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Evaluating US Consumers' Perception of Foods Made with Cricket Powder

Ryan Paul Ardoin

EVALUATING U.S. CONSUMERS' PERCEPTION OF FOODS MADE WITH INSECT POWDER

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Ryan Paul Ardoin
B.S., Louisiana State University, 2009
B.S., Louisiana State University, 2016
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ABSTRACT

Expanding the consumption of edible insects has been proposed as a strategy for global food security due to their sustainability of production and high nutritional value. In the U.S.A., the idea of eating insects is generally unappealing. This research took a methodical approach to understanding U.S. consumers perceptions of insects as food- specifically, products made with cricket powder. Recent consumer-oriented entomophagy research (2015-2020) was reviewed to consolidate understanding of Westerners' perceptions of edible insects and to evaluate research trends. An online survey of 1,005 U.S. consumers investigated appropriate products for insect protein powder incorporation (based on willingness to try; WTT), identified reasons for aversion, and tested the effect of entomophagy benefit information on WTT. Based on the findings, whole-wheat snack crackers were formulated, substituting whole-wheat flour with cricket powder (*Acheta domesticus, Gryllodes sigillatus*) at increasing levels. Liking, preference, and acceptability of snack crackers were measured, and data were used to propose a modified consumer rejection threshold, a modified hedonic rejection threshold, and a newly developed rejection tolerance threshold and rejection range. These results informed practical limits on cricket powder addition in snack crackers. Additionally, the effects of cricket powder on physical properties and U.S. consumers' perceptions (color, texture, flavor, and overall perceptions) of snack crackers were analyzed. Western consumers are hesitant to accept insects as food, and while disgust and fear are prevalent responses, so are a group of newly coined "food-evoked sensation seeking emotions." Protein supplementation (protein bars, protein shakes), snacks (crackers) and baked/cereal products (bread, muffins) were most appropriate for insect incorporation, and unfamiliarity with entomophagy was the biggest hurdle to trial intent, followed by concerns about sensory quality. Newly proposed rejection-type threshold

methodologies can provide practical guidance for food product development and quality control applications, including use of novel ingredients. Cricket-based snack cracker development should continue using between 4% and 7.9% cricket powder, until issues of darkness, hardness, and flavor are improved, or until cricket's sensory properties become familiar and appreciated. Information can influence intention, but familiarity and positive eating experiences through enjoyable insect-based products may be key to changing attitudes, negative emotions, and ultimately consumption behaviors.

CHAPTER 1. INTRODUCTION

1.1. Research Justification

With the global population projected to reach 9.8 billion people by the year 2050, demand for food is expected to rise by over 50 percent, and even more so for animal-based products. Considering that almost half of the world's vegetated land is already being used for agriculture, and the environmental toll of meat production, it becomes alarmingly evident that existing food production practices are unsustainable (Searchinger *et al.*, 2019). A search for solutions has prompted interest in expanding consumption of edible insects (entomophagy). The strategy involves changing consumers' attitudes and habits, which can be difficult, but not impossible (Köster, 2009). This dissertation offers sensory and consumer science-based approaches to introducing an unusual (and often objectionable) ingredient, cricket powder, to Western consumers.

Sustainability of production- related to high feed conversion efficiency, less water and land usage, and low greenhouse gas emissions- compared to conventional sources of animal protein (i.e., livestock) make insects an interesting prospect for addressing food security (van Huis *et al.* 2013). For Western consumers, however, the rational justifications for entomophagy are not alone able to offset psychological aversions to insect trial, much less motivate meat replacement (Hartmann & Siegrist, 2017). Shifts in well-established eating behaviors may be better be directed by sensory-driven product development strategies (Deroy *et al*, 2015), which rely on understanding both consumers' wants and their objections to insects as food.

Insects have been eaten throughout human history and remain a part of approximately 2 billion people's diets worldwide, primarily in Africa, Asia, and Latin America (Kouřimská, & Adámková, 2016). In most Western societies though, such as the U.S.A., eating bugs is culturally inappropriate and met with disgust. The diversity of edible insects (around 2,000 species) lends to various traditional preparations, with beetles being the most commonly consumed variety (van Huis *et al.*, 2013). Insects' sensory properties vary by species, developmental stage, processing method, and the animal's diet (Mishyna *et al.*, 2020). Crickets are reported to have a mild taste, are high in protein (up to 70% dry weight) (Elhassan *et al.*, 2019), and are commercially available in powdered form (which is more approachable to consumers) from online retailers. Therefore, cricket powder (*Acheta domesticus* and *Gryllodes sigillatus*) was chosen as a vehicle to explore U.S. consumers' perceptions of entomophagy.

1.2. Research Overview

For the previously cited reasons, there has been a surge in entomophagy research during the early 21st century. Consumers' beliefs and attitudes about insects as food are becoming increasingly well understood, particularly demographic and psychographic factors that may predict openness to entomophagy (Mancini *et al.*, 2019a) and barriers to insect consumption (Baker *et al.*, 2016). Cross-cultural entomophagy studies are less common than focused regional evaluations, and varied methodologies have been employed for perceptual measurement. Therefore, a comprehensive review was written (Chapter 2) to unify published findings, from the past five years (since 2015), on Western consumers' perceptions and emotional responses to entomophagy, with careful attention paid to regional variation and theoretical context. Additionally, the current status of edible insect regulations in Australia, Canada, Europe, and the U.S.A. was discussed in relation to entomophagy adoption.

Intuitively, the societal benefits of broadening the market for edible insects have been framed in terms of replacing less sustainable meat consumption and production (Hartmann & Siegrist, 2017). In a processed form (i.e., a powder or flour), Western consumers are more accepting of insects in food, and the right product concepts may increase trial intent. However, even so-called "appropriate" preparations have been chosen by researchers rather than potential consumers (Tan *et al.*, 2017b). To address this bias, Chapter 3 sought out product development guidance directly from U.S. consumers using an online survey which compared willingness-to-try responses among thirty hypothetical insect-containing products. Additionally, reasons for aversion and the effects of an entomophagy benefit message on trial intent were investigated.

For U.S. consumers, adding cricket powder to common foods tends to decrease liking, and the product becomes unacceptable at higher levels (Castro Delgado *et al*., 2020). Affective sensory threshold methods have been previously developed (Prescott *et al.*, 2005; Filho *et al.*, 2015) to objectively inform defect limits for particular compounds or ingredients, but their interpretability may be improved through modifications. The tendency of cricket powder to directionally deteriorate product quality made it a suitable stimulus for demonstration of such modified rejection-type threshold methodologies, as well as proposal of two new threshold concepts (Chapter 4).

Informed by our survey results (Chapter 3), snack crackers were formulated using cricket powder, and our newly proposed rejection-type threshold methodologies (Chapter 4) were employed to set practical limits on whole-wheat flour substitution in snack crackers. In place of wheat flour, insect powders have shown to clearly affect both instrumental and perceptual sensory properties (Osimani *et al*., 2018). Perceptions of insect-based products likely arise from an integration of organoleptic features and expectations, and combating conditioned distaste toward insects may be a key to improving consumer's attitudes and generating new consumption behaviors (Deroy *et al*., 2015). As such, U.S. consumers' perceptions of color, texture, flavor, and overall perceptions of snack cracker made with increasing levels of cricket powder were measured, along with the crackers' physical properties (Chapter 5) to guide further product development. The overall objectives of this dissertation were to improve understanding of U.S. consumers' perceptions of entomophagy and to present methods for enhancing the perceived quality of novel foods like insects.

CHAPTER 2. CONSUMER PERCEPTIONS OF INSECT CONSUMPTION: A REVIEW OF WESTERN RESEARCH SINCE 2015

2.1. Introduction

Insects have been a part of human diets since prehistoric times (Kouřimská & Adámková, 2016) and remain common fare in many areas to date. These include around 2,000 species consumed by over 2 billion people across 113 countries (Elhassan *et al*., 2019; Tao & Li, 2018). However, consumption of insects, termed entomophagy (or more specifically, anthropo-entomophagy/human entomophagy when related to people), is not a globally accepted practice. Developed Western populations, in particular, remain largely averse to eating insects. The question as to "why" has been contemplated for some time (Holt, 1885; Vane-Wright, 1991; Shelomi, 2015) but has garnered particular attention in the 21st century, especially since the Food and Agriculture Organization of the United Nations began to promote edible insects as a prospect for global food security (van Huis *et al*., 2013). The continued motivation for researchers, governments, and industry to introduce this traditional-yet-novel food to new populations stems from its nutritional value and promise of sustainable production.

Edible insects are particularly renowned for their protein content (up to 80% on dry basis; de Castro *et al*., 2018; Kouřimská & Adámková, 2016), including favourable amino acid profiles (Payne *et al*., 2016) and bioactive peptides (Nongonierma & FitzGerald, 2017). Compared to more common sources of animal protein (i.e., livestock), insects offer advantages in terms of high feed conversion rates, less land and water usage, and lower emissions of greenhouse gasses and environmental contaminants (van Huis *et al*., 2013). While varied by species and developmental stage, they also provide fibre (from chitin), valuable lipids, and various micronutrients (Payne *et al*., 2016). However, translating these potential benefits into practical outcomes may be a slow and challenging process.

If long-term goals of improving global food security and sustainability through entomophagy are to be realised, not only must insects (or insect derivatives) in food become fully sanctioned, commercialised, and enjoyed in Western diets, but unsustainable meat production practices must in turn be curtailed. The global demand for animal proteins is expected to continue its rise (Baldi & Gottardo, 2017), so while wholesale cessation of traditional meat consumption is unlikely, consumers are showing increasing interest in alternative protein sources (Joseph *et al*., 2020). In this arena, insects are competing with plant-based proteins and cultured meats, and recent literature indicates that Western consumers are not quite ready to replace meat with insects (Hartmann & Siegrist, 2017). In fact, their willingness to even try an insect-containing food varies from study to study (Mancini *et al*., 2019a), emphasising that significant obstacles must be overcome if the benefits of large-scale entomophagy adoption are to be unfolded.

A criticism of consumer research in the entomophagy area has been its focus on individual cognitive factors affecting consumption, and a lack of emphasis on broader contextual factors, such as price, availability, and product quality and positioning (House, 2016). Along with conducive legislation, there is a critical interplay between these elements. However, until sufficient demand is forecasted, food companies and government agencies may be hesitant to direct resources toward insects as food. In the meantime, food technologists should capitalise on our growing understanding of adoption-oriented product development strategies, and continue testing new insect-based products with consumers who are ready to try them.

Exploring insects' place in mainstream Western food systems has spanned multiple disciplines (Halloran *et al*., 2018), including both social and natural sciences, the humanities, business, and culinary arts. Table 2.1 presents the scope of topics covered in recent review articles, revealing a few gaps that this review aims to address through a careful examination of up-to-date literature related to Western entomophagy.

Table 2.1. Recent Reviews^ in Entomophagy

Citation	Major focus of the review	Specific topics of interest
Nongonierma & FitzGerald (2017)	Bioactive peptides from edible insects generated using enzyme hydrolysis.	Edible insect protein content and extraction; insect protein hydrolysates: enzymatic hydrolysis, antihypertensive properties, antioxidant antidiabetic activity, technofunctional properties, and safety; and legislation.
Hartmann & Siegrist (2017)	Consumer perceptions and behaviours regarding sustainable protein consumption (especially as a meat alternative).	Consumers' awareness of the environmental impact of meat production and consumption, willingness to reduce meat consumption, acceptance and perception of meat substitutes and alternative proteins.
Cito *et al.* (2017)	Insects as a source angiotensin converting enzyme (ACE) inhibitors.	Insect sources of ACE inhibitory peptides, *in vitro* ACE inhibitory activity of insect protein hydrolysates, identification of ACE inhibitory peptides in insect protein hydrolysates.
de Castro *et al.* (2018)	Nutritional, functional, and biological properties of insect proteins,	General nutritional aspects of insects, biological and chemical risks of insect consumption, effects of processing on nutrient extraction, functional peptides from insects.
Ribeiro *et al.* (2018)	Allergic risks of consuming edible insects.	Review of all reported cases of edible insect allergic reactions; cross-reactivity/co-sensitisation between edible insects, crustaceans and house dust mites; prevalence studies.
Tao & Li (2018)	A general review of motivating factors and perceptions of edible insects, with data from an original consumer acceptance study.	Food insecurity; nutritional content of edible insects; social, environmental, and economic impacts of entomophagy; consumer perception and sensory evaluation of both edible insects in general and a study of insect-fortified extruded rice products.

(table cont'd.)

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Citation	Major focus of the review	Specific topics of interest
Kauppi *et al.* (2019)	Consumer acceptance of edible insects and adoption strategies.	Justifications for eating insects, factors influencing consumer perceptions of insects as food (regulations, individual factors, product properties), entomophagy adoption strategies, with presentation of three specific design interventions.
Mancini *et al.* (2019a)	The willingness of European consumers to adopt entomophagy and the factors influencing European consumer's acceptance of insects as food.	An overview of relevant European studies analysed by techniques employed (structured, semi-structured, unstructured) and target populations; drivers of consumer's choice to eat insects (sociocultural and psychological; familiarity, visibility, taste, and price); limitations and future recommendations.
Melgar-Lalanne *et al.* (2019)	Production, processing technologies, and commercialisation of edible insects (traditional and innovative strategies).	Aversion to insect consumption; edible insect farming, cooking, and processing techniques/technologies (blanching, drying, extraction technologies), and storage; commercialisation of edible insects and commercial products across the world.
Elhassan *et al.* (2019)	An overview of production and quality aspects of edible insect species- with a focus on mealworms.	Nutritional value, sensory aspects (descriptive and instrumental), acceptability, processing effects, toxicity and allergenicity, rearing, packing and storage-focusing on mealworms.
Mishyna *et al.* (2020)	Sensory attributes of edible insects and insect-based foods.	Sensory properties (esp. aroma, taste, flavour, and texture) and approaches to alter the sensory characteristics (production, processing, taste education, product formulation) of insects and insect-based foods.
Batat & Peter (2020)	Factors effecting acceptance and adoption of entomophagy in Western cultures.	Historical and sociocultural perspectives, sustainability and health benefits, and factors related to acceptance and adoption of insects as food (idiocentric and allocentric)- with an emphasis on marketing and policy strategies.
Toti *et al.* (2020)	An overview of nutrition, safety, and aversions to entomophagy- with a focus on neophobia in Italy.	Nutrition, safety, disgust, neophobia and intentions surrounding entomophagy- with a focus on neophobia in Italy.

^These only include review articles published in peer-reviewed scientific journals since 2017 directly relevant to Western entomophagy.

In particular, we aimed to:

- highlight some cross-cultural variation between Western consumers' entomophagy perceptions while considering the different methods/measures used for data collection,
- analyse the existing theoretical approaches to entomophagy research,
- expound upon entomophagy-relevant emotions and personality traits,
- account for broader external factors, especially regulations, which influence insect consumption in the West, and
- suggest directions and practical strategies to move entomophagy research forward.

2.2. Scope of Reviewed Literature

For this review article, we focused mainly on peer reviewed academic journal articles published from 2015 to 2020 to provide the most currently informed perspectives with sufficient context. These were not limited to the field of food technology and also included research from other disciplines (e.g., psychology, marketing, economics, and legislation). For the purposes of addressing cultural barriers to insects as a novel food source, we defined "Western" countries to include: the Australian continent, Canada, the European continent, and the U.S.A., and so research conducted in other parts of the world or results focusing on other groups of consumers were not of primary interest.

Additionally, empirical data from our study of cricket-containing tortilla chips (briefly discussed in Ardoin *et al*., 2019) were included. Consumers (N=84) recruited from Louisiana State University campus (Baton Rouge, LA, U.S.A.) evaluated three flavours of tortilla chips, in a randomised order, formulated with 6.8% cricket (*Acheta domesticus*) flour. Along with ratings of appearance, aroma, crunchiness, and flavour liking (9-point hedonic scale), product-elicited emotions were selected at three times: first based solely upon visual evaluation, then after tasting, and finally after delivery of an entomophagy benefit message (see Ardoin & Prinyawiwatkul, 2020)- using a check all that apply (CATA) format with twenty-five emotion terms (EsSense25 lexicon; Nestrud *et al*., 2016). This review will focus on the resultant emotional data.

2.3. Readiness to Adopt Entomophagy

2.3.1. Current Trends in Data Collection

Once the impetus for advancing entomophagy was provided (van Huis *et al*., 2013), initial academic interest was taken into individual factors (or idiocentric factors; Batat *et al*., 2017) standing in the way. Online surveys have become an increasingly popular method for investigating the psychological drivers (or inhibitors) of insect consumption. Meanwhile, interviews and focus groups have sought more exploratory qualitative information about relevant beliefs and attitudes (Balzan *et al*., 2016; Tan *et al*., 2015).

The internet has allowed investigators to capture perceptions from consumers who might otherwise turn away from in-person insect evaluations. Compared to central location testing (CLT; Cicatiello *et al*., 2016), telephone surveys (Van Thielen *et al*., 2019), and mail-in questionnaires (Schlup & Brunner, 2018), online surveys have been able to reach a much larger number of respondents (Ardoin & Prinyawiwatkul., 2020; Hartmann *et al*., 2018; Piha *et al*., 2018), and facilitate multicultural entomophagy studies (Castro & Chambers, 2019; Hénault-Ethier *et al*., 2020). While this method of data collection relies on participants having internet access and basic computer skills, recruitment may be accelerated through the popularity of online social media platforms and “snowball” sampling (Cicatiello *et al*., 2020; Zielińska *et al*., 2020).

Still, university-conducted entomophagy research has tended to favour samples comprised mostly of students (Ardoin *et al*., 2020; Berger *et al*., 2019; Lombardi *et al*., 2019). Therefore, interpretations of Westerners' attitudes, beliefs, and intentions regarding insect consumption from the current body of literature should carefully consider characteristics of the sub-population sampled. Educationally oriented young adults have shown to be more receptive to insects as foods (Cicatiello *et al.*, 2016; Roma *et al*, 2020) than general populations. Furthermore, students attending a university where entomophagy has been extensively studied may gain disproportionate familiarity with edible insects (Laureati *et al*., 2016), and may not be from the same country/culture in which the study was conducted (Tao & Li, 2018).

2.3.2. Predicting Insect Consumption

The theory of planned behaviour (TPB; Ajzen, 1991) poses that a system of beliefs, attitudes, and subsequent intentions account for considerable variability in actual behaviours. This and other related theories assume a largely conscious and rational basis for food-choice. Entomophagy research operating within this cognitive framework relies on consumers' awareness of their beliefs and attitudes about insects, their ability to report them accurately, and a meaningful relationship between self-reported intentions and actual outcomes.

Measures of reported intent, or "willingness," have been the predominate means of assessing openness to entomophagy in the West. These have included willingness to: try/consume insects in various forms (La Barbera *et al*., 2019; Ruby *et al*., 2015; Woolf *et al*., 2019); buy insect-foods (Piha *et al*., 2018); pay for insect-based products (de-Magistris *et al*., 2015; Lombardi *et al*., 2019); and replace meat with insects (Caparros Megido *et al.*, 2016; Verbeke, 2015). Collectively, the data suggest that willingness to try insects is highly variable between studies (discussed later); effective informational cues can increase willingness to try/buy/pay for insect-based products; and Western consumers are not ready to give up meat for insects.

Mancini *et al*. (2019b) identified perceived behavioural control (related to the ease or difficulty of performing the behaviour) as the main predictor of insect trial intent. In practical terms, one's ability to actually try insect-based foods may be limited by the availability of appealing options. Although TPB was effective in explaining intent, Menozzi *et al*. (2017) found intention to eat a cookie made with cricket flour to explain only 19% of the behavioural variance. Lammers *et al*. (2019) described familiarity, previous insect consumption, and neophobia as the "classical" variables in Western entomophagy research, which, along with gender and disgust sensitivity, represent the typical set of predictors used to model the likelihood of insect consumption. Sogari *et al*. (2019b) tested a more complex model (inputting some of the "classical" variables) where intention showed a stronger association (65%) with insect-eating behaviour. This apparent "intention-behaviour gap" has been noted in entomophagy research (Berger *et al*., 2018).

Hypothetical bias suggests that when subjects are not required to commit to any action or take on any of the risks common to entomophagy (Baker *et al*, 2016), estimates of the behaviour can be inflated (Alemu & Olsen, 2018). However, in one case (Jensen & Lieberoth, 2019), social pressure prompted 81% of Danish students to taste roasted mealworms (when passed around a classroom), whereas only 53% initially reported willingness via online survey. A less common approach is to ask consumers about past instances of insect eating behaviours (House, 2016), which may be more closely aligned with reality than hypothetical intentions, but is still prone to inaccurate self-reporting.

Competing psychological theory suggests that food-related behaviours may be better explained by implicit cognitive processes (or intuitive thinking) which operate outside of our awareness, separately from conscious attitudes and intentions (Köster, 2009). Investigating consumers' perceptions of entomophagy through the lens requires a less direct line of questioning to uncover attitudes and beliefs. For example, Hartmann *et al*. (2018), revealed that Swiss consumers viewed insect eaters as "imaginative," "brave," and "interesting" by using the shopping list method, where respondents characterised other (hypothetical) consumers based on their respective grocery lists. Combing an implicit association test (meant to capture subconscious positive and negative attitudes about insects) with an intention-based model, La Barbera *et al*. (2018) found that implicitly held negative associations had an indirect effect on trial intent via disgust.

This paradigm views the link between belief and behaviour as more automatic than reflective, so non-verbal metrics are often evaluated under the supposition that subjects are neither consciously aware of certain aspects of their behaviour nor that they are being monitored. Le Goff & Delarue (2017) recorded consumers' interactions with products and found longer durations of negative facial expressions prior to tasting and shorter positive reactions while eating supposed insect enriched samples, compared to those in the control condition. Subconscious physiological responses, or "biometrics," have been used with machine learning models to predict liking of insect-based foods with high accuracy (Fuentes *et al.*, 2020). It has also been argued that emotional reactions are more important to food choice than rational evaluations (Köster, 2009). As such, other implicit measures are presented in our later discussion of entomophagy-evoked emotions.

