencies when conducting sensory profiling, with numbers varying between 21% and 42% rated attributes (Schouteten, De Steur, Sas, De Bourdeaudhuij, & Gellynck, 2017; Schouteten et al., 2017). For emotional attributes, which task is sometimes deemed as less easy to perform by consumers (Jaeger, Cardello, & Schutz, 2013), usage frequencies varied between 11% and 19% in previous Belgian research using the RATA scale (Schouteten et al., 2017; Schouteten et al., 2017). Given that non-checked terms resulted in a 0 value for the data analysis, as suggested by the research of Meyners et al. (2016), low usage frequencies automatically leads to low RATA intensities. However, it should be noted that such lower RATA intensities are not uncommon for sensory attributes (Ares et al., 2018; Schouteten et al., 2017; Tan, Tibboel, & Stieger, 2017) and emotional terms (Jaeger et al., 2018; Schouteten et al., 2017). In the present study, participants first needed to check the applicable terms before a scale appeared and the rating of the applicable term needed to be carried out. It could be that this method of RATA encourages satisficing answering response strategies (Sudman & Bradburn, 1983). But also other factors could have played a role, such as the number of terms, the length of the scale (5-point scale), the fact that novel food ingredients were used and the selected product categories. Further, the terms were generated based upon a procedure applied in previous research (Schouteten et al., 2015), which involves the use of consumers for generating the terms which should have led to the inclusion of relevant terms. Therefore, future research might examine if similar results are obtained with other methodological implementations by for instance comparing the CATA and RATA results for sensory and emotion profiling.

5. Conclusion

In conclusion, this series of experiments with bakery products indicate that crude BSF LF can replace 25% of butter in these bakery products without changing liking and preference. In bakery products with direct heat contact, such as waffles, the substitution might even be up to 50% without influencing consumer's acceptance. However, a 50% substitution led to a lower preference and associations to sensory attributes such as rancid aroma and off-flavor. Differences occurred for some sensory attributes and emotional associations among bakery products. Especially for countries in which bakery products are an important component of the eating culture, like Belgium, the possibilities and the relevance for integrating them with innovative insect-based ingredients is high. A higher substitution of BSF LF into food could be achieved using refined BSF LF. Including insect fats in bakery products could lower the barriers for consumers to include insect-based foods in their diet. Future research should explore the changes in sensory perception of these products using analytical tools and sensory tests to understand the differences in perception at low BSF LF substitution levels.

Declaration of Competing Interest

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

Acknowledgements

The authors thank Protix B.V. (Dongen, the Netherlands) for providing samples of black soldier fly larvae fat (LipidX™) for this study.