2.3.3. Cross-Cultural Comparisons

While the Western world, taken as a whole, is generally unready to adopt entomophagy, treating it as one homogenous food culture is misguided, although some predictors of insect eating behaviour do persist throughout. Being male, having low levels of neophobia, low disgust sensitivity, and previous insect consumption consistently characterise potential early adopters of entomophagy across the West (Hartmann & Siegrist, 2016; Schlup & Brunner, 2018; Verbeke, 2015). More detailed investigations reveal nuanced attitudes and differential drivers of entomophagy between countries and cultures. However, the varied research methodologies employed and previously mentioned limitations to generalising results can give low resolution to comparisons.

Cross-cultural consumer studies best elucidate differences in particular market characteristics which may guide approaches to edible insect normalisation. For example, French Quebeckers' knowledge of entomophagy was more closely aligned with their French speaking European counterparts than with their English speaking North American neighbours (Hénault-Ethier *et al*., 2020). Quebeckers also distinguished themselves from both groups by placing more importance on environmental and health motivations. Piha *et al*. (2018) found Northern European consumers to generally exhibit a more positive attitude toward entomophagy than Central Europeans. Additionally, while previous consumption and low levels of neophobia are consistently correlated with openness to entomophagy, these factors were more salient among Central Europeans consumers. Further variation within European markets is described in Mancini *et al*.'s (2019a) review article. Within the same country, sampling from different states in the U.S.A. exposed clear differences in willingness to consumer insect-containing foods, again citing previous exposure as the most prominent predictor of associated attitudes (Woolf *et al*., 2019). Even the generally accepted concept of maleness as an indicator was challenged in a qualitative study of Australian consumers, where some men viewed replacing traditional meat with insects to be a threat to ideals of masculinity (Sogari *et al*., 2019a).

Cautiously comparing similar investigations from a few countries suggests different stages in entomophagy readiness at the time of data collection. On the surface, willingness-to-try data showed that U.S. consumers seem relatively open to the idea of trying insect-containing food products, with 72% of respondents in one study (Ruby *et al.*, 2015), and 60% in another (Ardoin & Prinyawiwatkul, 2020), responding positively. In contrast, when similar questions were posed to Italian consumers, trial intent ranged from only 17%-31% in three separate studies (Cicatiello *et al*., 2016; Laureati *et al*., 2016; Palmieri *et al*., 2019). However, Castro & Chambers (2019), collecting data from multiple countries, found similarly low willingness to eat insects among consumers in the U.S.A., U.K., Spain, and Australia (all between 33% and 36%).

Along with cultural differences, additional variation from study to study likely arises from sample characteristics (e.g., size and demographics), type of questions asked, scale(s) used, and testing platform (i.e., online survey vs. in-person testing). For example, using likert-type scales, data from Sogari *et al*. (2018) suggested more openness to entomophagy trial (2.27 on a bipolar scale from -3 to 3) among Italians than was obtained from discrete choice data (Cicatiello *et al*., 2016; Laureati *et al*., 2016; Palmieri *et al*., 2019). Swiss respondents averaged a willingness-to-consume score of 2.5 on a unipolar 6-point scale (Schulp & Brunner, 2018), and in a German study, average willingness to try was 3.3 on a 10-point scale (Schäufele *et al*., 2019). It quickly becomes apparent that direct cross-cultural comparisons are limited by inconsistent scaling. Therefore, careful interpretation is required to avoid misleading conclusions.

The terminology used in questioning also makes a difference. U. S. consumers, for example, seemed less willing to consume insect-containing foods on a "regular basis" (Woolf *et al*., 2019) than to merely try them (Ruby *et al.*, 2015). In a Polish study, 41% of consumers would purchase insect-based products, “if they were available on the market” (Zielińska *et al*., 2020). Tuccillo *et al*. (2020) suggested use of the general term “insect” to be a limitation of previous measures and found 41% of Italian respondents to be “in favour” of consumption when specific species and preparations were evaluated. Similarly, suggestion of specific product concepts increased trial intent from U.S. consumers (Ardoin & Prinyawiwatkul, 2020). Distinctions in language can affect how consumers report openness to entomophagy and even influence intentions, but responses still may not directly overlap with actual consumption behaviours.

Educational information seems to positively influence hypothetical intentions, but its impact on actual behaviours is inconsistent, and likely depends on the nature of the message and its subjects. Over half (51%) of N=159 of Belgian students who participated in an informative seminar actually registered for a subsequent insect tasting session (Caparros Megido *et al*., 2016). After an informational session conducted in Italy, 66 out of 165 students (40%) participated in the product evaluations (Mancini *et al*., 2019b). Berger *et al*. (2018) demonstrated that in these situations, the type of information used in eliciting insect consumption matters, and knowledge of health and environmental benefits is not nearly as effective as hedonic appeals.

2.4. Emotions and Personality

2.4.1. The Entomophagy Emotion Wheel

Combining consumers’ check-all-that-apply (CATA) and rate-all-that-apply (RATA) emotional data from Italy (Tuccillo *et al*., 2020), Belgium (Delicato *et al.*, 2020; Schouteten *et al*., 2016), and the U.S.A. (Table 2.2; Ardoin *et al*., 2019), the Entomophagy Emotion Wheel was created (Figure 2.1). The inclusion of positive and negative emotional descriptors was based on >20% selection frequency in any of the eliciting conditions across CATA studies. This criterion has been used successfully elsewhere to designate salient food-evoked emotions (Pujols *et al.*, 2019; Wardy *et al.*, 2018). Emotions with mean rating scores greater than 1.0 (on a 5-point scale) from Delicato *et al*. (2020) were represented, as all five qualifying terms (*calm*, *good*, *happy*, *pleasant*, *satisfied*) also met selection requirements from the CATA studies. *Curiosity* was also included on the wheel due to its frequently mentioned association with the decision to consume insects (Caparros Megido *et al*., 2016; Tuccillo *et al*. 2020). The resulting Entomophagy Emotion Wheel was intended to be a descriptive representation of emotions most relevant to Western consumers' perceptions of entomophagy, but may be converted to a rating tool in the future.

Table 2.2. U.S. Consumer Emotions[1] Elicited by Tortilla Chips Containing Cricket Powder[2]

	Plain			**Italian**			**Cajun**		
Emotion	Visual	Taste	After BI	Visual	Taste	After BI	Visual	Taste	After BI
Adventurous	38	24	31	29	24	26	40	25	27
Calm	17	13	13	14	10	8	11	7	8
Disgusted	8	14	11	10	13	12	14	19	16
Enthusiastic	9	5	8	11	11	8	11	13	17
Good	9	18	14	12	19	17	11	14	12
Interested	46	28	27	37	27	38	41	27	32
Mild	11	12	12	19	13	11	10	13	12
Satisfied	4	16	17	5	17	14	8	6	9

[1] Emotions selected (CATA) by over 20% of (N=84) consumers from a list of 25 terms (Nestrud *et al.*, 2016) based on appearance (Visual), after tasting (Taste), and after delivery of entomophagy benefit information (BI).
[2] Three flavours (Plain, Italian, and Cajun) of tortilla chips were formulated with 6.8% cricket (*Acheta domesticus*) powder.

The wheel (Figure 2.1) depicts 22 emotions (13 positive, 7 negative, and two potentially neutral: *wild* and *mild*). According to Scherer's (2005) "alternative dimensional structures for the semantic space of emotions" chart, entomophagy-evoked emotion segments (Figure 2.1) were oriented radially, relative to each other, in four appraisal dimensions: valence (positive vs.

negative), coping potential (high vs. low power/control), arousal (active/aroused vs. passive/calm), and goal conduciveness (conducive vs. obstructive). The locations of emotion labels within this space are relative and not absolute. Positive emotions are generally more often associated with foods (Nestrud *et al*., 2016), which is reflected in food emotion lexicons and subsequently on our Entomophagy Emotion Wheel (Figure 2.1). Yet, the resulting larger segments on the wheel for negative terms seem appropriate, given the emotional negativity bias (Carretié *et al*., 2001) observed in entomophagy literature. This is clearly demonstrated from Ardoin *et al*.'s (2019) data, where *disgusted* was the fourth most cited feeling (behind *interested, adventurous,* and *good*; Table 2.2), but imposed the largest penalty on overall liking (-2.61 on the 9-point scale). Surprisingly, some negative food-evoked emotions (e.g., *guilty, unsafe*) commonly associated with novel foods (Sukkhown *et al.*, 2019), and included in presently employed lexicons, did not prove pertinent to entomophagy, although concerns about safety (*unsafe*) may be encompassed by *worried* (Pujols *et al.*, 2019) and *distrustful*.

Admittedly, some of the feelings represented on the wheel present similarly (e.g., *satisfied/content* or *glad*/*pleased*), but have been distinguished in other two-dimensional spatial models (Scherer, 2005). We further suspect that U.S. consumers' *mild* ratings (Ardoin *et al*., 2019; Table 2.2) were at times attributed to the taste of the product rather than their feelings, as the same panel disproportionately selected *warm* after tasting Cajun flavoured chips containing cayenne pepper. Indeed, it can sometimes be unclear whether verbal emotion labels refer to the nature of the stimulus object or the feeling induced by it (Scherer, 2005), particularly in the food domain. Still, we believe retaining these terms on the Entomophagy Emotion Wheel gives a more complete picture of the surprisingly expansive range of entomophagy-relevant feelings, and may cover nuanced appraisals across Western cultures and subsequent translations thereof

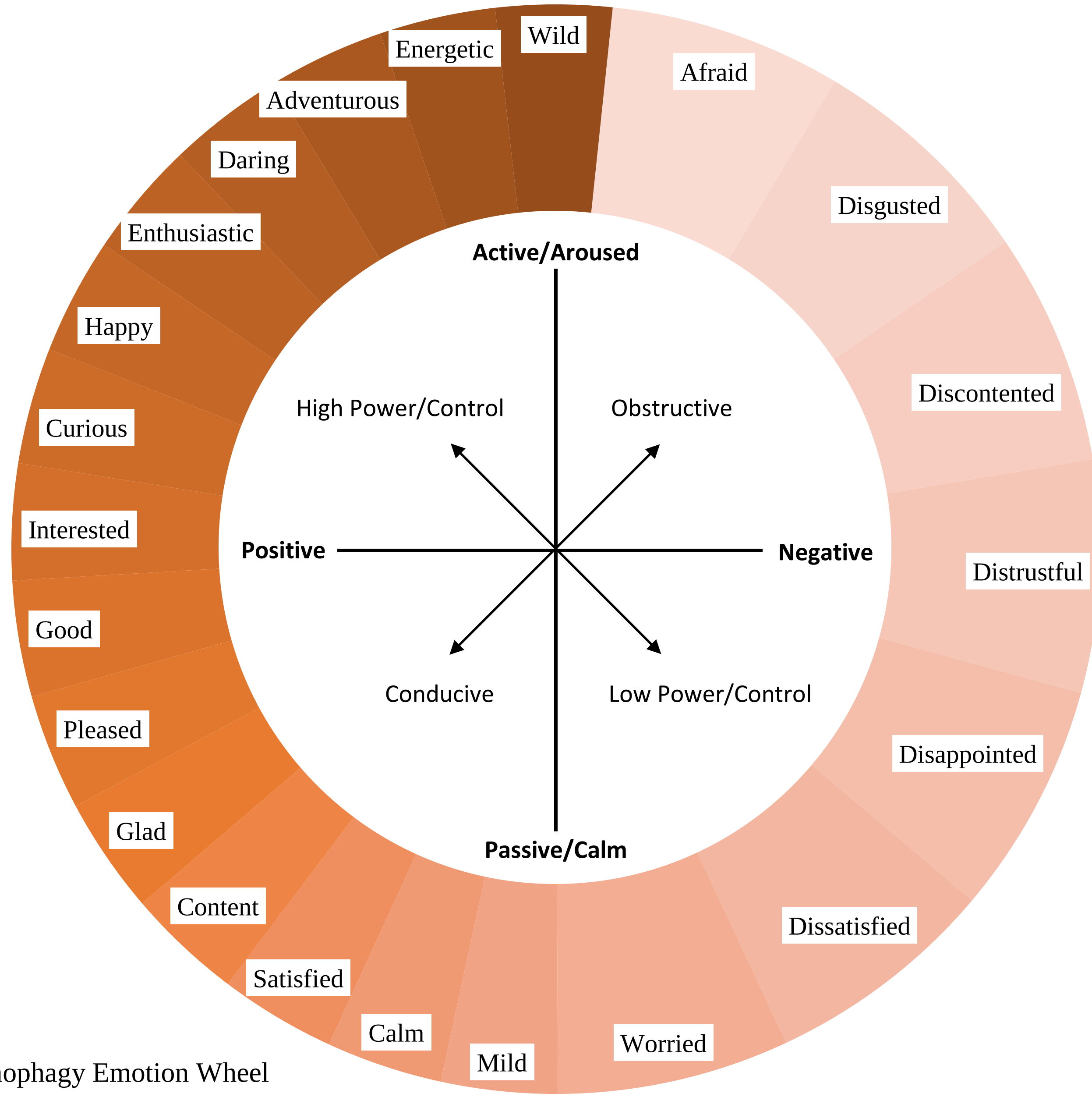

Figure 2.1. Entomophagy Emotion Wheel

2.4.2. Disgust and Disgust Sensitivity

More than any other emotional construct in the currently reviewed literature, disgust seems to be the most salient and immediate reaction to eating insects in the West (Hartmann & Siegrist, 2016; Jensen & Lieberoth, 2019; La Barbera *et al.*, 2018; Ruby *et al.*, 2015), and plays a major role in entomophagy avoidance. Disgust has been described as revulsion at the prospect of consuming an offensive substance, can render a food unacceptable, and may even manifest physiologically as nausea. Researchers (Rozin & Fallon, 1987) distinguished rejection based on: disgust (the origin of the item and its offensive properties), distaste (dislike of taste/smell/texture/appearance), danger (anticipated harmful consequences), and inappropriateness (items not classified as food). Most consumers are probably not so accurate when describing their repulsion to eating insects, and so perhaps "disgust" has become a catch-all term for these causes.

However, it is important to distinguish entomophagy-evoked disgust from the "moral" disgust that most Westerners would associate with eating pet animals like cats or dogs (Hartmann & Siegrist, 2018). Food-elicited disgust is generally "core" disgust, which relates to incorporation of an offensive substance into the body, but Hamerman (2016) found both core and "animal reminder" disgust to reduce attendance at a bug-eating event. Perhaps this reminder of "animalness" is commutative, which would explain why meat products are less acceptable vehicles for insects than snacks and baked goods (Ardoin & Prinyawiwatkul, 2020), and why insects are preferred in their processed form (no recognisable body parts) (Ardoin *et al.*, 2020).

Although multiple scales exist for disgust sensitivity measurement, Ammann *et al*. (2018) and Hartmann & Siegrist (2018) identified the need for a food-specific metric and used insects as stimuli to validate two new scales: the Food Disgust Scale, and Food Disgust Picture Scale, respectively. Because of its strong associations with behavioural inhibition, disgust sensitivity as an individual trait has been used to predict entomophagy outcomes (Berger *et al*., 2018; Hartmann & Siegrist, 2016). This suggests that the tendency of a consumer to be disgusted by insects, may be somewhat stable, but there is evidence that associatively based disgust reactions can be subject to extinction over time (Simpson *et al*., 2006)- perhaps if insect-containing foods become common and socially acceptable.

2.4.3. Fear and Neophobia

Fear of consuming insects may be related to fear of harm to the body (physical risk), fear of an unpleasant eating experience (functional risk), fear of social outcomes (social risk), or fear of damage to the ego or emotions (psychological risk) (Baker *et al*., 2016). Although fear of consuming insects is often associated with unfamiliarity, this response may also result from conditioned psychological associations with insects in other aspects of life, and transient feelings of fear should not be mistaken for a predisposition to food neophobia.

Food neophobia describes a more consistent personality trait related to avoidance across unfamiliar foods. While food neophobia is relatively stable (in adulthood), education, income, and urbanisation may affect expression, and by definition, exposure to the novel food should reduce aversion over time (Meiselman *et al*., 2010). Because of insects' blatant novelty in Western food cultures and the prevalence of fear, the condition of food neophobia is sometimes mis-diagnosed (or at least misinterpreted) when explaining consumers' aversions to entomophagy.

We suggest that a majority of consumers who reject insects as food do so because of cultural conditioning rather than pure novelty (therefore not highly "neophobic" *per se*). Additionally, neophobes tend to avoid consumer testing (Meiselman *et al*., 2010), so finding a significant number of these individuals participating in food evaluation studies is unlikely. The tendency for cultural biases against insects to be mistaken for "neophobia in itself" was cleverly evidenced by Iannuzzi *et al*. (2019), demonstrating through a conjoint analysis that when the "innovative ingredient" (cricket flour) was unknown, its corresponding preparation (pizza) was widely chosen among other options. However, when the secret ingredient was revealed, the pizza containing cricket flour became the least chosen option, prompting many participants to change their selection. Thus, novelty was not the rejection criterion.

More accurate interpretations of the significant relationship between neophobia and insect consumption require consideration of the personality continuum ranging from neophobia to its antipode trait of neophilia. Therefore, the Food Neophobia Scale (FNS, or modifications thereof) has become a common tool in entomophagy research, and scores consistently correlate negatively with intentions to eat insects (Hartmann & Siegrist, 2016; Sogari *et al.*, 2019b; Verbeke, 2015), as have those from the Food Technology Neophobia Scale (Lammers *et al*., 2019; Schlup & Brunner, 2018). However, these scales may not be as sensitive to characterising consumers on the opposite end of the spectrum (potential innovators or early adopters of entomophagy) who actively seek out new eating experiences.

2.4.4. Variety Seeking and Sensation Seeking

Individuals high in variety seeking and sensation seeking traits are prime candidates to become early adopters of entomophagy. These consumers enjoy and even pursue new products and diverse eating experiences. Inherent in these behaviours is a favourable attitude towards risk (Lenglet, 2018). Therefore, common hurdles to entomophagy may not impede their desire for varied, novel, and complex sensations and experiences (Zuckerman, 2009). Neophilia and variety seeking are not completely analogous though, as consumers may find sufficient variety by rotating familiar foods in the diet without inclusion of new ones.

The Varseek-scale (for variety seeking) has demonstrated better predictive validity for willingness to try unfamiliar food than FNS (Lenglet, 2018). Implicit behavioural data showed consumers with higher variety seeking tendencies to taste insect-labelled products sooner (shorter time to begin eating) than those scoring lower in the trait (Modlinska *et al*.; 2020). Variety seekers may also experience lower negative affect toward insect labelling on food products (Le Goff & Delarue, 2017).

Applying the Brief Sensation Seeking Scale (BSSS) to entomophagy research, positive relationships have been found between sensation seeking tendencies and willingness to consume insect foods in both Germany and the U.S. (Lammers *et al*., 2019; Ruby *et al*., 2015). This valuable information can be lost when research only employs scales structured toward one end of the personality spectrum (i.e., FNS alone). That is, being "low in neophobia" does not necessarily imply being "high in variety/sensation seeking" traits; the later may be equally or more important to entomophagy trial. An innovative self-reporting instrument, the Entomophagy Attitude Questionnaire, was recently developed by La Barbera *et al*. (2020), based on a three-factor design- two of which closely align with disgust and neophilia, respectively.

Some of the feelings prominently associated with insect eating (Figure 2.1) indicate a positive disposition (*happy*, *enthusiastic*), a want for experience (*interested, curious*) with willingness to take on risk (*daring, adventurous*), and an excited state (*energetic*, *wild*). These emotions are represented in the top left quadrant of the Entomophagy Emotion Wheel (Figure 2.1) and have been reported both as motivators for insect consumption (Tucillo *et al*., 2020) and as responses to insect-based products before and after eating (Ardoin *et al*., 2019). Due to their active, experiential, and risk tolerant nature, we coined the term “food-evoked sensation seeking emotions” for the first time for these food-related affect modalities: *adventurous*, *curious*, *daring*, *energetic*, *interest*ed, and *wild*. Specifying their residence in the food realm is meant to distinguish the positive regard for novel eating experiences from negative implications of sensation seeking with social deviance elsewhere (Zuckerman, 2009).

Comparable to expectations of other personality measures (disgust sensitivity, food neophobia) to explain a portion of associated emotive responses (disgust, fear) to entomophagy, we predict that BSSS (and similar scales) should correlate positively with an individual’s tendency to experience sensation seeking emotions from novel foods like insects. Even so, as with the other aforementioned scales and emotions, edible insects may have a unique tendency to elicit these sensation seeking feelings from individuals who are not particularly high in the personality trait. This relationship should be validated experimentally and statistically. Emoji-based scales also have been used in recent entomophagy research (Fuentes *et al.*, 2020), as has the following icon:  (Tuccillo *et al*., 2020), which may serve as an adequate representation of food-evoked sensation seeking emotions in future emoji assessments.

2.4.5. Positive Emotions

Two important emotions involved in the decision to give edible insects a try across Western cultures are curiosity and interest, which in some cases, can be enough to motivate tasting even when expectations are low. As such, effective hedonic appeals should enhance the power of these drivers (Berger *et al*., 2018). With unfamiliar foods such as insects, garnering trial relies on levels of interest and curiosity outweighing those of fear and disgust (Balzan *et al*., 2016; Tan *et al*., 2015). Among Belgian students who agreed to participate in an insect tasting experiment, curiosity (69%) was a more prevalent than fear (14%) and disgust (13%) at the prospect of eating insects (Caparros Megido *et al*., 2016). Tuccillo *et al*. (2020) noticed curiosity to be a prominent motivation for including insects in the diet of Italians. We found that, based on visual observation, *interested* and *adventurous* were the two most frequently selected emotions by consumers for tortilla chips containing cricket powder (Table 2.2). Entomophagy adoption strategies can benefit from pre-trial and product-elicited evocations of positive feelings, which may be reinforced through enjoyable eating experiences.

2.5. Sensory Quality

2.5.1. Visual and Informational Cues

The Total Food Quality Model (see Tan *et al*., 2017a) suggested that consumers may first ascertain product information through "search qualities" evaluated before purchase. These can come in the form of intrinsic (inherent to the product itself) and/or extrinsic (related to but not part of the product) visual information (Chonpracha *et al*., 2020). As most Western consumers do not have direct experience with edible insects, inferences about insect-containing products are often based on incomplete information. Visual cues such as naming, logo, or labelling (extrinsic), and/or visible features of the actual food (intrinsic) can help consumers extract clues about a product's attributes, expected quality, and potential benefits (Tan *et al*., 2017a). To illustrate these effects, Table 2.3 presents images of visual stimuli used in entomophagy studies.

The most important single strategy to promote positive (or mitigate negative) appearance evaluations of insects in food is to make them "invisible," that is, not recognisable as an ingredient. This would generally begin by using a processed form of the organism (e.g., a cricket flour or powder; Barton *et al*., 2020), and may be aided by effective technologies to make the product's colour as "normal" as possible. Ribeiro *et al*. (2019) found ground crickets to have a negative effect on colour of fruit and cereal bars, making them more "brownish" than the ideal "golden" colour. As found with snack crackers (Ardoin *et al*., 2020), cricket powder can lend to darkening of certain products (e.g., pork pâté; Smarzyński *et al*., 2019) and subsequently, decreased liking. Portraying an image of a burger made with ground mealworms in a typical presentation (Lammers *et al*., 2019; Table 2.3) increased consumers' willingness to try, buy, and substitute insects for meat, compared to an image of whole buffalo worms. Observing certain insects in food may be more problematic than others (e.g., risotto with maggots (Laureati *et al*., 2016)), leading to negative associations beyond distaste. As one Italian consumer noted, "If I see a maggot I associate it with food degradation" (Balzan *et al*., 2016).

Table 2.3. Images of Insect-Containing Products Used to Test Intrinsic and Extrinsic Visual Cues among Western Consumers

	Effective	Ineffective
Intrinsic Visual Quality	 (de-Magistris *et al*., 2015)[1]  (La Barbera *et al*., 2019)[2]  (Lammers *et al*., 2019; ©Bugfoundation)[3]	 (de-Magistris *et al*., 2015)[1]  (La Barbera *et al*., 2019)[2]  (Baker *et al*., 2016)[4]

(table cont'd.)

(table cont'd.)

	Effective	Ineffective
Extrinsic Visual Quality	(logo) (de-Magistris *et al.*, 2015)[1]  (Baker *et al.*, 2016)[4]	 (Balzan *et al.*, 2016)[5]  (Baker *et al.*, 2016)[4]

[1] Reprinted from *British Food Journal*, Vol. 117 No. 6, 2015, Tiziana de-Magistris, Stefano Pascucci, and Dimitrios Mitsopoulos, "Paying to see a bug on my food How regulations and information can hamper radical innovations in the European Union, Page No. 1782, © Emerald Publishing Limited all rights reserved.
[2] Reprinted from *Quality-Access to Success*, Francesco La Barbera, Fabio Verneau, and Adele Coppola, "Entomophagy: A Contribution to the Understanding of Consumer Intention;" *20(S2)*, page 331.
[3] Reprinted from *Food Quality and Preference*, Vol 77, Patrik Lammers, Liza Marleen Ullmann, and Florian Fiebelkorn, "Acceptance of insects as food in Germany: Is it about sensation seeking, sustainability, consciousness, or food disgust?," Page No. 81, copyright 2019 with permission from Elsevier.
[4] Reprinted from Melissa A. Baker, Jungyoung Tiffany Shin, and Young Wook Kim, "An Exploration and Investigation of Edible Insect Consumption: The Impacts of Image and Description on Risk Perceptions and Purchase Intent," in *Psychology & Marketing*, © 2016 Wiley Periodicals, Inc.
[5] Reprinted from Stefania Balzan, Luca Fasolato, Serena Maniero and Enrico Novelliauthors, in *British Food Journal*, Vol. 118 No. 2, 2016, page number 321, © Emerald Publishing Limited all rights reserved.

From a packaging and labelling standpoint, attractive naming and description, communication of health benefits, branding (logo), and product image are important to consumers' perceptions of insect foods. de-Magistris *et al*. (2015) found Dutch consumers were willing to pay a premium price for an insect-based product with logo (Table 2.3) and health claim related to the "omega 3" content. Much as with intrinsic evaluations, consumers prefer not to see the source-insect on a product's label. Examples of each (with and without a picture of an intact water bug) are shown in Table 2.3 (Baker *et al*., 2016). Finally, giving inviting names to insect-based foods is an inexpensive strategy to enhance both visual and verbal appeal. This has proven effective in promoting frog legs ("cuisses de nymphe a l'aurore") and Patagonian toothfish ("Chilean sea bass") in the past (Deroy *et al*., 2015). The most effective naming strategy seems to be replacing the insect's common or scientific name with a more ambiguous one non-invocative of the creature's "animalness." A vague description (e.g., "Neomorpha Asian Spice Mix"; Table 2.3) would be preferable to a more explicit one ("Giant Waterbug Asian Spice Mix"; Baker *et al.*, 2016).

Information about the insect ingredient can have a significant impact on quality expectations and even perceptions, which may in fact have little to do with the actual taste (Tan *et al*., 2017a). This becomes quite obvious when examining research using deception (Modlinska *et al.*, 2020), in which products were evaluated with a false claim of insect incorporation. In one study (Tan *et al*., 2016), burgers labelled as containing an unusual ingredient (frog meat, lamb brain, or mealworm) received lower expected liking scores than a beef burger, but scores became similar after tasting. Interestingly, mealworms burgers were expected to be significantly worse than frog meat, but similar to lamb brain. Falsely labelled "insect bread" was liked significantly less in appearance, flavour, and overall than the same product labelled "insect-free" (Barsics *et al.*, 2017). This demonstrates a horns effect (Lawless & Heymann, 2010), where one salient belief carried over to unrelated organoleptic evaluations when no real differences were present.

In another study, an opposite effect was observed immediately following an entomophagy information seminar, where bread allegedly supplemented with insect powder received higher scores for flavour, texture, and overall liking (Mancini *et al*., 2019b). With flavoured potato chips, an "insect protein enriched" claim did not bring about differences in liking (Le Goff & Delarue, 2017).

2.5.2. Hedonic Evaluations

Successful introduction of novel insect-based foods to Western markets necessitates finding a product category that makes sense to consumers (Deroy *et al*., 2015). Appropriate product concepts should promote positive expectations and trial intent (Tan *et al*., 2016). This approach requires an understanding of cultural palates rather than a one-size-fits-all approach. In a survey of U.S. consumers, protein supplementation (protein bars and shakes), snacks, and baked cereal products were most fitting (Ardoin & Prinyawiwatkul, 2020). Similarly, in Belgium (Van Thielen *et al*., 2019), shakes and energy bars were most acceptable, followed closely by burgers. In Italy (Laureati *et al*., 2016) biscuits seemed more appropriate than a cereal bar, while Modlinska *et al*. (2020) suggested sweet products or snacks for Polish consumers. To explore both regional and product-based differences in sensory acceptability, Table 2.4 presents a summary of hedonic ratings for various insect-based products tested by local consumers. Since descriptive sensory analyses are objective in nature and should be consistent across well-trained panels (regardless of culture), they are not addressed here (see Mishyna *et al*., 2020 for a review).

Comparing Spanish and U.S. panels, an apparent optimal-type distribution for cricket powder level in chocolate chip cookies existed among Spanish judges, who liked the 15% cricket formulation over the cricket-free control. Here, the difference was evidently related to sensorial rather than attitudinal differences, as more Spanish than U.S. consumers liked the cookies even

Table 2.4. Western Consumers' Hedonic Evaluations of Various Products Containing Insects

Product	Insect	N[1]	Key Results	Country[2]	Citation
Protein powders (plant based)	Cricket (*Acheta domesticus*) powder	102	30% inclusion of cricket powder in chocolate and unflavoured protein powders was acceptable.	Canada	Barton *et al*. (2020)
Energy bars and protein bars (commercially available, several flavours)	Cricket (*Acheta domesticus*) powder	96	Orange and pineapple flavoured bars from the Czech manufacturer were preferred, coinciding with directionally higher smell and taste pleasantness ratings, to U.S. bars.	Czech Republic	Adámek *et al.* (2018)
Buckwheat pasta	Silkworm (B*ombyx mori*) powder	45	Silkworm enrichment improved acceptability of buckwheat pasta, with the 10% enrichment receiving the highest liking scores overall (with a positive influence of taste) and for colour.	Hungary	Biró *et al.* (2019)
Chocolate bar Dried whole crickets with salt and vinegar Tortilla chips Dried whole mealworms with sweet/savoury flavouring	Cricket (*Acheta domesticus*): whole and flour Mealworm (*Tenebrio molitor*) whole	62	A mean overall liking of 6.48 (on 9-point scale) was observed across products, with highest scores for chocolate bar containing 5.5% cricket flour. Appearance liking was lower for visible insect products.	Italy	Cicatiello *et al.* (2020)
Bread	Mealworm (*Tenebrio molitor*) powder	9	Mealworm powder addition decreased overall liking of bread.	Italy	Roncolini *et al.* (2019)

(table cont'd.)

(table cont'd.)

Product	Insect	N[1]	Key Results	Country[2]	Citation
Bars	Mealworm (*Tenebrio molitor*): whole and ground Crickets (*Acheta domesticus*): ground	101	Bars made with ground (flavoured) mealworms were rated higher than those with whole mealworms and ground crickets in terms of appearance, tastiness, smell, and overall.	Poland	Bartkowicz & Babicz-Zielińska (2020)
Pork pâté	Cricket powder	30	Overall rating of pâté with 2% cricket powder was similar to the control, but dropped incrementally with 6% and 10% incorporation.	Poland	Smarzyński *et al.* (2019)
Chocolate chip cookies	Cricket powder (*Acheta domesticus, Gryllodes sigillatus*)	200 (Spain) and 200 (U.S.A.)	U.S. consumers expressed no differences in liking between the control and 15% cricket sample, but liked 30% cricket cookie less. Spanish consumers liked the 15% cricket sample significantly more than the control, and the and 30% cricket sample less than the control.	Spain and U.S.A.	Castro Delgado *et al.* (2020)
Extruded rice product	Cricket flour Locust flour	120	Cricket flour products were preferred to Locust flour. Flavour/taste and texture/mouthfeel were significant in differentiating overall liking between the two insect flours.	U.S.A.	Tao & Li (2018)

[1] Number of consumers participating in the sensory evaluation.
[2] Country where the study was conducted.

before knowing they contained insects (Castro Delgado *et al*., 2020). An effective understanding of Czech consumers' particular wants in an energy bar was exhibited in a study (Adámek *et al*., 2018) where commercially available bars, containing cricket powder, from a Czech manufacturer were preferred to those made in the U.S.A. Preferences among insect types/species should also be considered. Within a Polish population sample (Bartkowicz & Babicz-Zielińska, 2020), bars made with ground mealworms performed better than those made with ground crickets.

Further considerations of insects' effects on sensory quality should be given to the specific product type. Biró *et al*. (2019) found silkworm powder to improve the colour of buckwheat pasta, and for some Hungarian consumers, to mask the unpleasant flavour of buckwheat. The authors suggested a bimodal distribution for acceptance of odour intensity, and using preference mapping, found the highest level of silkworm powder (10%) to be the most accepted. For most products though, especially ones initially well-liked without insects, there exist so-called rejection-type thresholds (Ardoin *et al.*, 2020), above which the insect ingredient impairs sensory quality. In a study of bread, for example, mealworm powder addition directionally decreased overall liking (Roncolini *et al*., 2019). It may additionally serve researchers to track these changes across sensory attributes to guide product improvement strategies (Ardoin *et al*., 2020).

2.6 Impacts of Regulations on Adoption

Governments play a decisive role in facilitating a shift toward new and sustainable food options. The first priority must be consumer safety, which despite existing evidence and emerging research, seems to be a sticking point for entomophagy in Western countries. Secondly, low hurdles to production are essential to instilling confidence throughout the supply chain. Lastly but crucially, legislators must turn to consumer science to understand the wants of end-users. Overlooking critical drivers of product acceptance- such as only allowing for whole insects in foods- results in *de facto* regulatory failure (de-Magistris *et al.*, 2015).

The assurance of safety alone removes a layer of risk from entomophagy (Baker *et al.*, 2016), is likely to promote willingness to try insect-based foods, and may potentially alleviate feelings of worry and distrust. Under Australian, Canadian, and E.U. law, edible insects are considered "novel" foods when there is no local history of safe consumption and thus require pre-market safety evaluations and authorisation (Lähteenmäki-Uutela *et al*., 2017; Sogari *et al.*, 2019c). However, certain species have been approved for commercial sale as human food: *Acheta domesticus* (house cricket), adult *Locusta migratoria* (migratory locus), and *Tenebrio molitor* larvae (mealworms) in Switzerland (Sogari *et al*., 2019c); and *Acheta domesticus*, *Tenebrio molitor,* and *Zophobas morio* (super mealworm) in Australia (Lähteenmäki-Uutela *et al*., 2017). Edible insects have yet to obtain GRAS (generally recognised as safe) status in the U.S., but are currently allowed in food if current good manufacturing practices (CGMPs) are followed, and products must be labelled with a crustacean/shellfish allergen warning (Lähteenmäki-Uutela *et al*., 2017).

While existing regulations may mention other invertebrates (e.g., molluscs) by name, specific references to insects are often absent, leading to uncertain guidelines within which food companies must operate. This reflects the lack of consideration given to entomophagy when original laws were written. According to Belluco *et al*. (2017), legislative constraints present the greatest hurdle to insects becoming a part of the European food chain. Absence of specific provisions for edible insects in the E.U. has resulted in a divergence of strategies among individual Member States, as there is still much ambiguity (Belluco *et al*., 2017). In U.S. food regulation, only cochineal (*Dactylopius coccus costa*) is explicitly addressed as an intentional food component (for use as a colourant; Sogari *et al.*, 2019c). Clear-cut regulatory guidelines should expand the production and availability of innovative insect-based food products as well as set a precedent for their safety.

Progress toward largescale entomophagy adoption will require a gradual re-positioning of insects in the marketplace and in the minds of consumers; both are dependent on governments prioritising legislation to move entomophagy forward. In Switzerland, the discourse on regulating edible insects has been productive, and policy continues to move forward in response to civil interest (Holloran *et al*., 2015). While this review article was being prepared, the Court of Justice of the European Union (CJEU) issued a ruling stating that commercial production of whole insects for human food may continue across the E.U. until the first (new) novel food authorisations enter into force (CURIA, 2020). With increased exposure to edible insects will also come familiarity, which is necessary (by definition) to overcome neophobia where novelty is truly at the root of aversion. Even more persistent associations of edible insects with disgust may diminish with time and well-guided product development (Simpson *et al.*, 2006).

2.7. Conclusions and Future Directions

Under current conditions, Western consumers do not seem primed for any rapid shift toward insect consumption. Finding a niche, outside of novelty goods, for insects in modern food systems will require continued effort on the part of researchers, food companies, and governments, and likely be a very gradual process. Changing the minds and (more importantly) behaviours of large consumer segments is a daunting task, especially given that food choice is partly irrational and claims of environmental and societal benefits are too temporally and culturally distant to appear relevant. With so many cheap, convenient, and tasty food options readily available and established in Western dietary habits, insect-derived foods must come to deliver the same immediate satisfaction without a trade-off between quality and sustainability.

Future entomophagy research should, therefore, focus on improving the intrinsic sensory quality of insect-based foods for potential early adopters on a regional/cultural basis. Strategies should focus on the sensation seeking nature of potential early entomophagists, and as products become more appealing, existing negative emotions may diminish over time. With progressive exposure to insects in the food space and access to enjoyable products, it is possible that associations of unfamiliarity, inappropriateness, and disgust will be weaker for future generations. The potential of insect production, compared to other alternative protein sources, as a substitute for traditional livestock can be re-evaluated once edible insects are appreciated on their own merit. To build upon the existing body of research and conform with existing regulatory trends, product development should proceed with a couple common species; crickets and mealworms are the obvious choices.

The unique ability of insects to elicit strong perceptual and emotive responses gives added value to their use in food research. As such, their study has lent to development of new emotion scales and sensory methodologies that are applied to a variety of food stimuli. If entomophagy is not a practical way to meet the nutritional needs of the growing global population, its study should nonetheless inform strategies for introduction of other novel foods. If new markets for edible insects do eventually emerge, their advancement will be informed by an expanding foundation of scientific knowledge.

CHAPTER 3. PRODUCT APPROPRIATENESS, WILLINGNESS TO TRY, AND PERCEIVED RISKS OF FOODS CONTAINING INSECT PROTEIN POWDER: A SURVEY OF U.S. CONSUMERS

3.1. Introduction

With the world's population growing amongst limited resources, the agriculture industry must consider beyond simply growing and harvesting (Kuttiyatveetil *et al*., 2019). This looming challenge has led to increased scientific interest in entomophagy (human consumption of insects) in the early 21st century. Briefly, edible insects provide advantages of feed conversion efficiency, water and land usage, and greenhouse gas emission over traditional livestock farming (Van Huis *et al.*, 2013). Edible insects can also be particularly high in protein and provide valuable micronutrients and functional peptides (Zielińska *et al.*, 2018; Lacroix *et al*., 2019), although it is important to note that nutritional composition varies amongst species and stage of development (Kouřimská & Adámková, 2016).

Despite this rationale, several obstacles still stand in the way of large-scale entomophagy adoption (Deroy *et al.*, 2015). These hurdles include cultural and social norms (Looy *et al.*, 2014), negative emotions- particularly disgust (Hamerman, 2016; La Barbera *et al.*, 2018), poor sensory appeal (Deroy *et al*., 2015), and potential food neophobia (Sogari *et al.*, 2019b; Verbeke, 2015). Though long part of some traditional Eastern diets (Van Huis *et al*., 2013), Westerners' aversion to eating insects is nothing new (Holt, 1885). Leading research has been conducted across Europe to explore consumers' attitudes and aversions towards entomophagy (Mancini *et*

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al., 2019a). Strategies to normalise this food source in the U.S. (Baker *et al.*, 2016; Hamerman, 2016; Ruby *et al.*, 2015) have been less explored, but may take cues from the existing literature.

Tan *et al.* (2017b) suggested that developing more appealing, or appropriate, insect-containing products can influence trial intention, sensory-liking, and willingness to buy among Dutch consumers. This concept of appropriateness as a cognitive dimension of food choice (Schutz & Martens, 2001) is essential to the present study. Appropriateness has been used to describe the context of the eating situation (Schutz & Martens, 2001), the combination of foods in a meal (Elzerman *et al.*, 2011), or the perceived suitability of product preparation (Tan *et al.*, 2017b). Here, we use 'product appropriateness' to characterise the incorporation of an ingredient (insect protein powder) within a product that would be deemed desirable, acceptable, or fitting (based on previous experience or expected outcomes), especially in such a way that would influence trial of the product (Tan *et al.*, 2015).

The present research suggests willingness to try (WTT) as fundamental to collecting meaningful sensory data, elucidating market potential, and guiding product development of insect-containing foods in the U.S. Consumers may hold strong preconceptions about unfamiliar foods based on expected rather than experienced outcomes, so achieving trial intent is key to exposure, which will then dictate actual likes/dislikes and preferences (Ruby *et al*., 2015; Tan *et al*., 2015). Initial consumption of insect products has been suggested to promote future instances (Hartmann & Siegrist, 2016), but may depend on moderating factors such as sensory quality (Deroy *et al*., 2015; Tan *et al.*, 2016).

Human food choice is influenced by complex interactions of psychological and biological factors (Köster, 2009). As such, this study also examined perceived risks (Baker *et al*., 2016), as self-reported inhibitors to consumers' WTT insect products. To address some of these risks, consumers were made aware of entomophagy benefit information (EBI). In previous studies (Deroy *et al*., 2015; Hamerman, 2016; Lombardi *et al.*, 2019; Pambo *et al.*, 2018; Piha *et al.*, 2018), educational information and rational appeals to entomophagy have demonstrated mixed results on consumer intentions.

Indeed, food attitudes and subsequent behaviours toward entomophagy are shaped by cultural exposure (Tan *et al*., 2015). In this regard, we suggest that the 'West' not be considered as one culturally or attitudinally homogenous food market (Labrecque *et al.*, 2006). In fact, just between Northern and Central Europe, Piha *et al*. (2018) found regional differences in consumer attitudes toward insect foods. From a product development standpoint, it is important to consider different consumer preference structures, even within the same market (van Trijp & Steenkamp, 2005). The present research is among the first to provide specific qualitative guidance from the 'voice of the consumer' [N=1,005] across a range of potential products [30] and associated concerns [11], specific to the U.S. market for entomophagy. Ruby *et al*. (2015) did examine U.S. consumers' willingness to eat insects in different product forms, albeit with a smaller sample size.

The objectives of the present study were to identify specific food products (and more broadly, product categories) most appropriate for incorporation of insect protein powder based on willingness-to-try (WTT); to identify perceived risks (reasons) motivating unwillingness or reluctance to try insect-containing products; and to evaluate the effect of entomophagy benefit information (EBI) on WTT– all among U.S. consumers.