References

Addinsoft. (2019). XLSTAT statistical and data analysis solution. In. Long Island, NY, USA.
Ares, G., Bruzzone, F., Vidal, L., Cadena, R. S., Giménez, A., Pineau, B., et al. (2014). Evaluation of a rating-based variant of check-all-that-apply questions: Rate-all-that-apply (RATA). *Food Quality and Preference, 36*, 87–95.
Ares, G., Picallo, A., Coste, B., Antúnez, L., Vidal, L., Giménez, A., et al. (2018). A comparison of RATA questions with descriptive analysis: Insights from three studies with complex/similar products. *Journal of Sensory Studies, 33*(5), e12458.
Cevoli, C., Fabbri, A., Marai, S. V., Ferrari, E., & Guarnieri, A. (2014). Estimation of thermal conductivity of short pastry biscuit at different baking stages. *Journal of Agricultural Engineering, 45*(2), 64–69.
Dalenberg, J. R., Gutjar, S., ter Horst, G. J., de Graaf, K., Renken, R. J., & Jager, G. (2014). Evoked emotions predict food choice. *PLoS ONE, 9*(12), e115388.
Dayrit, F. M. (2015). The properties of lauric acid and their significance in coconut oil. *Journal of the American Oil Chemists' Society, 92*(1), 1–15.
Dravnieks, A. (1982). Odor quality: Semantically generated multidimensional profiles are stable. *Science, 218*(4574), 799–801.
Evers, J. M., Crawford, R. A., & Kissling, R. C. (2003). Determination of moisture, solids-not-fat and fat-by-difference in butter using routine methods according to ISO 8851/IDF 191—an international collaborative study and a meta-analysis. *International Dairy Journal, 13*(1), 55–65.
Logic8 B.V. EyeQuestion https://eyequestion.nl/. Accessed 15 March 2019.
Federaal Agentschap voor de Veiligheid van de Voedselketen (2019). Zijn insecten het vlees van de toekomst? http://www.favv.be/onzevoeding/insecten/vleesvandetoekomst/ Accessed 2 August 2019.
Gmuer, A., Nuessli Guth, J., Hartmann, C., & 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.
Gold, M., Tomberlin, J. K., Diener, S., Zurbrügg, C., & Mathys, A. (2018). Decomposition of biowaste macronutrients, microbes, and chemicals in black soldier fly larval treatment: A review. *Waste Management, 82*, 302–318.
Homann, A. M., Ayieko, M. A., Konyole, S. O., & Roos, N. (2017). Acceptability of biscuits containing 10% cricket (Acheta domesticus) compared to milk biscuits among 5–10-year-old Kenyan schoolchildren. *Journal of Insects as Food and Feed, 3*(2), 95–103.
IBMCorp (2017). *IBM SPSS Statistics for Windows.* Armonk, NY: IBM Corp.
Jaeger, S. R., Cardello, A. V., & Schutz, H. G. (2013). Emotion questionnaires: A consumer-centric perspective. *Food Quality and Preference, 30*(2), 229–241.
Jaeger, S. R., Lee, S. M., Kim, K.-O., Chheang, S. L., Roigard, C. M., & Ares, G. (2018). CATA and RATA questions for product-focused emotion research: Five case studies using emoji questionnaires. *Food Quality and Preference, 68*, 342–348.
La Barbera, F., Verneau, F., Amato, M., & 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.
Lagast, S., Gellynck, X., Schouteten, J. J., De Herdt, V., & De Steur, H. (2017). Consumers' emotions elicited by food: A systematic review of explicit and implicit methods. *Trends in Food Science & Technology, 69*, 172–189.
Lensvelt, E. J. S., & Steenbekkers, L. P. A. (2014). Exploring consumer acceptance of entomophagy: A survey and experiment in Australia and the Netherlands. *Ecology of Food and Nutrition, 53*(5), 543–561.
Lombardi, A., Vecchio, R., Borrello, M., Caracciolo, F., & Cembalo, L. (2019). Willingness to pay for insect-based food: The role of information and carrier. *Food Quality and Preference, 72*, 177–187.
Marangoni, A., Goldstein, A., & Seetharaman, K. (2014). Lipids. In W. Zhou, Y. H. Hui, I. De Leyn, M. A. Pagani, C. M. Rosell, J. D. Selman, & N. Therdthai (Eds.). *Bakery Products Science and Technology*. Chichester, West Sussex, UK: John Wiley & Sons Ltd.
Menozzi, D., Sogari, G., Veneziani, M., Simoni, E., & 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.
Meyners, M., Jaeger, S. R., & Ares, G. (2016). On the analysis of rate-all-that-apply (RATA) data. *Food Quality and Preference, 49*, 1–10.
Ng, M., Chaya, C., & Hort, J. (2013). The influence of sensory and packaging cues on both liking and emotional, abstract and functional conceptualisations. *Food Quality and Preference, 29*(2), 146–156.
Oonincx, D. G. A. B., van Broekhoven, S., van Huis, A., & van Loon, J. J. A. (2015). Feed conversion, survival and development, and composition of four insect species on diets composed of food by-products. *PLoS One, 10*(12).
Rehman, K. U., Rehman, A., Cai, M., Zheng, L., Xiao, X., Somroo, A. A., et al. (2017). Conversion of mixtures of dairy manure and soybean curd residue by black soldier fly larvae (Hermetia illucens L.). *Journal of Cleaner Production, 154*, 366–373.
Schouteten, J. J., De Steur, H., De Pelsmaeker, S., Lagast, S., De Bourdeaudhuij, I., & Gellynck, X. (2015). An integrated method for the emotional conceptualization and sensory characterization of food products: The EmoSensory® Wheel. *Food Research International, 78*, 96–107.
Schouteten, J. J., De Steur, H., De Pelsmaeker, S., Lagast, S., Juvinal, J. G., De Bourdeaudhuij, I., et al. (2016). Emotional and sensory profiling of insect-, plant- and meat-based burgers under blind, expected and informed conditions. *Food Quality and Preference, 52*, 27–31.
Schouteten, J. J., De Steur, H., Sas, B., De Bourdeaudhuij, I., & Gellynck, X. (2017). The effect of the research setting on the emotional and sensory profiling under blind, expected, and informed conditions: A study on premium and private label yogurt products. *Journal of Dairy Science, 100*(1), 169–186.
Schouteten, J. J., Gellynck, X., De Bourdeaudhuij, I., Sas, B., Bredie, W. L. P., Perez-Cueto, F. J. A., et al. (2017). Comparison of response formats and concurrent hedonic

measures for optimal use of the EmoSensory® Wheel. *Food Research International, 93*, 33–42.
Shelomi, M. (2015). Why we still don't eat insects: Assessing entomophagy promotion through a diffusion of innovations framework. *Trends in Food Science & Technology, 45*(2), 311–318.
Smetana, S., Schmitt, E., & Mathys, A. (2019). Sustainable use of Hermetia illucens insect biomass for feed and food: Attributional and consequential life cycle assessment. *Resources, Conservation and Recycling, 144*, 285–296.
Spinelli, S., Masi, C., Zoboli, G. P., Prescott, J., & Monteleone, E. (2015). Emotional responses to branded and unbranded foods. *Food Quality and Preference, 42*, 1–11.
Sudman, S., & Bradburn, N. M. (1983). Asking questions: a practical guide to questionnaire design.
Tan, H. S. G., Fischer, A. R. H., Tinchan, P., Stieger, M., Steenbekkers, L. P. A., & van Trijp, H. C. M. (2015). Insects as food: Exploring cultural exposure and individual experience as determinants of acceptance. *Food Quality and Preference, 42*, 78–89.
Tan, H. S. G., Tibboel, C. J., & Stieger, M. (2017). Why do unusual novel foods like insects lack sensory appeal? Investigating the underlying sensory perceptions. *Food Quality and Preference, 60*, 48–58.
Tan, H. S. G., van den Berg, E., & 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.
Thielen, L. V., Vermuyten, S., Storms, B., Rumpold, B., & Campenhout, L. V. (2019). Consumer acceptance of foods containing edible insects in Belgium two years after their introduction to the market. *Journal of Insects as Food and Feed, 5*(1), 35–44.
Venkateshmurthy, K., & Raghavarao, K. S. M. S. (2015). Analysis of modes of heat transfer in baking Indian rice pan cake (Dosa,) a breakfast food. *Journal of Food Science and Technology, 52*(8), 5357–5363.
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., & Grunert, K. (2016). The effect of communication and implicit associations on consuming insects: An experiment in Denmark and Italy. *Appetite, 106*, 30–36.
Walstra, P., Geurts, T. J., & Noomen, A. (1999). *Dairy technology: Principles of milk properties and processes.* New York: Dekker.
Wassell, P. (2014). *Bakery fatsFats in food technology* (2nd ed.). Oxford: John Wiley & Sons Ltd.