3.2. Methods

3.2.1. Surveys, Consumers and Recruitment

This research involving human subjects was approved by the Louisiana State University (LSU; Baton Rouge, LA, U.S.A.) Agricultural Center Institutional Review Board (IRB# HE18-9). Two online surveys were designed and administered using Qualtrics software (Qualtrics, Provo, UT, U.S.A.) to collect data about U.S. consumers' perceptions of foods containing insect protein. The first survey (S1) was completed by 403 adult U.S. consumers, and the second survey (S2) by 602 adult U.S. consumers. These 1,005 combined responses were the focus of this study.

Participants were recruited through various online platforms, from a consumer database compiled by the LSU AgCenter Sensory Services Lab, and from LSU campus (Baton Rouge, LA, U.S.A.). Web-links and QR codes were generated for survey distribution. Some paper versions of the surveys were also printed and administered to students on LSU's campus. Consumers were not compensated for participation.

Data-points from S1 and S2 (combined N=1,005) regarding general willingness to try (GWTT) foods containing insects, product appropriateness, general inhibitors to trying insect foods, and consumer segmentation were combined for analysis. Unique variations in design between S1 and S2 served to accomplish specific aims of this research. S1 (n=403) explored perceived risks *specific to each product*, while S2 (n=602) tested the effect of an entomophagy benefit information (EBI) on WTT. Separate surveys were used to limit questionnaire length and response time in order to encourage participation, completion, and quality of responses (Galesic & Bosnjak, 2009).

The sample consisted of 68.4% females and 31.6% males. Overall, 43.5% of participants (38.7% females and 53.9% males) reported previous insect consumption. Most participants (92.7%) were typically willing to try new foods. To investigate whether the other 7.3% were truly food neophobic persons, more formal evaluation would be needed (Pliner & Hobden, 1992). Respectively, 48.6% and 50.9% of participating consumers reported making consumption decisions based on sustainability and environmental impact of the food source.

3.2.2. Questionnaires

First, consumers were screened for age (18 years or older). After consumers had agreed to terms outlined in a consent form, demographic (gender) and psychographic data were collected from them. The following questions were answered using a 'Yes/No' scale: "Do you make consumption decisions based on the sustainability of the food source?", "Do you make consumption decisions based on environmental factors (such as chemical use, greenhouse gas emissions, land usage, pollution, waste production) associated with the food source?", "Are you typically willing to try new foods?", and "Have you ever eaten food containing insect as an ingredient?". These questions were based on potential predictors of entomophagy adoption (Verbeke, 2015).

Consumers have shown more openness to eating insects in the 'invisible' form (Ruby *et al.*, 2015; Tan *et al.*, 2016), such as flour or protein powder (Barton *et al.*, 2020), which are commercially available in the U.S. Therefore, all WTT questions were asked using the phrase "containing insect protein powder," (e.g., "Would you try BREAD containing insect protein powder?"). All WTT responses were recorded on a 'Yes/Maybe not/No' scale.

For both surveys, consumers first reported general willingness-to-try (GWTT) any "food, beverage or snack containing insect protein powder." Then, to assess product appropriateness, WTT was evaluated for thirty products- intended to represent a broad range of processed foods commonly consumed in the U.S., from six proposed categories (Table 3.1)- with products presented alphabetically. Those products yielding highest 'Yes' response frequencies were deemed most appropriate.

Upon each instance of a 'Maybe not' or 'No' response to GWTT (both surveys) or WTT (S1 only), "Why not?" was asked. Consumers then selected perceived risks (Baker *et al*., 2016) associated with their negative intent from the following list: Appearance, Cultural or religious beliefs, Negative emotions (boredom, disgust, fear, guilt, worry, etc.), Nutrition, Odour/aroma, Price, Taste, Texture/mouthfeel, Safety, Social acceptability, and Unfamiliarity with insects as a food source. Risks were reported in a check-all-that-apply (CATA) format for GWTT and as "the top three reasons" for product-specific WTT. For individual product WTT, "I do not eat this product" was also an option.

For S2 only, after WTT was asked for all thirty products, the following entomophagy benefit information (EBI) was presented: "Edible insects are safe to eat and are considered a sustainable source of high quality protein and other nutrients. Edible insect production has less negative environmental impact than traditional livestock production. An estimated 2 billion people worldwide consume edible insects" (Van Huis *et al*., 2013). After reading EBI, consumers again rated WTT for all thirty products.

3.2.3 Data Analysis

For GWTT, WTT, and perceived risks, raw response frequencies were compared. A cumulative logistic regression model was used to evaluate the relationship between sociographic indicators and GWTT (Agresti, 2019). To evaluate effects of EBI on WTT, the Stuart Maxwell test (Sun & Yang, 2008) and McNemar's test (Agresti, 2019) for marginal homogeneity were employed. Data were analyzed using Microsoft Excel (2013) and SAS (2013) software.

3.3. Results and Discussion

3.3.1. General Willingness to Try

Of the N=1,005 responses collected (combined from S1 and S2), 166 U.S. consumers (16.5%) initially claimed they would not try any "food, beverage or snack containing insect protein powder." Based on these initial 'No' responses to the general willingness to try (GWTT) question, 'No' responses were also assigned to each individual product (data represented in Table 3.1). However, these consumers did receive EBI (S2 only) and were then asked to rate WTT for each product individually, to measure any effects of the additional information. This portion of consumers would not represent the target market for introduction of entomophagy in the U.S., as they deemed all products unsuitable for consumption.

Instead, 'early adopters' should be the focus of new product development in the U.S. (House, 2016). Six-hundred U.S. adults did respond affirmatively ('Yes') to the GWTT question, representing 59.7% of the population sample. The remaining 239 consumers (23.8%), expressed hesitance, but not complete unwillingness, by responding 'Maybe not.' Interestingly, positive WTT for some individual products (protein bar, chips or snack crackers, protein shake; Table 3.1) exceeded the above mentioned 59.7% rate of 'Yes' response from GWTT. This indicated that appropriate products could sway some initial 'Maybe not' consumers toward trial intent. In fact, 729 consumers (72.5%) reported positive WTT ('Yes' response) for at least one product when evaluated individually. Similarly, Ruby *et al*. (2015) reported that 72% of 179 Americans surveyed would consider eating some forms of insect food.

Table 3.1. General Willingness to Try (GWTT)[a] and Product Appropriateness Based on WTT[b] for Products Containing Insect Protein Powder

		% Yes	% Maybe not	% No
GWTT		59.70	23.78	16.52
Category	Product			
Candy/Snack	Protein Bar or Energy Bar	65.37	11.64	22.99
Candy/Snack	Chips or Snack Crackers	61.29	14.83	23.88
Beverage	Protein Shake	60.00	12.44	27.56
Bakery/Cereal	Bread	59.50	17.91	22.59
Bakery/Cereal	Muffin	56.72	15.62	27.66
Bakery/Cereal	Tortilla	56.62	13.53	29.85
Bakery/Cereal	Pasta	55.82	15.72	28.46
Bakery/Cereal	Cake	54.33	18.11	27.56
Beverage	Smoothie	54.23	16.12	29.65
Bakery/Cereal	Cookies	53.83	16.92	29.25
Candy/Snack	Candy Bar	53.63	18.31	28.06
Candy/Snack	Trail Mix	51.24	15.22	33.53
Meat/Poultry/Seafood	Hamburger	49.65	15.82	34.53
Meat/Poultry/Seafood	Omelette or Quiche	47.36	16.42	36.22
Bakery/Cereal	Doughnut or Pastry	46.57	19.10	34.33
Meat/Poultry/Seafood	Hot Dog or Sausage	45.37	18.51	36.12
Candy/Snack	Gummi Candy	45.27	16.42	38.31
Meat/Poultry/Seafood	Chicken Nuggets	44.58	18.41	37.01
Candy/Snack	Hard Candy, Sucker, or Lollipop	41.29	19.00	39.70
Beverage, Dairy	Milkshake	40.80	19.30	39.90
Meat/Poultry/Seafood	Crab Cake	40.60	17.81	41.59
Beverage	Sports Drink	40.20	19.60	40.20
Dairy	Pudding or Custard	39.50	19.20	41.29
Meat/Poultry/Seafood	Fish Sticks	39.40	17.21	43.38
Dairy	Yogurt	38.01	18.41	43.58
Dairy	Butter	37.41	27.16	35.42
Dairy	Ice Cream	37.41	19.40	43.18
Beverage	Vegetable Juice	37.11	18.41	44.48
Beverage	Fruit Juice or Fruit Drink	34.33	21.19	44.48
Dairy	Cheese	34.13	26.87	39.00

(Based on N=1,005 responses)

[a] General willingness to try food beverage or snack containing insect protein powder.

[b] Willingness to try (WTT) expressed as percent response frequencies (Yes/Maybe not/No) for each product. Greater frequency of 'Yes' responses indicates higher product appropriateness.

Comparing our findings to surveys in other Western societies (and them to each other), discrepancies in regional attitudes about entomophagy are apparent. A telephone survey with 388 Belgian consumers found that less than half were willing to taste insect products (Van Thielen *et al.*, 2019), but in another study of 189 Belgian consumers, 77.7% reported willingness to eat insects (Caparros Megido *et al*., 2014). In a medium-sized Italian city, only 31% (of 201 respondents) expressed willingness to try insect foods (Cicatiello *et al.*, 2016). Aside from cultural preferences, additional variance may be explained by experimental methods (Cicatiello *et al*., 2016), e.g., question-type, method of panelist recruitment, and sample size. The high proportion of Americans in the present study (over 72%) expressing willingness to try at least one product containing insect protein powder may not be generalisable to the entire U.S. population, but did spark interest into identifying a target segment of consumers.

To evaluate the relationship between sociographic information and GWTT, a cumulative logistic regression model was applied (Table 3.2). Along with gender [0=Female, 1=Male], responses [0=No, 1=Yes] to questions about prior insect consumption (Prior), purchase decisions based on environmental impact (Environment), purchase decisions based on sustainability (Sustainability), and willingness to try new foods (Openness) were used as predictors of GWTT. The final working model was reduced to three significant indicators of GWTT: gender, Prior, and Openness (Table 3.2), with no significant interactions present. Sustainability and Environment variables did not significantly account for GWWT responses. With the assumption of proportional odds satisfied, odds ratio (OR) estimates for the effect of gender, Prior, and Openness were obtained (Table 3.2).

Estimated odds of GWWT = ‘Yes’ (as opposed to ‘Maybe not/No’) were 76% higher for men (OR=1.76, Table 3.2). From the present sample, 71.3% of men and 54.3% of women expressed positive GWTT. These findings aligned with other reports of Western males being more inclined to try entomophagy than women (Caparros Megido *et al*., 2016; Menozzi *et al.*, 2017). While the Openness (willingness to try new foods) question was not an explicit measure of neophobia, it was expected that by this metric alone (holding Gender and Prior constant), odds of reporting trial intent would be almost three times higher for "Yes" responders to Openness (OR=2.93). The regression model suggested that males open to new foods could comprise a large portion of the early market for entomophagy, and once initial trial was achieved, the probability of future intentions would increase. While not everyone in the sample who had previously eaten insects was willing to do so again, Prior (prior insect consumption) showed the largest multiplicative effect on GWTT odds (OR=4.51), providing further motivation to facilitate insect trial in the West. Projections of actual consumption are hypothetical, so behavioural measures are needed to validate these effects.

Table 3.2. Parameter Estimates[^] for Cumulative Logistic Regression Model[*] of General Willingness to Try (GWTT)[a]

Parameter	Estimate	p-value	Odds Ratio
Intercept1[b]	-1.37[b]	<0.001	n/a
Intercept2[b]	0.03[b]	0.88	n/a
Gender	0.56	<0.001	1.76
Prior	1.51	<0.001	4.51
Openness	1.08	<0.001	2.93

(Based on N=1,005 responses)

[^] Based on proportional odds assumption, with an intercept term for each of the two non-redundant logit models. Inclusion of dependent variables in model was based on Type III sum of squares ($P < 0.05$). Regressors were coded as responses to socio-demographic questions about Gender (0=Female, 1=Male), prior insect consumption (Prior; 0=No, 1=Yes), and willingness to try new foods (Openness; 0=No, 1=Yes).

[*] $\text{Logit}(P(Y \leq j)) = \log[P(Y \leq j)/P(Y>j)]$, with j=3 ordinal response categories (1=Yes, 2=Maybe not, 3=No).

[a] General willingness to try food beverage or snack containing insect protein powder.

[b] Intercept estimates correspond to j-1=2 non-redundant cumulative logit models, *P*-value based on H_o: estimate=0. n/a = not applicable.

Variations between the current sample and the general U.S. population should be acknowledged. On the surface, a disproportionately female sample may suggest underestimation of overall GWTT and WTT, as American men have shown more openness to eating insects (Ruby *et al.*, 2015). However, since an unknown portion of responses came from LSU's population (where entomophagy research has been conducted) and an existing consumer database (perhaps more inclined to try new foods), observed odds of positive intent may be inflated compared to the general population, especially given relatively high rates of prior consumption and openness to new foods (see Table 3.2). Although educational status was not asked, we suspected bias toward higher levels, attributed to electronic survey distribution (Verbeke, 2015) and on-campus recruitment. These deviations should be considered when interpreting raw WTT proportions.

3.3.2. Product Appropriateness and Willingness to Try

The current investigation sought to assign appropriateness of a product concept from the consumer's point of view, or 'voice of the consumer' (Van Trijp & Steenkamp, 2005). This qualitative approach should help food scientists make insect-containing foods that are more approachable to potential new markets, by looking directly to consumers for guidance. A critical step to collecting valid sensory data is recruiting the 'right' panelists (Stone *et al.*, 2012). This may become increasingly difficult with products containing insect protein due to commonly held aversions (Baker *et al*., 2016). We hope that by first incorporating insect protein into the 'right'- or 'appropriate'- products, psychological hurdles can be overcome, research participation can be encouraged, and better products can be developed.

Based on the highest positive WTT rate, from 65.4% of consumers, a *protein bar or energy bar* was deemed most appropriate for incorporation of insect protein powder (Table 3.1).

The next most appropriate product was *chips or snack crackers* (61.3% positive WTT). At the time of this research, both product-types were found to be available on the U.S. market. Also exceeding the 59.7% of 'Yes' responses from GWTT, was a *protein shake* containing insect powder, prompting reported willingness to try from 60% of consumers surveyed (Table 3.1). A functional protein powder (containing crickets) marketed for this purpose is also commercially available. Considering only potential early adopters of entomophagy (removing the 166 'No' respondents from the GWTT question), it is observed that 78.3%, 73.4%, and 71.9%, respectively, would try *protein bar or energy bar, chips or snack crackers*, and *protein shake.*

On average, *bakery or cereal based* products yielded the highest positive WTT (54.8%), followed closely by *snacks and candy* (53%) (Table 3.3). Examples of these products, such as cricket-containing pasta and cookies are also currently available from at least a few specialty retailers in the U.S. In our study, these two product concepts ranked seventh (55.8% WTT for *pasta*) and tenth (53.8% WTT for *cookies*) in terms of relative appropriateness (Table 3.1).

Table 3.3. Relative Product Appropriateness[a] by Category (N=1,005 adult U.S. consumers)

Category	Highest[*]	Lowest[*]	Average[*]
Bakery/Cereal	59.50 (Bread)	46.57 (Doughnut or Pastry)	54.77
Candy/Snack	65.37 (Protein or Energy Bar)	41.29 (Hard candy, Sucker, or Lollipop)	53.02
Beverage	60.00% (Protein shake)	34.33 (Fruit juice)	44.44
Meat/Poultry/Seafood	49.65 (Hamburger)	39.40 (Fish sticks)	44.49
Dairy	39.50 (Pudding or Custard)	34.13 (Cheese)	37.29

(Based N=1,005 responses)
[a] Product appropriateness based on the rate of 'Yes' responses from willingness to try questions.
[*] Percent frequency of 'Yes' responses to willingness to try (WTT) questions.

In the case of baked goods, Delicato *et al.* (2020) partially replaced butter with fat from soldier fly larvae, at up to 25%, without significantly changing liking for Belgian consumers. In Italy, Menozzi *et al.* (2017) garnered trial intent, from 48% of subjects, for cookies made with cricket flour. However, slightly less than half of those consumers attended the actual tastingemphasizing the discrepancy between measures of consumer intention and behaviour. Whether observed parallels between our survey results and existing products on the U.S. market reflect actual demand, past experience, or mere coincidence are unclear. Perhaps, some consumers had been previously exposed to one of the commercial products. Extrapolating from the cumulative logit model for GWWT (Table 3.2), previous consumption of such foods would be expected to increase odds of positive WTT over fourfold (OR=4.51).

Much of the previous sensory and willingness-to-consume research has focused on insects as meat substitutes (used in the same culinary capacity as meat) (Caparros Megido *et al*., 2016; Gere *et al*., 2007; Schouteten *et al*., 2016; Tan *et al*., 2016, 2017b; Verbeke, 2015). This approach may seem intuitive because of the high animal protein content (Kouřimská & Adámková, 2016), genetic similarity to crustaceans (Pennisi, 2015), and the impetus to promote entomophagy as the potential successor to unsustainable livestock consumption (Van Huis *et al*., 2013). However, European consumers seem reluctant (Verbeke, 2015), or even unwilling (Vanhonacker *et al.*, 2013), to replace their meat with insects, thus these products may not be the ideal vehicle for the first-time insect consumers.

In the present analysis, all *meat, poultry, or seafood* products generated negative WTT ('Maybe not' or 'No') by over 50% of consumers (Table 3.3). The highest positive WTT in this category was observed for *hamburger* (49.7%), and the lowest was for *fish sticks* (39.4%) (Table 3.1). Here, we see a divergence between relative product appropriateness between U.S. and Belgian consumer perspectives (Van Thielen *et al*., 2019). Although both energy bars and energy shakes were at the top of both lists, burgers outranked snacks as potential carriers for processed mealworm in the Belgian survey. In the present investigation *burgers* ranked 13th in relative appropriateness (out of 30 products) with less than 50% positive WTT, behind snacks like *chips or snack cracker*, *candy bar*, and *trail mix*.

By the current metric, *meat, poultry, or seafood* products would be considered less appropriate for insect protein powder addition than *bakery or cereal based* products and *snacks and candy*, considered similarly appropriate to the *beverage* category (average WTT of 44.49% for *meat, poultry, or seafood* vs. 44.44% for *beverages*), and considered more appropriate than *dairy* products (average WTT of 37.3%) (Table 3.3).

The *dairy* products evaluated seemed least appropriate for insect incorporation, with positive WTT ranging from 34.1% (*cheese*) to 39.5% (*pudding or custard*) (Table 3.3). A slightly higher proportion of consumers (40.8%) did express willingness to try a *milkshake* with insect protein (which is also a dairy product, but was arbitrarily assigned to the *beverage* category).

Comparing meatballs (deemed ‘appropriate’) with a dairy drink (deemed ‘unappropriated’) - both containing mealworms, Tan *et al*. (2017b) found a positive correlation between product appropriateness and expected sensory liking. However, the correlation between liking and appropriateness diminished after tasting. This and other work have emphasised the importance of achieving acceptance beyond WTT (Tan *et al*., 2016), suggesting that product preparation and sensory quality are key to repeat consumption after trial (Caparros Megido *et al*., 2014; House, 2016; Mishyna *et al*., 2019). In this regard, it is important to note that since no actual products were tested this study, consumers’ WTT was based on some idealised version of each item. Follow-up investigations of appropriateness should involve product-concept validation through sensory testing of actual foods prepared with insect protein powder.

By no means is the current list of thirty products a comprehensive survey of all potential preparations, but within the limitations of this study, we did hope to depict common foods within the American diet. Product-category data could prompt additional concepts. In the U.S., other insect-dishes have been formulated in niche restaurants and by at-home entomophagy enthusiasts. If there is a larger market to be realised in the U.S., developers should begin with more approachable or 'appropriate' products. The present results point to protein bars and protein shakes, baked goods, and snacks like chips or crackers as a starting point.

3.3.3. Perceived Risks

Items on the list of perceived risks- considered potential reasons for entomophagy avoidance- fall into at least one of the four risk perception dimensions employed by Baker *et al*. (2016): functional risks (A*ppearance, Odour/aroma*, *Taste*, *Texture/mouthfeel*, *Price*), physical risks (S*afety, Nutrition*), social risks (S*ocial acceptability*), psychological risks (C*ultural or religious beliefs, Negative emotions (boredom, disgust, fear, guilt, worry, etc.), I do not eat this product*, *Unfamiliarity with insects as a food source*) (Table 3.4).

At each instance of a 'Maybe not' or 'No' responses to GWTT (S1 and S2), a CATA scale was used for reporting. For WTT individual products, the top concerns (up to three) were identified (Table 3.4). To focus only on perceived risks associated with insect incorporation, observations were deleted when *I do not eat this product* was selected. For clarity and relevance of discussion, data for risks selected with less than10% frequency for GWTT (i.e., C*ultural or religious beliefs*, *Nutrition, Price*) are not shown.

Food neophobia, characterised by the reluctance to ingest novel substances (Domjan, 2018) has been previously identified as a significant hurdle to adoption of entomophagy (Hartmann & Sirgrist, 2016; Mancini *et al.*, 2019b; Verbeke, 2015). Of the 405 consumers who responded negatively (‘Maybe not’ or ‘No’) to GWTT, approximately 75% cited *Unfamiliarity with insects as a food source* (Table 3.4). It was also the most frequently referenced concern for 21 of the 30 products. However, to clearly attribute responses to neophobia, novelty must be isolated as the rejection criterion (Domjan, 2018).

Table 3.4. Perceived risks associated with products containing insect protein powder[^]

Product	Appearance	Emotions[a]	Odour[b]	Safety	Taste	Texture[c]	Unfamiliarity[d]
GWTT[b]	25.68	54.57	36.05	32.10	47.16	48.40	74.57
Bread	9.68	46.24	8.60	21.51	38.71	38.71	70.97
Butter or Spread	19.26	36.30	17.04	14.81	45.93	47.41	54.81
Cake	7.69	35.16	18.68	14.29	51.65	39.56	63.74
Candy bar	10.75	37.63	20.43	13.98	47.31	43.01	61.29
Cheese	15.72	35.22	16.98	13.84	51.57	51.57	45.28
Chicken nuggets	7.37	36.84	14.74	24.21	50.53	37.89	53.68
Chips or Snack crackers	15.12	44.19	18.60	23.26	41.86	31.40	65.12
Cookies	13.33	34.44	18.89	18.89	48.89	38.89	60.00
Crab cake	7.69	35.04	19.66	25.64	47.86	40.17	48.72
Doughnut or Pastry	12.63	37.89	13.68	18.95	51.58	40.00	63.16
Fish sticks	8.86	40.51	21.52	21.52	50.63	37.97	51.90
Fruit juice or Fruit drink	17.65	31.62	23.53	11.76	60.29	42.65	47.79
Gummi candy	11.39	31.65	15.19	13.92	59.49	41.77	59.49
Hamburger	8.33	34.38	14.58	25.00	47.92	38.54	58.33
Hard candy, Sucker, or Lollipop	20.45	35.23	18.18	17.05	59.09	40.91	55.68
Hot dog	8.51	39.36	15.96	21.28	48.94	39.36	56.38
Ice cream	13.85	40.00	22.31	16.15	59.23	48.46	53.08
Milkshake	15.24	33.33	20.95	18.10	59.05	41.90	57.14
Muffin	11.54	46.15	14.10	17.95	51.28	43.59	65.38
Omelette or Quiche	14.43	38.14	16.49	19.59	50.52	44.33	53.61

(table cont’d.)

(table cont'd.)

Pasta	16.28	41.86	16.28	20.93	46.51	39.53	63.95
Protein bar or Energy bar	8.62	44.83	13.79	20.69	46.55	43.10	72.41
Protein shake	11.86	42.37	15.25	23.73	52.54	42.37	62.71
Pudding or Custard	12.12	38.38	13.13	10.10	55.56	53.54	52.53
Smoothie	11.69	42.86	15.58	19.48	62.34	44.16	59.74
Sports drink	14.81	37.04	13.58	18.52	54.32	40.74	56.79
Tortilla	11.54	43.59	16.67	20.51	47.44	38.46	64.10
Trail mix	18.57	34.29	17.14	17.14	57.14	41.43	64.29
Vegetable juice	9.09	30.68	15.91	12.50	64.77	44.32	50.00
Yogurt	13.76	34.86	16.51	16.51	55.96	50.46	45.87

[abcd] Risks were presented in the questionnaires as: [a] Negative emotions (boredom, disgust, fear, guilt, worry, etc.), [b] Odour/aroma, [c] Texture/mouthfeel, [d] Unfamiliarity with insects as a food source.
^ Values expressed as percent selection rates- based on top (up to three) concern for each product (N=403 from the S1 survey), or check-all-that-apply for General Willingness to Try GWTT (N=1,005), following 'Maybe not' or 'No' responses to willingness to try questions.

Experimentally, food neophobia can be evaluated by comparing responses to a food at first exposure to subsequent instances after familiarisation (Domjan, 2018). It is expected that for neophobic individuals, repeated exposure (thus increased familiarity) to insect foods would increase positive responses, until limited by some other factor (liking or preference, availability, price, etc). Other research has used the Food Neophobia Scale developed by Pliner & Hobden (1992) to relate neophobia, as independent variable, to suppression of insect consumption (Hartmann & Siegrist, 2016; Piha *et al*., 2018; Sogari *et al.*, 2019b; Tan *et al*., 2016; Verbeke , 2015), and more recently alongside the Entomophagy Attitude Questionnaire (La Barbera *et al.*, 2020). In the present study, consumers' food neophobia was not formally measured. However, 41 of 405 consumers specified unfamiliarity as the sole factor limiting GWTT.

Seventy-three of the 1,005 consumers surveyed (7.3%) identified as “not typically willing to try new foods,” of whom, 51 expressed negative GWTT. Only 38 of these 51 respondents reported unfamiliarity as a concern related to GWTT. In fact, three of these consumers had previously eaten insects. This segment of 35 consumers whose responses most suggested neophobia (not typically willing to try new foods, concerned about unfamiliarity, and have never consumed insects) only represented 8.64% of reluctant individuals and 3.48% of the total sample.

When comparing responses to a novel food (such as one containing insects) to a familiar one (such as the insect-free version), it is important to counterbalance other variables affecting consumption behaviour (Domjan, 2018). On average, consumers reported 3 or 4 (mean value of 3.56) reasons for negative GWTT using the CATA scale. The prevalence of other perceived risks alongside unfamiliarity prevented us from directly isolating neophobia as the main contributor to entomophagy aversion in the present study, despite the highest selection rate of *Unfamiliarity with insects as a food source*.

Here, unfamiliarity may be related to uncertainty of whether the proposed insect-containing products will meet consumers’ sensory expectations. For GWTT, 65.6% of unfamiliarity responses were accompanied by concern about at least one sensory attribute. The most reported sensory concerns related to GWTT were *texture/mouthfeel* (48.40%) and *taste* (47.16%), followed by *odour/aroma* (36.05%) and *appearance* (28.68%) (Table 3.4).

Of the 166 of people from S1 who had previously consumed insects, 16 (9%) claimed they would not try insects again. This suggests that after overcoming any initial barriers, there was some deficit in the experience that led to future avoidance. Distaste for a food due to negatively perceived sensory properties (not limited to the sense of taste) is a common motivator for rejection, and has been suggested to account for most individual differences of within-culture food preference (Rozin & Fallon, 1987). For consumers who had not previously eaten insects, concerns over sensory quality would be based on sensory expectations rather than experience.

Regarding individual products, *taste* was the most common concern for 10 products (one tie with unfamiliarly), and second most common (behind unfamiliarly) for 17 others (Table 3.4). Sogari *et al.* (2018) demonstrated that initial negative taste expectations of jellies made with cricket could be overcome after trying the products. However, when sensory quality is poor, the opposite effect has been observed (Tan *et al*., 2016). Beyond trial, repeat consumption may also rely on taste (House, 2016) and effective hedonic marketing appeals (Berger *et al.*, 2018). Mishyna *et al*. (2019) suggested that taste education is necessary to alleviate unfamiliarity with this novel food source.

Texture/mouthfeel was the highest cited risk for cheese, the third most common risk for 19 other products, and on average, third across all products (Table 3.4). Undesirable hardness of the exoskeleton and 'getting particles trapped in teeth' have been reported with intact crickets (Sogari *et al*., 2018), and unacquainted consumers may have imagined similar effects from protein powder. 'Too granular' texture from cricket flour in jelly has been perceived negatively (Sogari *et al*., 2018).

Over half (54.57%) of participants with negative GWTT indicated *negative emotions (boredom, disgust, fear, guilt, worry, etc.)* as a deterrent. When asked to choose their top three concerns, at least 30% of unwilling consumers pointed to negative emotions for each of the 30 products (Table 3.4). Although not specified here, the most common inhibitory reaction toward edible insects in the U.S. seems to be disgust (Ruby *et al*., 2015), which is a powerful motivator for food avoidance (Rozin & Fallon, 1987). Aside from disgust, Gmuer *et al.* (2016) also found dissatisfaction to have a negative impact on Swiss consumers' willingness to eat tortilla chips containing cricket flour. Future research should expand upon consumer emotional profiles, and their impact on liking and behaviour (Carabante *et al*., 2018; Pujols *et al.*, 2019), toward insect foods in the U.S.

In the present case, negative emotions were of concern in the absence of any actual food stimuli- that is, based just on the idea. Rozin & Fallon (1987) described this type of food rejection as 'ideational,' and gave the example of 'rejecting a grasshopper just because it is a grasshopper.' Ideational motivations and disgust are largely learned through social and cultural constructs (Rozin & Fallon, 1987). Although *cultural or religious beliefs* and *social acceptability* were only cited 6.91% and 17.53% of the time, respectively, for negative GWTT and less frequently attributed to specific product aversions (data not shown), their implicit associations with negative emotions may be unavoidable (Mancini *et al*., 2019b).

Another reason for food rejection (and also a source of disgust) is fear of danger or harm to the body (Rozin & Fallon, 1987). This would be considered a physical risk (Baker *et al*., 2016) related to the safety of ingesting insects. In the U.S. where insects are considered pests and often associated with unclean conditions or decaying matter (Looy *et al*., 2014), it is not surprising that some consumers would hold this apprehension. When handled and processed appropriately, the only inherent safety risk for processed edible insects would be potential allergic reactions, such as those associated with crustacean allergy (Belluco *et al*., 2015).

Safety was the sixth most cited concern in CATA format (32.10%), and ranked behind unfamiliarity, negative emotions, and certain sensory attributes for all 30 products evaluated. This suggested that more often than not, U.S consumers did not consider insect protein to be unsafe to eat, and affective aspects like emotional reaction and sensory quality were of greater concern (Table 3.4). Existing misconceptions about edible insect safety may be corrected through education.

General consistency between inhibitors of GWTT foods containing insect and WTT specific products suggested that behind unfamiliarity, negative emotions and sensory appeal were the most salient psychological barriers among U.S. consumers (Table 3.4). Negative emotions seemed to be a more general concern, whereas *taste* and *texture/mouthfeel* expectations were more important to product specific aversions. Addressing these risks may expand trial of insect products as they become available, and overcoming the most commonly cited hurdle of *unfamiliarity with insects as a food source* can only be achieved through exposure. The effects of a brief message (EBI) addressing some of the potential risks from this study are addressed in the following section.

3.3.4. Effect of Entomophagy Benefit Information (EBI)

To evaluate the effect of EBI on WTT, Stuart-Maxwell tests for marginal homogeneity (Sun & Yang, 2008) were run for all 30 products using the n=602 observations from S2. Significant ($p<0.05$) shifts in response distributions were found for each product, comparing before and after EBI (Table 3.5). Specifically, it was hypothesised that EBI would have a positive effect on WTT, yielding a higher rate of 'Yes' answers after its delivery. To evaluate, 'Maybe not' and 'No' responses were collapsed, creating a 2x2 table for each product (with 'before EBI' responses as rows and 'after EBI' responses as columns), and McNemar tests were performed (Table 3.5). Significant differences were found across the board (increases in 'Yes' for all products after EBI), leading to the conclusion that EBI significantly increased WTT, overall and for each product.

Providing consumers with product benefit information after consumption has been shown to positively impact hedonic scores, consumer emotional profiles, and purchase intent for foods such as grass-fed beef steaks (Carabante *et al*., 2018), and low-sodium roasted peanuts (Pujols *et al*., 2019). In these studies, the implied benefit was related to the healthfulness of a specific food ingredient or component. In the present study, the nutritional appeal in the EBI referred to insects as a “source of high-quality protein and other nutrients.”

The EBI also emphasised that edible insects are “sustainable” and have “less negative environmental impact than traditional livestock,” which may motivate consumers for various reasons (Berger *et al*., 2018). Additionally, the EBI was meant to address potential concerns of safety and social prevalence (Baker *et al*., 2016): “Edible insects are safe to eat,” and “An estimated 2 billion people worldwide consume edible insects” (Van Huis *et al*., 2013).

Different information types can differentially affect attitudes- which guide behaviours- toward insect consumption across markets (Piha *et al*., 2018). Attitudes can be cognitive (beliefs and rationale) or affective (hedonic and emotional) in nature (Berger *et al*., 2018). While rational appeals influenced U.S. consumers in this study, this has not consistently been the case in other Western countries. In a study with Canadian students, an informational session did not so clearly ameliorate negative attitudes toward eating insects (Looy & Wood, 2006). However, Lombardi *et al*. (2019) found that providing information about nutrition, environmental impact, social benefit, and safety did increase willingness to pay for insect products in Italy. In Germany, Berger *et al*. (2018) found hedonic marketing to be more important than utilitarian claims in increasing willingness to consume insects.

These types of claims have been called ‘go-betweens' between intrinsic and extrinsic food properties (Roosen *et al.*, 2007). Although the information is external to the product and its composition (extrinsic), it has been shown to influence hedonic scores (intrinsic), such as for buns made with cricket-flour (Pambo *et al*., 2018). In contrast, effects of EBI in the present study can only be attributed to perceived extrinsic value, as no products were consumed. To our knowledge, the effects of these informational cues have not been previously evaluated with such a large sample of U.S. consumers across such a range of products.

Based on perceived risk data from this research, it is expected that consumers used the new information contained in the EBI to mediate judgment of negative consequences of unfamiliar products (Baker *et al*., 2016). Our analyses demonstrated a significant impact of EBI on U.S. consumers' WTT the proposed products (Table 3.5), but the observed attitudinal shifts should not be mistaken for behavioural outcomes (House, 2016).

A present limitation to data interpretability was that the response for self-reported WTT foods does not necessarily predicate the action. Menozzi *et al.* (2017) found a relatively weak (yet statistically significant) correlation between intention to eat insect cookies and the actual tasting behaviour. While intention is a valid predictor of trial (Sogari *et al.*, 2019b), it is suggested that observed WTT rates would overestimate actual occurrences. Future studies should evaluate correspondence between WTT and trial behaviour in the U.S.

Assimilation of insects into Western diets calls for a multifaceted approach. Interrelationships between consumers' past experiences, new information, and subsequent expectations must be considered (Mancini *et al.*, 2019b); and factors influencing repeat consumption may differ from those guiding introductory behaviours (House, 2016). As the presently proposed products were hypothetical, logical next steps are to formulate samples of appropriate products (e.g., protein bars or snack crackers) and conduct sensory taste testing. Insect protein powder is likely to affect multiple dimensions of functionality and sensory quality.

Table 3.5. Effect of Entomophagy Benefit Information (EBI) on Willingness-to-Try Products Containing Insect Protein Powder

Product	'Yes' Before EBI*	'Yes' After EBI*	Stuart Maxwell p-value[1]	McNemar p-value[2]
Bread	370	408	< 0.0001	< 0.0001
Butter	197	246	< 0.0001	< 0.0001
Cake	318	345	0.0004	0.0004
Candy bar	324	346	0.0048	0.0105
Cheese	177	222	< 0.0001	< 0.0001
Chicken nuggets	260	302	< 0.0001	< 0.0001
Chips or Snack Crackers	383	413	< 0.0001	< 0.0001
Cookies	318	359	< 0.0001	< 0.0001
Crab cake	224	252	< 0.0001	< 0.0001
Doughnut or Pastry	258	307	< 0.0001	< 0.0001
Fish sticks	227	264	< 0.0001	< 0.0001
Fruit juice	190	238	< 0.0001	< 0.0001
Gummi candy	259	288	< 0.0001	0.0004
Hamburger	288	320	< 0.0001	< 0.0001
Hard candy, Sucker, or Lollipop	231	281	< 0.0001	< 0.0001
Hot dog	258	301	0.0498	< 0.0001
Ice cream	198	234	< 0.0001	< 0.0001
Milkshake	213	248	< 0.0001	< 0.0001
Muffin	333	365	< 0.0001	< 0.0001
Omelette or Quiche	270	300	< 0.0001	< 0.0001
Pasta	328	373	< 0.0001	< 0.0001
Protein bar or Energy bar	415	437	0.0002	0.0015
Protein shake	381	402	< 0.0001	0.0046
Pudding or Custard	212	252	< 0.0001	< 0.0001
Smoothie	320	342	< 0.0022	0.0045
Sports drink	224	258	< 0.0001	< 0.0001
Tortilla	335	368	< 0.0001	< 0.0001
Trail mix	287	330	< 0.0001	< 0.0001
Vegetable juice	202	230	< 0.0001	< 0.0001
Yogurt	193	236	< 0.0001	< 0.0001

(Based on N=602 responses from S2)

* Willingness to try ('Yes'/'Maybe not'/'No') was asked for all products 'Before' and 'After' consumers read a brief message about the benefits of entomophagy (EBI).

[1] Stuart Maxwell test for marginal homogeneity was performed comparing 3x3 tables 'Before' and 'After' EBI.

[2] McNemar's test for marginal homogeneity was conducted, after significant ($\alpha<0.05$) results from Stuart Maxwell test, comparing 2x2 tables 'Before' and 'After' EBI (collapsing 'Maybe not' and 'No' responses).

Based on current findings, addressing taste and texture may be particularly important. Therefore, future evaluations should include both classical affective methodology (e.g., preference and acceptance tests), as well qualitative investigations into consumer wants (e.g., focus groups and conjoint analysis) regarding insect-containing foods. These should serve both to increase familiarity and improve product acceptability. While this current research focused on U.S. consumers, product development strategies should be tailored to satisfy regional preferences.

3.4. Conclusion

Product appropriateness influenced trial intentions, as the three products deemed most appropriate for insect protein powder incorporation (*protein bars, chips or snack crackers*, and *protein shakes*) received more positive WTT responses than the general idea of 'food beverage or snacks' alone. Additional research is needed to test whether this approach will stimulate insect consumption behaviour. Significant increases in WTT, for all 30 products, after delivery of EBI gave evidence for- at least a somewhat substantial- cognitive basis of entomophagy aversion in the U.S. However, addressing hedonic and emotional appeal may show further promise, as these factors were among the most prominent risks associated with insect products and would be expected to promote repeat consumption. Since 92.7% of consumers in this study expressed typical willingness to try new foods, the sample was not necessarily comprised of markedly food neophobic individuals. The most cited concern about unfamiliarity may rather point to uncertainty about product functionality. Efforts to make insect-containing products sensorially appealing in the U.S., especially in terms of taste and texture, should begin with baked or cereal products and snacks, as opposed to the meat-substitution often employed in research.

CHAPTER 4. EXPLORING NEW AND MODIFIED REJECTION-TYPE THRESHOLDS USING CRICKET SNACK CRACKERS

4.1. Introduction

Sensory thresholds represent the limits of auditory, visual, tactile, olfactory and/or gustatory capacities. Conceptually, a threshold is a value on a stimulus continuum (a boundary of sorts) where a perceptual change occurs (Meilgaard *et al.*, 2006). This point is not fixed for all people at all times, so empirical threshold estimates are based on some mathematical models or probability distribution (Lawless & Heymann, 2010). Conventional threshold measurements have modelled physiological responses to stimuli, but more recently, threshold methods have been devised for affective responses to food and beverages. We will refer to the later concepts, collectively, as rejection-type thresholds, as they originally involved tracking the deterioration of perceived product quality by increasing or decreasing the intensity of a specific stimulus (Lima Filho *et al.*, 2015; Prescott *et al.*, 2005). While classical thresholds (absolute/detection, recognition, difference, and terminal thresholds) rely on perceived differences in attribute intensity (Lawless & Heymann, 2010; Meilgaard *et al.*, 2006), these differences may or may not trigger a change in affect for a given individual. It is implied, however, that for any perceptual effect of a stimulus to be observed, its concentration must surpass the detection threshold (Prescott *et al.*, 2005), and for subsequent changes in affect to occur, the just-noticeable-difference must be reached or exceeded (Lawless & Heymann, 2010).

Since Prescott *et al.* (2005) introduced the first threshold of its kind, the consumer rejection threshold (CRT), using a paired-preference test, other authors have expanded the

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methodology to include measures of compromised acceptance (compromised acceptance threshold (CAT)) and sensory rejection of a food product (hedonic rejection threshold (HRT)) based on scores from the 9-point hedonic scale (Lima Filho *et al.*, 2015; 2018). Most recently, Lima Filho *et al*. (2020) demonstrated a similar approach based on *increased* liking (favored acceptance threshold, (FAT)) as well as analysis to effectively account for effects of two stimuli within a food matrix (hedonic thresholds methodology varying two stimuli (HTM_{2s})). Modifications to the CRT and HRT are presently proposed.

These affective sensory threshold methods have exhibited a wide range of valuable uses to the food industry, including but not limited to: informing limits on natural preservative use (de Carvalho *et al.*, 2019), determining practical sodium reduction levels (Lima Filho *et al.*, 2019), and mitigating negative effects of radiation on produce quality (Lima Filho *et al.*, 2014). CRT measures have also been applied to compounds which may be desirable to some consumers at moderate levels, but eventually reach a breakpoint at higher concentrations (Gaby *et al.*, 2020; Saliba *et al*., 2009), and even to stimuli for which specific lack of sensitivity is sometimes observed (Gaby *et al.*, 2020). In these cases, our proposed modification which accounts for "no preference" judgments may help to characterize such market segments. Most importantly, since comparative assessments of preference do not always distinguish acceptable products from unacceptable ones, rejection-type threshold methodologies should include more explicit measures of rejection as the perceptual construct of interest (Lima Filho *et al*., 2015).

Taking guidance from our previous study on appropriate product concepts for insect protein powder (Ardoin & Prinyawiwatkul, 2020), the present vehicle for data collection was snack crackers formulated with increasing levels of cricket powder in place of whole-wheat flour, at up to 20% replacement. The resulting implications to insect-containing foods as a potential sustainable alternative protein source (van Huis *et al*., 2013) are outside the scope of this paper. However, setting practical addition limits on a novel ingredient in food products adds to the growing list of real-world threshold applications. Because the stimulus (cricket powder) effected changes in multiple sensory dimensions, separate thresholds were determined based on color, texture, flavor, and overall perceptions of snack crackers. Until recently (Lima Filho *et al*., 2019), rejection-type thresholds had only focussed on overall product quality.

The interpretation of each rejection-type threshold is contingent upon the affective dimension being measured, whether it be: preference (CRT, Prescott *et al*., 2005), relative degree of liking (CAT, Lima Filho *et al*., 2015; FAT, Lima Filho *et al*., 2020), or absolute degree of liking (HRT, Lima Filho *et al*., 2015). However, these projections of product rejection can be somewhat arbitrary, and as shown later, may not reliably align with more direct evaluations of acceptance. To more resolutely characterize rejection of a food product, we proposed use of a simple binary yes/no question. The resulting threshold estimates may offer more relevant guidance to food companies.

Additionally, we proposed two new rejection-type threshold concepts, the rejection tolerance threshold (RTT) and an associated rejection range (RR) using probit regression modelling. Along with demonstrating these new threshold methods using cricket powder in whole-wheat snack crackers, this research also presents modifications to two existing rejection-type thresholds methodologies: a modified consumer rejection threshold (M-CRT) using a 2-AC test (Lawless & Heymann, 2010) with "no preference" option; and a modified hedonic rejection threshold (M-HRT) employing a one-sample t-test for added statistical rigor. These contributions should augment the expanding set of affective threshold methodologies available for sensory-driven product development.

4.2. Materials and Methods

This research involving human subjects was approved by the Louisiana State University Agricultural Center Institutional Review Board (IRB# HE18-9 and IRB# HE 18-22).

4.2.1. Samples

The test-samples used for this research were baked whole-wheat snack crackers modeled after a popular commercial product. Crackers were formulated with varying levels of cricket powder (*Acheta domesticus, Gryllodes sigillatus;* Griopro®, Midwest City, OK, U.S.A.) as a substitute for whole-wheat flour (w/w). The base formulation (whole-wheat flour, water, soybean oil, sugar, corn starch, salt, baking powder), without cricket powder, was used as a control. For threshold determination, test samples were formulated by substituting whole-wheat flour with cricket powder at levels of 0% (control), 5%, 10%, 15%, and 20%. Crackers were oven-baked at 350° F (approximately 177° C) and cooled at room temperature. Samples (two crackers each) were portioned into lidded plastic cups, labeled with three-digit blinding codes, and stored at room temperature overnight before testing.

4.2.2. Consumer Test

Consumers (N=150) were recruited for participation from Louisiana State University campus (Baton Rouge, LA, U.S.A.). Sample presentation followed a balanced incomplete block design (B.I.B.; t=4, k=2, r=3, b=6, λ=1) (Cochran & Cox, 1992). To allow for each cricket-containing sample (t=4) to be directly compared to the control, each consumer was served two pairs of samples (k=2 pairs), each consisting of one control and one stimulus sample. This resulted in six possible serving combinations (b=6). Twenty-five replications of the design were carried out, such that 150 consumers participated (6x25=150 total panelists). Since each of the sample-pairs occurred three times (r=3) per replication, 75 observations per sample-pair were obtained (3x25=75 observations per sample-pair).

A balanced incomplete block (B.I.B) design was selected in favor of a randomized complete block design to minimize sensory fatigue and adaptation (Meilgaard *et al*., 2006). Despite requiring more panelists to obtain the same number of observations, every consumer was only asked to try four total cracker samples (two pairs), instead of eight samples (4 pairs), from a randomly assigned serving presentation. Both the order in which each pair was evaluated and the order within each sample-pairing (i.e., whether the control was evaluated first or second) was randomized in a counterbalanced fashion by the electronic questionnaire software (Qualtrics, Provo, UT, U.S.A.).

Testing was conducted in partitioned booths at the LSU Sensory Services Lab (Baton Rouge, LA, U.S.A.). Qualtrics online survey software (Qualtrics, Provo, UT, U.S.A.) was used for questionnaire presentation and response collection. Consumers were informed prior to testing that each sample may contain cricket. Although this knowledge could lead to expectation error (Meilgaard *et al*., 2006) and lower thresholds based on negative attitudes toward entomophagy (Ardoin & Prinyawiwatkul, 2020), it was deemed necessary to avoid any potential allergic reactions or unintended psychological distress. Samples were evaluated in terms of color, texture, flavor, and overall [liking/acceptability/preference], in that order. Consumers first rated each sample in the pair based on liking (a 9-point hedonic scale), followed by acceptability (a yes/no scale), for the above attributes. Once both samples in the pair were evaluated independently, consumers then reported preference (2-AC with “no preference” option; Lawless & Heymann, 2010) between the two samples for each attribute. Unsalted crackers and water were served for palate cleansing.

4.2.3. Modified Consumer Rejection Threshold

The existing method for CRT (Prescott *et al*., 2005) was modified from a forced-choice paired preference (2-AFC) to a 2-AC test with a "no preference" option (Ennis & Ennis, 2012a). The Thurstonian 2-AC modeling (IFPress) was used to estimate the critical value for the modified consumer rejection threshold (M-CRT) as the lowest level of cricket powder substitution that would result in significant (α=0.05) preference for the control. The hypotheses were as follows: Ho: Proportion(preferring control) ≤ Proportion(preferring stimulus sample) and Ha: Proportion(preferring control) > Proportion(preferring stimulus sample).

A straight line was modeled (where x = % cricket powder and y = proportion of subjects preferring the control) between the first stimulus-level to surpass the critical value and the preceding lower stimulus-level. Since the critical value changed based on the number of "no preference" responses (IFPress), another dashed line was constructed (where y=critical proportion of "prefer control" responses). The M-CRT was interpolated as the % cricket powder associated with the intersection of these two lines.

4.2.4. Hedonic Rejection Threshold and Modified Hedonic Rejection Threshold

The hedonic rejection threshold (HRT) was estimated following the established methods from Filho *et al*. (Lima Filho *et al*., 2015), except using a B.I.B. serving protocol.
With the same data used to determine the HRT, the modified hedonic rejection threshold (M-HRT) was calculated based on results from a one-sample t-test to estimate the point at which mean liking scores (μ) for color, texture, flavor, and overall liking were, respectively, less than 5 ("neither like nor dislike" on a 9-point hedonic scale). The hypotheses were as follows: Ho $\mu \geq 5$ and Ha: $\mu < 5$.

A simple linear regression (Fahrmeir *et al*., 2013) was used to model the calculated t-scores (y-axis, Equation 4.1) as a function of cricket powder level (x-axis, as a substitute for whole-wheat flour). The critical t-value of y=−1.67 (one tail, α=0.05, df=74) was superimposed to interpolate the M-HRT as the corresponding % cricket powder where mean liking would drop significantly below 5. This modification was expected to yield a more stringent criterion for assigning "rejection," and hence, a more liberal threshold estimate, by employing a test which accounts for dispersion of the liking data.

Equation 4.1. t-value (calculated) = $(\bar{x}-5)/(s/\sqrt{75})$

4.2.5. Rejection Tolerance Threshold

To more directly evaluate sensory rejection, a simple yes/no forced choice questions was asked (for color, texture, flavor, and overall acceptability), for example, "Is the flavor of sample 592 acceptable?" For this method, rejection of a given attribute was defined as a "no" response. To determine the rejection tolerance threshold (RTT), a probit regression model (Agresti, 2019) was fit using % cricket powder (x) as a predictor for the probability of rejection (y equaling a 0/1 "yes/no" response). As explained later, this approach to rejection-type threshold determination is based on a user-defined tolerance level (allowable proportion of rejection responses), and therefore dependent upon specific aims of the research, as opposed to a fixed critical value or hypothesis test. For the sake of this discussion, the RTT was demonstrated at a 25% rejection tolerance level. The RTT was thus estimated, from the model, as the % cricket powder expected to yield rejection from 25% of consumers.

4.2.6. Rejection Range

As the RTT is estimated from a generalized linear model, a confidence interval can be constructed around any point-estimate of the RTT (Agresti, 2019). The subsequent range of values bounded by this interval represents the rejection range (RR). To keep consistent with the α=0.05 significance level used to demonstrate other thresholds tests, here we used a 95% confidence interval to estimate the RR.

All of the above-mentioned thresholds were measured separately in terms of color, texture, flavor, and overall perception of snack crackers. Data were analyzed using Microsoft Excel (2013), SAS (2013), and R software (R Core Team, 2019).

4.3. Results and Discussion

To facilitate the following discussion, Table 1 presents the growing list of affective threshold concepts and their abbreviations, including contributions of the current study.

Table 4.1 Rejection-type threshold concepts.

Threshold Concept	Abbreviation	Reference
Consumer rejection threshold	CRT	Prescott *et al*. (2005)
Modified consumer rejection threshold	M-CRT	*Presently proposed*
Compromised acceptance threshold	CAT	Filjo *et al*. (2015)
Hedonic rejection threshold	HRT	Filjo *et al*. (2015; 2018)
Modified Hedonic rejection threshold	M-HRT	*Presently proposed*
Hedonic thresholds methodology	HTM	Filjo *et al*. (2017)
Hedonic thresholds methodology varying two stimuli	HTM_{2s}	Filjo *et al*. (2020)
Favored acceptance threshold	FAT	Filjo *et al*. (2020)
Rejection tolerance threshold	RTT	*Presently proposed*
Rejection tolerance range	RR	*Presently proposed*

4.3.1. Modified Consumer Rejection Thrshold

The CRT was the first affective threshold developed and originally used to find the level at which consumers would "reject" cork-tainted white wine (Prescott *et al*., 2005). The authors employed a forced-choice paired preference test (2-AFC) within a method of constant stimuli (Lawless & Heymann, 2010), comparing each tainted sample to a control. This particular concept has also been called simply "rejection threshold" (RjT; Methven *et al*., 2016). Despite its naming and intent, the CRT can only imply a comparative difference between two samples, without measures of magnitude or absolute acceptability, and therefore rejection should not be interpreted from this test alone.

The currently proposed modification which separated M-CRT from existing CRT methodology is the use of a "no preference" option, where, as opposed to a forced choice scenario (2-AFC) (Lawless & Heymann, 2016; Meilgaard *et al*., 2006), M-CRT methods allowed judges to express a perceived tie or lack of preference between cricket-free and cricket-containing crackers. The M-CRT test would thus be consistent with a 2-alternative choice (2-AC) protocol (Christensen *et al*., 2015). For the M-CRT and subsequent threshold determinations, it was assumed that cricket powder had a directionally negative effect on affective perceptions of snack crackers, as did cork-taint in wine (Prescott *et al*., 2005). For

We know from existing literature that when given the option, consumers do report ties, although their readiness to do so depends on (among other factors) the product category (Chapman & Lawless, 2015; Ennis & Collins, 1980; Kim *et al*., 2008). Properly accounting for ties (Ennis & Ennis, 2012b) when they do exist may provide added resolution, help substantiate product superiority claims, and distinguish populations expressing lack of preference from those consisting of segments of consumers, each with a decided preference (Christensen *et al*., 2015;

Ennis & Ennis, 2012a). For attributes which exhibit optimum levels, even among niche consumer segments (Gaby *et al*., 2020; Saliba *et al*., 2009), methods such as Landscape Segmentation Analysis® may provide added value (Ennis *et al*., 2017). Within the present range of cricket powder addition, the M-CRT methodology aimed to more clearly identify the shift from no overall preference or equal preference, to significant preference for the control crackers among consumers.

Instead of relying on a fixed critical value to assign the threshold as with the CRT, M-CRT used Thurstonian 2-AC modelling (IFPress; Thurstone, 1927), which incorporates both a decision-making rule (cognitive parameter) and the degree of difference between samples (difference parameter) (Braun *et al*., 2004; Christensen *et al*., 2015). Treatment of "no preference" votes has included splitting them equally, splitting them proportionally, or dropping them all together (Ennis & Ennis, 2012b). Our analysis, on the other hand, incorporated them into the statistical modeling used to determine the M-CRT. As such, critical values for M-CRT hypothesis testing depended upon the proportion of ties (IFPress), which ranged from 2.7% ties for overall preference (control vs. 20% cricket powder) to 25.3% ties for texture (control vs. 5% cricket powder). The M-CRT was interpolated for each respective attribute at the intersection of two straight lines, one connecting the observed percentage of consumers who preferred the control cracker, and the other connecting critical values for each level of comparison.

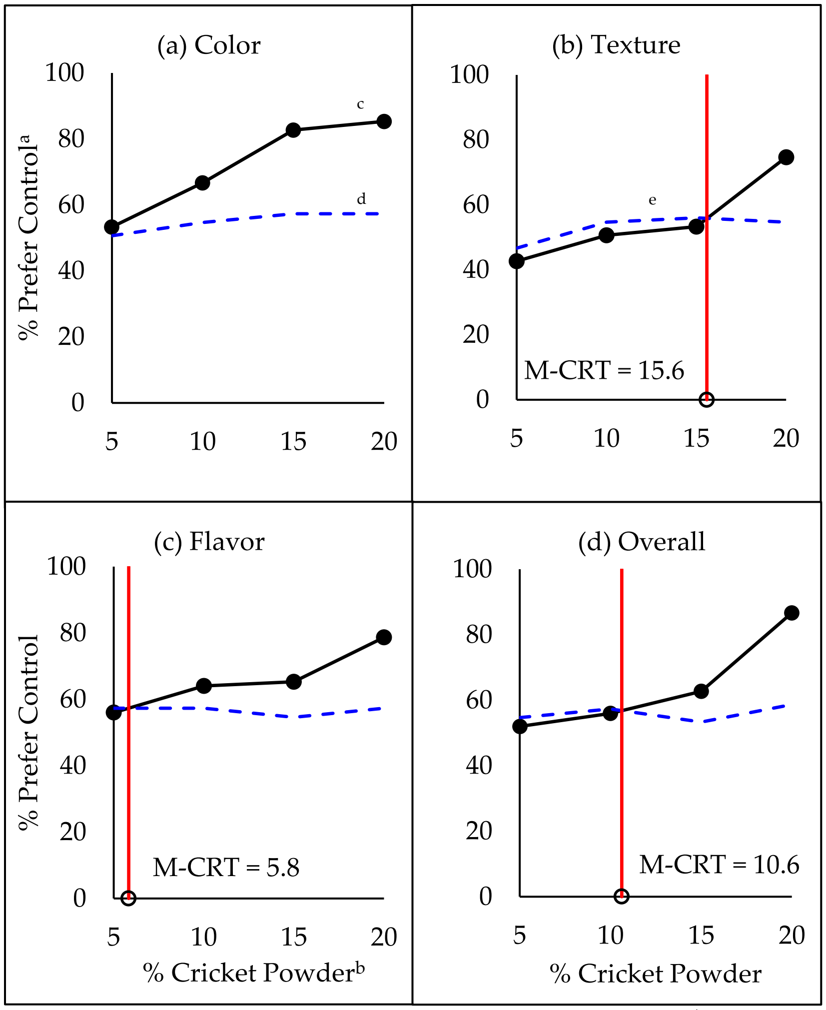

Figure 4.1. Modified Consumer Rejection Thresholds^ (M-CRT) for Cricket Powder in Whole-Wheat Snack Crackers

^Thresholds were measured based on 2-AC paired preference tests of (a) color, (b) texture, (c) flavor, and (d) overall preference.

[a] Percentage of consumers who reported preference for the control [0% cricket powder] sample.

[b] Percentage of cricket powder used in place of whole-wheat flour (w/w) in cracker formulations.

[c] Solid black lines connect points representing % of consumers preferring the control at each level of % cricket powder.

[d] Blue dashed lines connect points representing Thurstonian 2-AC critical values (α=0.05) at each level of comparison.

[e]Vertical red lines represent the M-CRT (% cricket powder), estimated at the intersection of lines c and d (not found for color).

A precise estimate for the color threshold could not be determined, as it fell short of our lowest cricket powder substitution-level of 5% (Figure 4.1(a)). Preliminary testing to verify that the minimum stimulus level performed similarly to the control in all aspects would have avoided this issue (Braun *et al*., 2004). The M-CRT methodology did produce threshold estimates for flavor at 5.8% cricket powder (Figure 4.1(c)), followed by overall preference at 10.6% cricket powder (Figure 4.1(d)), and lastly for texture at 15.6% cricket powder (Figure 4.1(b)). An appropriate interpretation of this result would be, for example, that whole-wheat flour could be substituted at up to 10.6% with cricket powder before overall preference would be significantly affected, but the flavor imparted by cricket powder would be less preferred than that of whole-wheat beyond 5.8% substitution.

Not surprisingly, the affective dimension of preference proved to be the most sensitive, among those addressed, to the effects of cricket powder on snack cracker quality. However, these discontinuities in preference should not be confounded with conclusions of acceptance or rejection. Proceeding hedonic data will show that cricket-containing crackers were still liked at levels well exceeding their M-CRT estimates.

4.3.2. Hedonic Rejection Threshold and Modified Hedonic Rejection Threshold

The gap in interpretation between comparative ratings of inferior preference and independent measures of acceptance or rejection was noted by Filjo *et al*. when they proposed two additional affective thresholds, the CAT and HRT (originally called RT) (Lima Filho *et al*., 2015). Both were based on scores from the 9-point hedonic scale, and together, along with the more recently defined FAT and HTM_{2s} (Lima Filho *et al*., 2020), were appropriately termed hedonic thresholds methodology (HTM; Lima Filho *et al*., 2017). To this list, we add a modified approach to the HRT, calling it simply a modified hedonic rejection threshold (M-HRT). As opposed to our M-CRT, which suggests an alternative approach to the existing methodology, the HRT and M-HRT offer slightly different interpretations, and can thus be obtained jointly from the same data set.

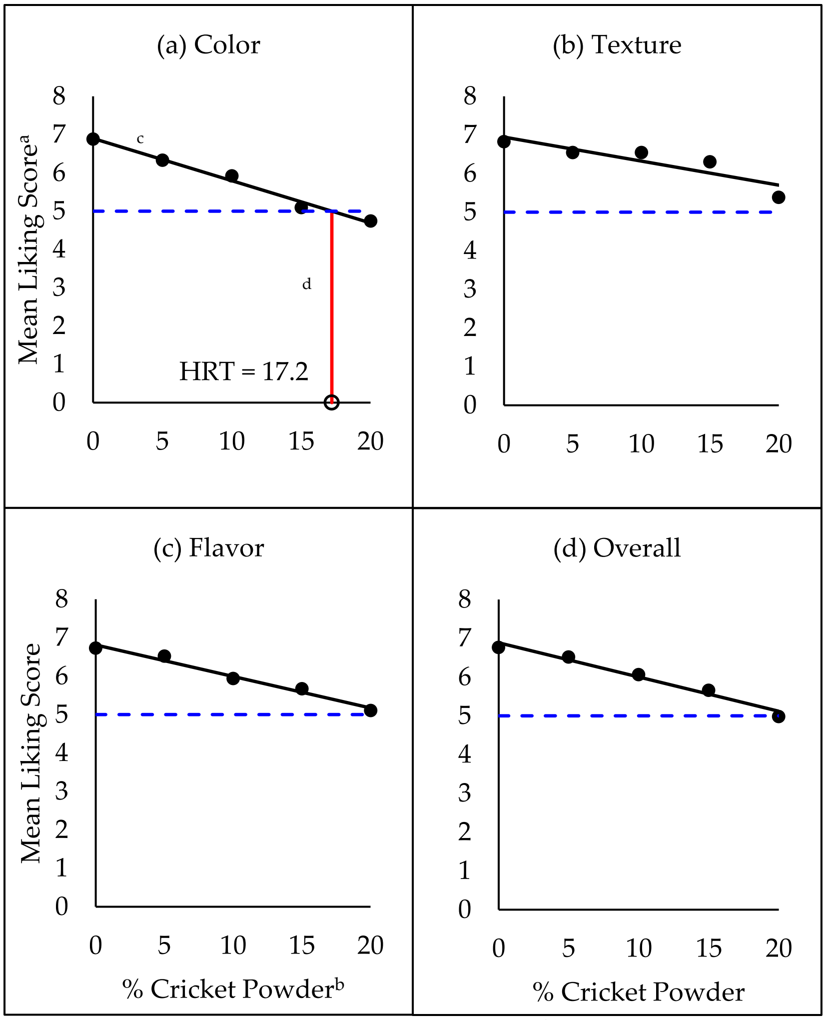

Figure 4.2. Hedonic Rejection Thresholds[^] (HRT) for Cricket Powder in Whole-Wheat Snack Crackers

[^]Thresholds were measured based on liking (a 9-point hedonic scale) of (a) color, (b) texture, (c) flavor, and (d) overall liking.

[a] Mean liking scores from a 9-point hedonic scale.

[b] Percentage of cricket powder used in place of whole-wheat flour (w/w) in cracker formulations.

[c] Black solid line represents a simple linear regression of liking scores (y) as a function of % cricket powder (x), and black dots represent observed mean liking scores for each treatment.

[d] Vertical red line represents the HRT, which was interpolated as the % cricket powder associated with a predicted hedonic score of 5 (blue horizontal dashed line) from the simple linear regression (not found for texture, flavor, or overall liking).

Although the words "liking" and "acceptance" are often used interchangeably, the present discussion describes data from a labeled 9-point hedonic scale (anchored at 1=dislike extremely and 9=like extremely) in terms of liking, and later, responses to a binomial yes/no questions about product acceptability in terms of acceptance (for "yes" responses) or rejection (for "no" responses). Using the 9-point hedonic scale, Filho *et al*. (2015) designated scores below the neutral category of 5 (neither like nor dislike) as "where rejection begins to occur." In essence, the HRT methodology uses a simple linear regression (SLR) (Fahrmeir *et al*., 2013) to estimate the stimulus level (x) corresponding to a hedonic score of 5 (y). The resulting threshold does not, however, account for any spread around the point-estimate. The M-HRT, on the other hand, imposes a one-sample t-test to evaluate a one-sided hypothesis (Ho: $\mu \geq 5$, Ha: $\mu < 5$). The associated question of interest is then related to the point where "liking drops significantly below 5." Following HTM protocol, which asked respondents to evaluate their liking of each product monadically, we estimated the HRT and M-HRT for cricket powder in snack crackers.

Whereas preference-based M-CRT estimates ranged from <5% to 15.6% cricket powder depending on the attribute evaluated (Figure 4.1), the mean liking scores for all attributes remained favorable (above 5) approaching 20% cricket powder. In fact, the only attribute for which the HRT could be determined within our stimulus range was color (HRT_{color} = 17.2% cricket powder; Figure 4.2(a)). Based on the HRT, color−liking of snack crackers would not be expected to drop below the neutral category until >17.2% whole-wheat flour substitution with cricket powder. In the present case, exceeding 20% wheat flour substitution without the addition of other functional ingredients would be challenging due to lack of dough cohesion when forming the thin snack crackers.

To determine M-HRT levels, a new SLR was fit to model calculated t-scores (y, based on the transformed difference of each mean from 5) as a function of % cricket powder (x) in snack crackers. The new M-HRT was interpolated at the intersection of the regression line with the critical t-value of −1.67, (74 df, one sided α=0.05). Again, color was the only attribute for which the hedonic threshold was obtained ($M\text{-}HRT_{color}$ = 19.97% cricket powder, Figure 3(a)). As expected from this more strenuous criterion, the M-HRT methodology yielded a more liberal (higher) threshold estimate than the existing HRT protocol, at approximately 20% cricket powder.

Intuitively, the extra statistical rigor from a significant t-test may deliver added confidence that the M-HRT dependably predicts stimulus levels (based on hedonic scores) consistent with rejection. By plugging the calculated M-HRT_{color} value of 19.97% cricket powder into the SLR equation (Equation 4.2, R^2=0.98) used to determine HRT_{color}:

Equation 4.2. $\hat{y} = -0.6214x + 10.745$,

color liking is estimated to be 4.7. Analyzing the raw liking data, we find that the mean liking score for color at 20% cricket powder substitution was in fact 4.7. While 4.7 is not a valid response on the categorical 9-point hedonic scale (one must choose either 4 or 5), Gamba *et al*. (2020) evaluated the performance of continuous unstructured and hybrid line scales with HTM and suggested the hybrid scale as an alternative to the 9-point hedonic scale, in which case, our proposed modification could still be applied. Nevertheless, binomial acceptance data suggested that the criteria consumers used for where acceptance ended and rejection began on the 9-point scale differed among individuals, and from the previously assigned cutoff of 5. The following discussion will turn to modeling rejection in a less arbitrary fashion.

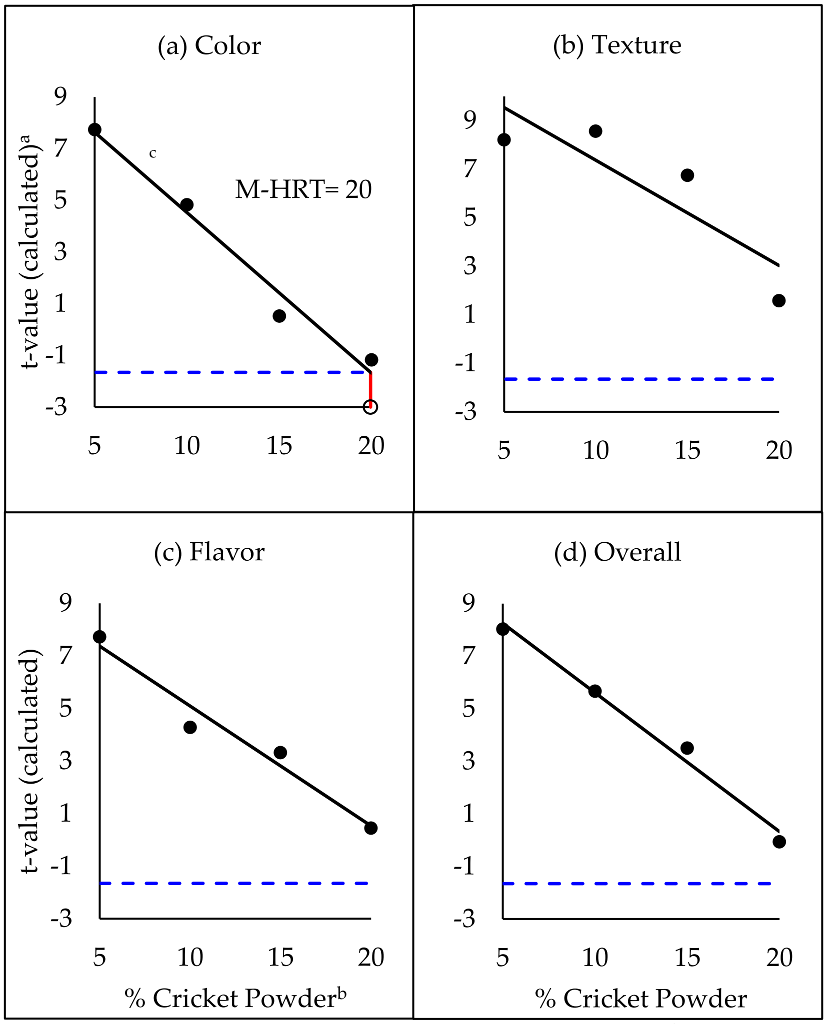

Figure 4.3. Modified Hedonic Rejection Thresholds^ (M-HRT) for Cricket Powder in Whole-Wheat Snack Crackers

^ Thresholds were measured based on liking (a 9-point hedonic scale) of (a) color, (b) texture, (c) flavor, and (d) overall liking.

[a] T-values were calculated from difference of mean liking scores (a 9-point scale) from a score of 5.

[b] Percentage of cricket powder used in place of whole-wheat flour (w/w) in cracker formulations.

[c] Black solid lines represent a simple linear regression of t-values (y) as a function of % cricket powder (x), and black dots represent observed t-values at each treatment level.

[d] Vertical red line represents the M-HRT, which was interpolated as the % cricket powder associated with a critical predicted t-value (α=0.05) of 1.67 (blue dashed horizontal line) from the simple linear regeression (not found for texture, flavor, or overall liking).

4.3.3. Rejection Tolerenace Threshold and Rejection Range

For each sample, consumers were also asked to report ("yes" or "no") whether the sample was acceptable overall and in terms of color, texture, and flavor. By compiling all these responses (2,400 total) and pairing them with their associated hedonic scores, it became evident that consumers held different standards. If we consider a "no" acceptability response as self-reported rejection, then 3.2% of 6 scores and 6.3% of 5 scores were associated with rejection, and at the hedonic category of 4, the observed rejection rate was 45%. This implies that, even with a "dislike slightly" score, samples were still deemed acceptable 55% of the time (data not shown).

Admittedly, consumers' perceptual responses to food and beverages are neither uniform nor consistent (Köster , 2003). This problem has led to doubt about the validity and usefulness of empirical thresholds (Lawless & Heymann, 2010; Meilgaard *et al*., 2006) and whether or not they actually exist in practice (Swets, 1961). To overcome this ambiguity of hedonic threshold estimates, the currently proposed rejection tolerance threshold (RTT) and rejection range (RR) relied on the binomial yes/no responses for acceptance, where rejection of an attribute was defined as a "no" response. Given that binary responses often follow an "S"-shaped curve, linear regression models may not be appropriate (Fahrmeir *et al*., 2013). Modeling thus requires a nonlinear link function, where in the present case, the slope of the effect depended on the amount of cricket powder present in snack crackers. The new methodologies aimed to provide more realistic interpretations of sensory-derived rejection limits by describing the tendency of consumers, within a given population, to accept or reject products as following a cumulative normal-type tolerance function. A similar approach is often used in medical and toxicological research to explore effective levels of a drug or lethality of poisonous substances (Agresti, 2019).

To estimate the RTT, probit regression was used to model the probability of rejection as a function of increasing cricket powder. Fechner *et al*. (1966) first applied a cumulative distribution curve to explain variability in perceptual responsiveness. The current nuanced application of the probit model to affective thresholds allows investigators to begin with an allowable proportion of rejection responses, or a "rejection tolerance", and estimate the stimulus level associated with such an outcome (Agresti, 2019). The resulting RTT is thus based on a user-defined tolerance of practical significance, rather than a critical statistical value or arbitrary boundary. Additionally, the estimate is derived considering the full range of data.

In one classical approach to thresholds (Lawless & Heymann, 2010; Meilgaard *et al*., 2006), the point at which crackers would be rejected 50% of the time (i.e., RTT_{50}) could be estimated by the mean of the distribution (Agresti, 2019). Other options would be to assign the threshold at the response probability 50% over that predicted by chance (here, 75% rejection) or based on the significant proportion of responses from a binomial test (here, corresponding to 60% rejection) (Lawless & Heymann, 2010). However, these levels of rejection were neither achieved within the present study nor do they seem practical. An advantage of the proposed protocol is that the RTT can rather follow some investigator-defined tolerance, based on consumer self-reporting and according to the researcher's objectives or company's goals. Conversely, acceptance could be modeled as the proportion of "yes" responses, equivalent to 1 minus the probability of rejection.

For illustrative purposes, let's suppose that a food company is willing to accept 25% rejection of their cricket-containing snack crackers. Based on this hypothetical rejection tolerance of 25%, the RRT_{25} was determined for flavor at 14.6%, overall acceptability at 15.3%, and color at 16.8% whole-wheat flour substitution with cricket powder (Figure 4.4(c), 4(d), and 4(a), respectively). Consistent with the other affective measures, texture quality held up best to cricket powder addition, and no RTT was found for texture below 20% substitution (Figure 4.4(b)). From our current consumer sample, we found that the product would begin to reach the given rejection tolerance (25%) at around 15% whole-wheat flour substitution with cricket powder.

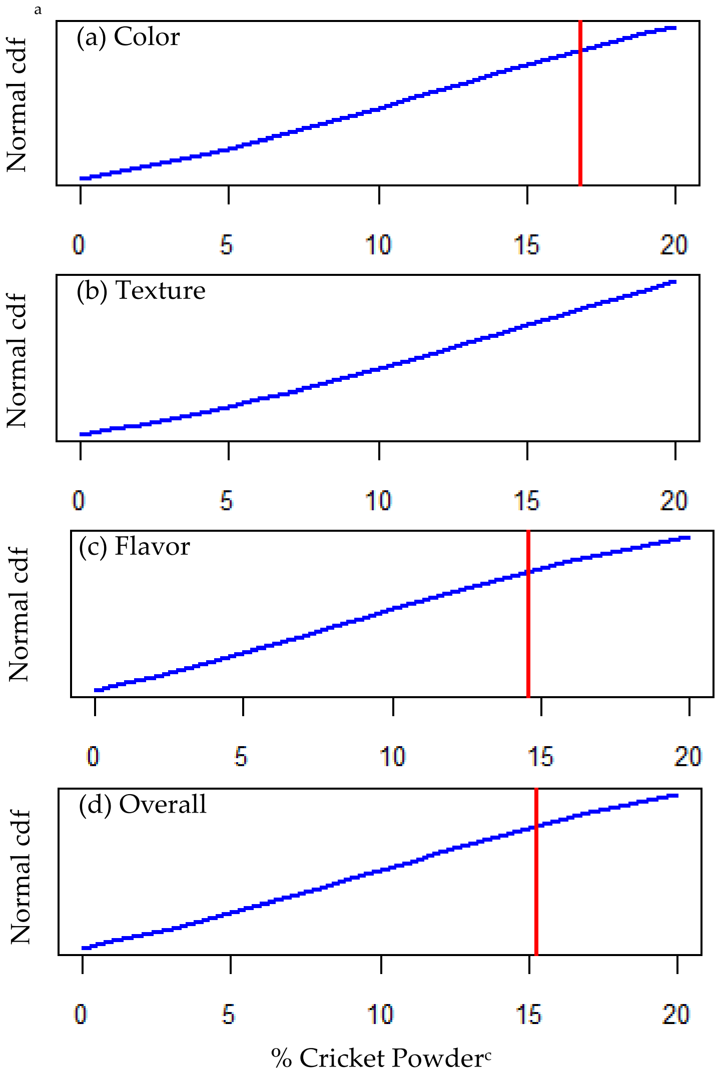

Figure 4.4. Rejection Tolerance Threshold$_{25\%}$[^] (RTT_{25}) for Cricket Powder in Whole-Wheat Snack Crackers

[^]Thresholds were measured for color texture, flavor and overall acceptance using probit regression, based on 25% rejection tolerance, where the cumulative left-tail probability = 0.25 (represented by an area under blue line).

[a]Normal cumulative distribution functions (cdf) were based on probit regression models, where the left-tail area under blue line represents the estimated probability of rejection (acceptability = ”no”) as a function of % cricket powder.

[b]Red vertical line represents the RTT_{25} as the predicted % cricket powder associated with 25% rejection (acceptability = ”no”) from probit models (not found for texture).

[c] Percentage of cricket powder used in place of whole-wheat flour (w/w) in cracker formulations.

Added value of this methodology is derived from the associated RR which provides the product developer with adaptable formulation guidelines. Based on the inferential nature of a well-fitting probit model, one can calculate a confidence interval around any point-estimate of the RTT with meaningful interpretations (Agresti, 2019; Fahrmeir *et al*., 2013). We thus defined the RR as the set of stimulus values contained within a confidence interval of interest, surrounding an RTT estimate. Presently, we estimated RR for cricket powder using 95% confidence intervals (RR_{95}; Figure 4.5).

The upper 95% confidence limit for color exceeded 20% cricket powder and, as previously mentioned, RTT_{25} for texture was not determined below 20% cricket powder. Therefore, so as not to interpolate outside the range of data used to fit our models, the RR_{95} is only shown for flavor (12.2%-17.8% cricket powder) and overall acceptability (13.0%-18.4% cricket powder) (Figures 5(a) and 5(b), respectively). As such, we would predict that 95% of equally sized samples from the same population would reach 25% overall rejection for snack crackers at cricket powder levels between 13% and 18.4% whole-wheat flour substitution, and flavor rejection (at a 25% rejection tolerance) would occur at slightly lower levels (between 12.2% and 17.8%).

Much as with the RTT, it is up to the researcher to choose the appropriate balance of reliability (a confidence level) and precision (width of the confidence interval) in characterizing a pragmatic RR, which may inform profitable decision making. For an ingredient such as cricket powder, which to some extent hinders affective quality, the first reaction may be to simply choose the lower bound of the RR. Instead, the RR should direct strategic adjustments of the product formulation to achieve goals related to: cost, quality, health or marketing claims, or nutritional value- all of which decidedly influence consumers' food choice (Köster, 2009) and ultimately product success.

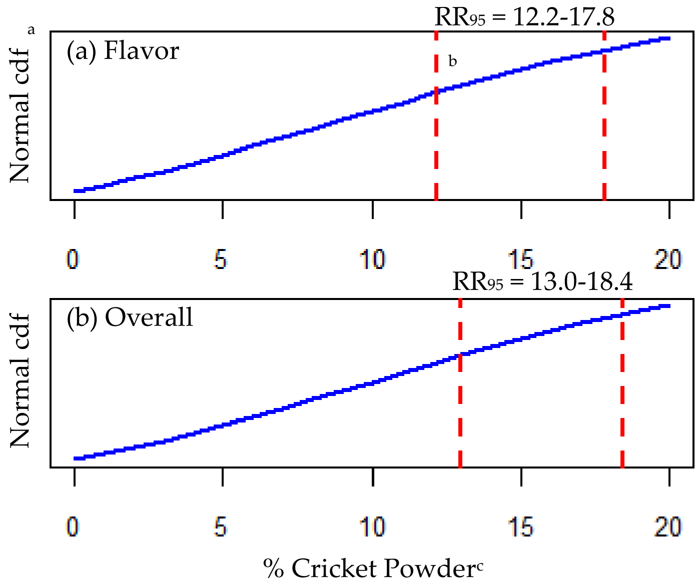

Figure 4.5. Rejection Range$_{95\%}$[^] (RR_{95}) for Cricket Powder in Whole-Wheat Snack Crackers
[^] RR_{95} was estimated, from a probit regression model, as the range of x-values (% cricket powder) bounded by a 95% confidence interval around the RTT_{25} (% cricket powder associated with 25% rejection) for flavor and overall acceptance.
[a]Normal cumulative distribution functions (cdf) were based on probit regression models, where the left-tailed area under the blue line represents the estimated probability of rejection (acceptability = "no") as a function of % cricket powder.
[b]Red dashed vertical lines represent the lower (left) and upper (right) bounds of the RR_{95} for (a) flavor and (b) overall acceptability, respectively, as % cricket powder.
[c]Percentage of cricket powder used in place of whole-wheat flour (w/w) in cracker formulations.

By narrowing down the stimulus region of interest, more focused testing (e.g., discrimination tests (Lawless & Heymann, 2010; Meilgaard *et al*., 2006)) within the RR may reveal opportunities to reduce ingredient costs or maximize nutritional benefits of a product by reaching acceptable upper limits of health-promoting compounds (or cutting back on unhealthy ones) (Lima Filho *et al*., 2019; Pujols *et al*., 2019). A carefully constructed RR can also be used to set quality control limits for contaminants (Prescott *et al*., 2005). For a novel ingredient like cricket powder, overcoming consumers' unfamiliarity and expectations of poor sensory quality, which have shown to inhibit trial intent (Ardoin & Prinyawiwatkul, 2020), may be achieved through exposure to acceptable products, developed based on consumer-driven data. Furthermore, separate RTT and RR values for different sensory dimensions can guide tailored strategies to improve products which promote sustainability (Ardoin & Prinyawiwatkul, 2020; Sukkhown *et al.*, 2019).

4.4. Conclusions

The present research presented two modified approaches to existing rejection-type threshold methodologies: the M-CRT and M-HRT as well as two newly proposed thresholds: the RTT and RR. Measures of preference, liking, and acceptance/rejection produced different threshold estimates for cricket powder in whole-wheat snack crackers, as these represent clearly different affective constructs. Terminology used to interpret each threshold should be considered accordingly. As all of the discussed rejection-type threshold methods present value to food research and industry, the authors suggest employing them in the same testing session. Doing so should typically require minimal additional time, sample, cost, and effort on the part of panelists, and provide a more complete view of stimulus effects. Tracking the differential impact of cricket powder on multiple sensory attributes was also valuable to exploring sensory-based limits of a novel ingredient. Other nonlinear approaches such as Landscape Segmentation Analysis® and internal preference mapping may be explored in future studies to reveal product attributes which drive acceptance/rejection across multiple segments of consumers.

These results supported existing criticisms of thresholds pertaining to inconsistency in consumers' perceptual evaluations and lack of congruence between theoretical intent and objective threshold estimates. Rather than relying on statistical significance or some arbitrary boundary between acceptance and rejection, the RTT and RR offered threshold strategies based on practical significance to the investigators or food companies. These concepts are suggested as more realistic approaches to modeling rejection of a food product and offer adaptable methodologies based on a new application of the probit regression model. The RTT can recommend a stimulus level based on an allowable rejection tolerance, and the RR can suggest a stimulus range that will satisfy such a tolerance with a quantifiable level of reliability. These protocols can be used to guide product formulation strategies to meet specific targets in terms of price, quality, nutrition, or functionality and are relevant to various food processing, ingredient, and contaminant effects. Future validation studies should investigate the repeatability of these threshold estimates within a given population.

CHAPTER 5. EFFECTS OF CRICKET POWDER ON SELECTED PHYSICAL PROPERTIES AND U.S. CONSUMER PERCEPTIONS OF WHOLE-WHEAT SNACK CRACKERS

5.1. Introduction

Throughout human history, people have eaten insects (Kouřimská & Adámková, 2016). This practice, called human entomophagy, persists in parts of Africa, Asia and Latin America, but insects have long disappeared from most modernised Western cuisine. The motivation for expanding entomophagy globally is well documented (e.g., van Huis *et al.*, 2013). Despite potential benefits to both individual health and global food security, aversions to entomophagy remain (Tao & Li, 2018), with reluctance to even try insect-based products among many consumers in the U.S.A. (Ardoin & Prinyawiwatkul, 2020).

While psychological barriers to insect trial, such as unfamiliarity, disgust and sociocultural taboos are becoming better understood (Batat & Peter, 2020), what may ultimately push entomophagy forward are comprehensive sensory-based strategies. Berger *et al.* (2018) demonstrated that hedonic claims are more appealing than rational ones to potential insect consumers, and repeat insect consumption behaviours will likely stem from enjoyable products and eating experiences (Deroy *et al.,* 2015). Effective development of such foods will rely on thorough evaluations of "real" insect-based products (as opposed to rough concepts or model systems) by target consumers. A study of cricket protein bars in the Czech Republic illustrated the importance of tailoring commercial products to regional taste preferences (Adámek *et al.*, 2018). More product-driven sensory research is needed in the U.S. if a market for entomophagy is to be realised.

Based on *product appropriateness* data obtained from U.S. consumers (Ardoin & Prinyawiwatkul, 2020), snack crackers with increasing levels of cricket powder (*Acheta* *domesticus* and *Gryllodes sigillatus*) were developed for the present investigation. We decided to mimic a popular thin whole-wheat snack cracker product, widely available from U.S. retailers, to clearly investigate perceptual effects of the insect ingredient on an otherwise familiar and successful product concept. Therefore, it was essential that our base-product (the cricket-free "control" crackers) be well-liked.

Perceptions of insect-based products likely involve a multisensory interaction with background expectations (Deroy *et al.*, 2015). It is clear from existing entomophagy research that powdered insects are less objectionable than whole or otherwise recognisable forms (Barton *et al.*, 2020). As a wheat flour substitute, cricket powders' lack of gluten presents challenges in terms of texture, but crickets offer valuable micronutrients which can be deficient in individuals on gluten-free diets (Montowska *et al.*, 2019). Flavour remains a critically important driver of liking for wheat products enriched with cricket powder (Carcea, 2020), and the novel flavour of cricket in a familiar product may be undesirable to new insect consumers (Osimani *et al.*, 2018).

Measuring different affective modalities expands options for applying modern sensory methods to novel food ingredients (Ardoin *et al.*, 2020). Preference judgments require comparison of at least two items, and in doing so, resemble processes involved in purchasing choices (Lawless & Heymann, 2010). They do not, however, reveal whether a given food item is liked/disliked, or any magnitude thereof. While the terms "liking" and "acceptance" are often used interchangeably, classifying a product as "acceptable" or "unacceptable" based on a scaled liking score discounts differences in individuals' variable standards and ignores situational variables unrelated to intrinsic quality, which may dictate the decision to accept or reject a food item (Schutz & Martens, 2001). Therefore, we used a labelled 9-point hedonic scale to evaluate degree of liking, a "yes/no" question to determine acceptor set size (percentage of consumers rating the product acceptable), and a 2-alternative choice (2-AC) test for preference (Ennis & Ennis, 2012a). All samples were evaluated in terms of colour, texture, flavour, and overall perceptions, across modalities.

While sensory perceptions of insect-based products can be biased by pre-existing attitudes, optimising the sensory properties of these foods may be the key to creating a place for insects in Western diets (Deroy *et al.*, 2015). The objectives of this research were to evaluate the effects of whole-wheat substitution with cricket powder on U.S. consumers' affective perceptions and relevant physical properties of snack crackers. These data would be useful for guiding strategies for cricket-based product development and improvement in the U.S.A.

5.2. Materials and Methods

5.2.1. Whole-Wheat Snack Crackers

Whole-wheat snack crackers were modelled after a popular commercial product in the U.S.A. Whole-wheat flour was substituted with cricket powder (*w/w*) at 0% (control; C0), 5% (C5), 10% (C10), 15% (C15), and 20% (C20). To form cracker doughs, whole-wheat flour (Gold Medal™, General Mills, Minneapolis, MN, U.S.A.), water, soybean oil (Great Value™, Bentonville, AK, U.S.A), sugar (Great Value™) , corn starch (Great Value™), salt (Great Value™), baking powder (Clabber Girl®, Clabber Girl Corporation, Terre Haute, IN, U.S.A.), and cricket powder (*Acheta domesticus*, *Gryllodes sigillatus*; Griopro®, All Things Bugs LLC, Midwest City, OK, U.S.A.) were mixed in a commercial food processor (WARING by Cuisinart, Waring Commercial, Torrington, CN, U.S.A.). Respective amounts of cricket powder were first hydrated ($\frac{1}{2}$ part water to 1 part cricket powder, *w/w*) to promote even mixing due to the ingredient's hygroscopic nature. Formed doughs were rested for two h under refrigeration (approximately 3°C). Rested doughs were brought to room temperature and rolled into strips (0.3

cm thickness) using a hand-crank pasta/dough rolling machine (KAPM-01, OxGord, Gardena, CA, U.S.A.), laid onto parchment-lined sheet pans, rolled with a docking tool, and cut into squares (3.6 cm by 3.6 cm). Doughs were oven baked (Baxter OV310G, Orting, WA, U.S.A.) at 350 °F (176.7 °C) for 12 min, removed and cooled to room temperature. Crackers were portioned into clear two-ounce lidded plastic cups (two crackers per cup) and labelled with three-digit blinding codes. Samples were stored at room temperature overnight prior to testing the following day.

5.2.2. Consumer Test

A total of N=150 consumers were recruited for participation from Louisiana State University campus (LSU, Baton Rouge, LA, U.S.A.). To avoid any potential allergic reactions, consumers were informed that samples may contain cricket. Also, in real-world eating or purchase situations, it is expected that consumers' awareness of the insect component would influence their consumption decision and subsequent perceptions. The consumer sample consisted of 44% males and 56% females. According to definitions from the Pew Research Center (2018), 5% were of generation X, 39% were millennials (generation Y), and a 53% majority were of generation Z. This sampling bias toward younger adults was expected, given recruitment from a college campus, hence it would limit generalisation of results to the broader population.

Testing was conducted in partitioned booths at the LSU Sensory Services Lab (Baton Rouge, LA, U.S.A.). Qualtrics online survey software (Qualtrics, Provo, UT, U.S.A.) was used for questionnaire presentation and response collection. This research was approved by the Louisiana State University Agricultural Center Institutional Review Board (IRB# HE18-9 and IRB# HE 18-22).

Sample presentation followed a balanced incomplete block design (B.I.B.; k=2, t=4, b=6, r=3, λ=1; Cochran & Cox, 1992). With B.I.B. protocol, the product of k and b (2x6=12) is equal to the product of t and r (4x3=12). Every consumer was considered a block, and every block received two pairs of samples (k=2 pairs). Each pair consisted of one control and one of the four cricket-containing (stimulus) samples, resulting in four possible combinations of control and stimulus (C0 alongside either C5, C10, C15, or C20; t=4). Both the order in which subjects evaluated each pair and the order within each sample-pairing (whether the control was tested first or second) was randomised and counterbalanced. For example, a given consumer may be served [C0, C20] as the first pair and [C10, C0] as the second. This method of constant stimuli, with C0 present in every pairing, is not typical of B.I.B. protocol but was chosen to allow for calculation of d-prime (d′) values (Lawless & Heymann, 2010) and modified consumer rejection thresholds (M-CRT; Ardoin *et al.*, 2020) from 2-AC preference tests.

With each consumer receiving two (k=2) of the four (t=4) possible sample-pairs, there were six unique serving combinations [$\binom{4}{2}$=6]. Therefore, one replication of the present B.I.B. design required six panellists (b=6 blocks per replication). Replicating this B.I.B. design twenty-five times, data from 150 total consumers were obtained (6x25=150 total panelists). All sample-pairs were evaluated three times (r=3) per replication, and thus seventy-five times over twenty-five replications of the design (3x25=75 total observations per pair).

Samples were evaluated in terms of liking (9-point hedonic scale), acceptability (yes/no scale), and preference (between the control and stimulus sample; 2-AC with “no preference” option). Each of these three perceptual dimensions were rated in terms of colour, texture, flavour, and overall [liking/acceptability/preference], in that order. Unsalted crackers and water were served for palate cleansing.

5.2.3. Instrumental Colour and Texture Measurements

Colour of snack crackers was measured in terms of $L*$, $a*$, $b*$ values (BC-10 Baking Contrast Meter, Konica Minolta Sensing Americas, Ramsey, NJ, U.S.A.). Twenty-five crackers were measured from each of the five cracker formulations (C0, C5, C10, C15, and C20). The three-dimensional colour space (CIE 1976 $L*$ $a*$ $b*$; Sharma & Bala, 2017) allowed for objective comparisons of instrumental lightness/darkness ($L*$), greenness/redness (−/+ $a*$), and blueness/yellowness (−/+ $b*$) across samples (via ANOVA), as well as calculation of the Euclidean distances (ΔE; n 5.1) between points in the colour space. Delta-E (ΔE) values were used to relate colour differences between treatments, in a pairwise fashion, to human perception (Equation 5.1; $L*$, $a*$, and b* represented mean values of each respective index, and subscripts $_1$ and $_2$ refer to two samples of interest; Sharma & Bala, 2017).

Equation 5.1. $\Delta E = \sqrt{(L_2^* - L_1^*)^2 + (a_2^* - a_1^*)^2 + (b_2^* - b_1^*)^2}$

Texture analysis (TA.XT*plus*® Texture Analyser, Stable Micro Systems, Godalming, U.K.) was performed by centring a cracker on the platform and shearing it with a knife edge blade under the following test settings: a pre-test speed = 3.0 mm/s; a trigger force = 40 g; a test speed = 1.50 mm/s; a strain = 75%. Twenty replications were performed for each of the five cracker treatments. Hardness was reported as the peak force (N) required to deform samples.

5.2.4. Data Analysis

A multivariate analysis of variance (MANOVA) was used to compare mean liking vectors (of colour, texture, flavour, and overall liking scores; 9-point hedonic scales) across treatments (C0, C5, C10, C15, and C20). A highly significant MANOVA result was obtained (Wilks' Lambda $p<0.0001$). Therefore, additional statistical methods were employed to explore the effects of cricket powder on component liking scores.

Considering liking of each sensory attribute (colour, texture, flavour, and overall liking; 9-point hedonic scales) separately, univariate analyses of variance (ANOVA) were run with post-hoc Tukey's tests. Each liking dimension was subsequently analysed for linear, quadratic, and cubic trends using polynomial contrasts. Descriptive discriminant analysis (DDA; Huberty & Olejnik, 2006) was used to investigate the contribution of attribute liking scores (amongst colour, texture, and flavour) to the observed group differences. Correlations analysis measured the strength of linear relationships between colour/texture/flavour liking and OL.

Paired preference results were used to calculate d′ ("d-prime") values, comparing the control crackers to each cricket-containing formulation, and statistical significance was assessed using Thurstonian 2-AC modelling (IFPress). Acceptor set size ("acceptability") was reported as the percentage of consumers responding "yes" to acceptability questions, and statistical significance was based on a 2-tailed binomial test (n=75, p=0.50; α=0.05). A rejection tolerance threshold (RTT) and rejection range (RR) were calculated for overall acceptability following the methods outlined in Ardoin *et al.* (2020).

ANOVA with Tukey's test was also used to report differences in mean L^*, a^*, b^* and textural (instrumental) hardness. All tests were performed at an overall significance level of α=0.05. Microsoft Excel (2019), SAS software (Copyright © 2016 SAS Institute Inc., Cary, NC, USA.), and R software (R Core Team, 2019) were used for data analysis.

5.3. Results and Discussion

Using cricket-free whole-wheat snack crackers as a baseline for comparison, it became clear that the products' sensory quality declined with increasing levels of cricket powder in place of whole-wheat flour. The "control" product (C0) was well-liked and highly acceptable, with mean liking scores approaching "like moderately" (6.7-6.9) in all sensory attributes (Table 5.1) and acceptor set sizes ranging from 94% for flavour to 97% for texture (Figure 5.1). Through in-house comparisons, marked sensory differences have been noticed between cricket powders from different manufacturers and subsequent characteristics imparted onto final products. Therefore, interpretations of the following results are specific to the commercial cricket powder we utilised. No attempts were made to mask or alter any of the properties imparted by increasing cricket addition levels. Rather, this research aimed to uncover opportunities for product improvement.

Table 5.1. Univariate Analysis of Variance (ANOVA)[1] and Polynomial Contrasts of Mean Liking Scores[2] of Whole-Wheat Snack Crackers Containing Cricket Powder

Treatment[3]	Colour	Texture	Flavour	Overall Liking
0%	6.9^{A}	6.8^{A}	6.7^{A}	6.7^{A}
5%	6.4^{B}	6.6^{AB}	6.6^{A}	6.6^{A}
10%	5.9^{B}	6.5^{AB}	5.9^{B}	6.0^{B}
15%	5.0^{C}	6.2^{B}	5.5^{BC}	5.5^{B}
20%	4.7^{C}	5.4^{C}	5.1^{C}	5.0^{C}
Polynomial Contrasts[4]	Colour	Texture	Flavour	Overall Liking
Linear	<0.0001	<0.0001	<0.0001	<0.0001
Quadratic	0.98	0.02	0.57	0.17

[1] Based on mixed model ANOVA using lsmeans and Tukey's post-hoc test. Different letters in the same column indicate significant differences between treatments (α=0.05).
[2] Liking scores rated on a 9-point hedonic scale.
[3] Percentage whole-wheat flour substitution with cricket powder in snack crackers.
[4] P-values from F test with one degree freedom.

5.3.1. Colour

Colour was the first attribute to be negatively affected by cricket powder, exhibiting a significant drop in liking at the lowest substitution level of 5% cricket powder (Table 5.1), and eventually falling (a total of 2.2 units on the 9-point hedonic scale) into the "dislike" region, with a mean colour liking of score of 4.7 at 20% cricket powder. As such, colour liking was the most discriminating hedonic feature amongst treatments (pooled within canonical correlation of 0.97 in Can1, which accounted for 90% of the total variance in the system; Table 5.2a). Colour was also the only attribute to show a significant shift in preference (α=0.05) toward the control at 5% cricket powder, based on the Thurstonian 2-AC test (d′=0.44; Table 5.3).

Table 5.2 a. Descriptive Discriminant Analysis[1] and b. Correlation Analysis[2]

a. Pooled Within Canonical Structure			
Variable	Can1[3]	Can2	Can3
Colour	0.97	0.16	-0.17
Texture	0.45	0.86	0.23
Flavour	0.61	0.24	0.76
b. Correlations	Colour liking	Texture liking	Flavour liking
Overall Liking	0.60	0.71	0.92
	$p<0.0001$	$p<0.0001$	$p<0.0001$

[1,2] Discriminant and correlation analyses were run using liking scores from a 9-point hedonic scale.
[3] Can1 accounts for 90% of the total variance explaining overall treatment differences.

Table 5.3. D-prime (d') Estimates[1]- Based on 2-AC Test with "no preference" Option

Treatment[2]	Colour	Texture	Flavour	Overall Liking
5%	**0.44**	0.2	0.31	0.24
10%	**0.83**	0.19	**0.61**	0.31
15%	**1.5**	0.26	**0.75**	**0.73**
20%	**1.68**	**1.17**	**1.27**	**1.67**

[1] Bold values indicate control was significantly preferred over cricket-containing treatment based on Thurstonian 2-AC model (α=0.05).
[2] Percentage whole-wheat flour substitution with cricket powder in snack crackers.

Deterioration of affective colour quality generally aligned with the incremental darkening of snack crackers (lower L* values; Table 5.4) when increasing cricket powder from 0% to 15% wheat-flour substitution. It is important to note that, other than C15 vs. C20 (ΔE=0.79), samples were readily discernible to the human eye. Values of ΔE ranged from 5.9 to 20.7, easily surpassing the difference threshold of $\Delta E \approx 2.3$, indicating obvious colour differences for human observers (Sharma & Bala, 2017).

Aspects of appearance, such as colour, may be the first source of sensory information upon which consumers base expectations of overall product quality (Chonpracha *et al.*, 2020), and can be particularly important to trial of novel insect-foods (La Barbera *et al.*, 2019). In the present research, consumers' liking of snack cracker colour prior to tasting showed a moderate correlation (Akoglu, 2018) with overall liking (OL) scores after eating ($r = 0.60$, $p < 0.0001$; Table 5.2b), albeit weaker than those (0.71-0.92) of texture and flavour liking. While there is evidence of *a priori* expectations about crickets negatively biasing product assessments (Barsics *et al.*, 2017), a positive disconfirmation of expectations would suggest that when overall product quality exceeds consumers' expectations, greater satisfaction could be achieved (Brown *et al.*, 2008). In our study, participants were asked to consume snack cracker samples regardless of initial presumptions, and subsequent data revealed that the total sensory experience was evaluated more favourably than colour alone for cricket-containing crackers (Table 5.1). However, in normal eating situations, intentions to consume insect-based snacks may be halted on the basis of appearance. Therefore, improving perceived colour quality is crucial to promote trial and raise consumers' tolerance for cricket powder in snack crackers.

It has become an accepted practice to hide the insect ingredients in familiar foods to improve initial perceptions (Carcea, 2020), such as with insect powders or flours which have extended insect-use in baked products (González *et al.*, 2019). Although not recognisable as crickets *per se*, crackers' dark colour at higher substitution levels likely served as a reminder of the insect's presence in the food. Since each cricket-containing sample was paired with a control cracker (C0), and because colour differences were so apparent (high ΔE values), immediately significant comparative differences (at 5% substitution; Tables 1 and 3) imply deviation from an ideal whole-wheat cracker colour (Brown *et al.*, 2008). Akullo *et al.* (2018) also found ground termites to decrease acceptance of cracker colour, while ground crickets discoloured cereal bars from an ideal "golden" to a less desirable "brownish" appearance (Ribeiro *et al.*, 2019). In the present study, C15 and C20 demonstrated a more negative shift (α=0.05) in b* values (less yellow; Table 5.4), a trend also observed when substituting wheat flour with cricket powder in muffins (Pauter *et al.*, 2018), pushing away from an optimal golden colour.

Table 5.4. Instrumental Colour (*L*, a*, b**)[1] and Hardness[2] Values of Whole-Wheat Snack Crackers Containing Cricket Powder

Treatment[3]	L*	a*	b*	Hardness (N)
0%	59.4 ± 1.6[a]	12.3 ± 1.2[b]	24.1 ± 1.1[a]	43.2 ± 9.6[c]
5%	53.6 ± 2.2[b]	13.2 ± 0.9[a]	24.2 ± 0.6[a]	54.1 ± 14.7[bc]
10%	47.8 ± 1.2[c]	13.5 ± 0.7[a]	22.7 ± 0.8[b]	55.1 ± 13.9[b]
15%	40.4 ± 1.1[d]	12.5 ± 0.7[b]	18.0 ± 0.8[c]	72.0 ± 11.3[a]
20%	39.9 ± 1.3[d]	12.4 ± 0.6[b]	17.4 ± 0.7[c]	75.8 ± 15.7[a]

[1] Mean ± SD (25 replications).
[2] Mean ± SD of peak-force from texture profile analysis (20 replications).
[3] Percentage wheat flour substitution with cricket powder in snack crackers.
Different letters in the same column indicate significant differences between treatments based on ANOVA with Tukey's post-hoc test (α=0.05).

5.3.2. Texture

Whereas colour ratings were most sensitive to affective differences, texture was more resilient, with evidence of a sharp decrease in texture liking only beyond 15% cricket powder addition, yielding a significant quadratic effect ($p<0.05$, Table 5.1) of increasing cricket powder on liking scores. In fact, no significant pair-wise differences in texture liking were observed until 15% cricket powder incorporation (C0 vs. C15; Table 5.1), but C15 was still liked similarly to C5 and C10- all retaining a mean hedonic score above "like slightly." A clear drop-off in hedonic impressions occurred at 20% cricket powder incorporation. Texture of C20 was liked least (α=0.05) among the formulations (mean score of 5.4; Table 5.1), showed the first significant shift in preference compared to the control (d′=1.17; Table 5.3), and a noticed a substantial drop in acceptor set size from 91% (C15) to 69% (C20) texture acceptability (Figure 5.1).

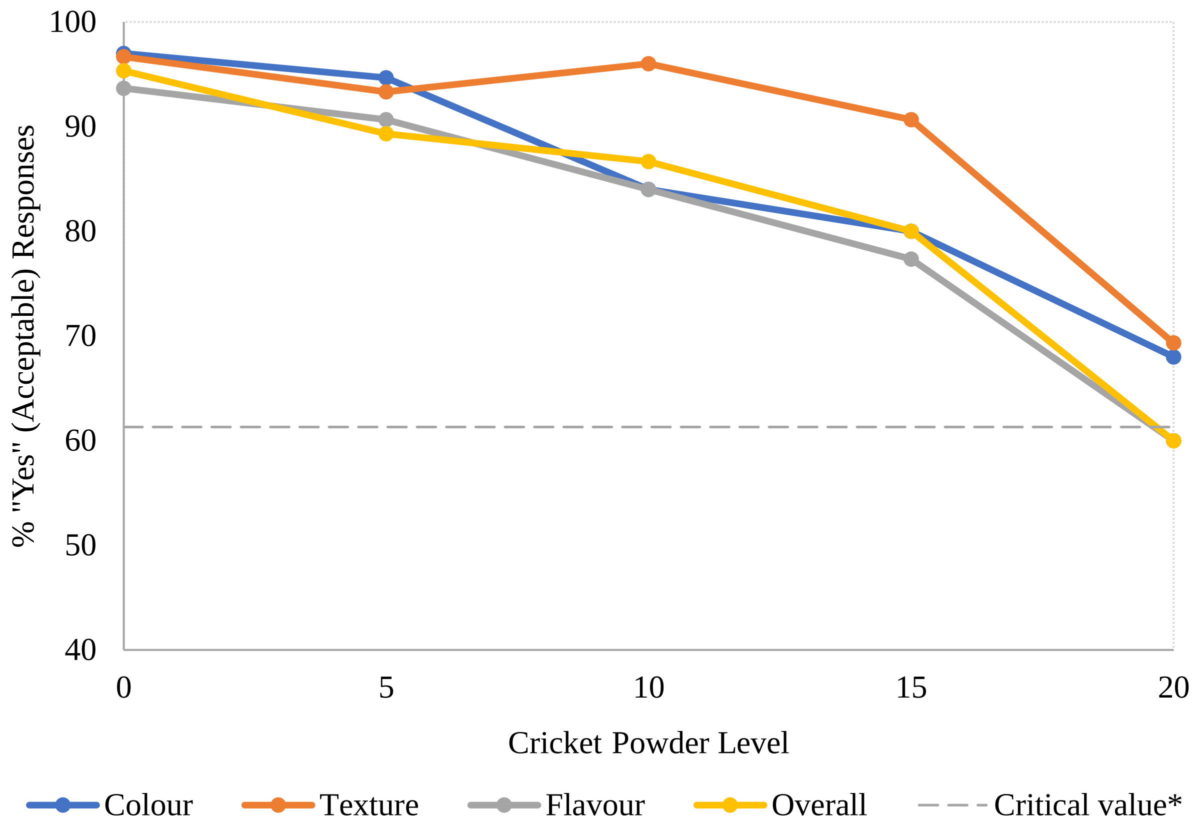

Figure 5.1. Acceptability of whole-wheat snack crackers containing cricket powder, shown as the percentage of ‘yes’ (acceptable) responses to binomial (‘yes/no’) acceptability questions for colour, texture, flavour, and overall acceptability.
* Critical value at 61.3% ‘yes’ responses, based on a 2-tailed binomial test for proportion ($p=0.50$, $n=75$; $\alpha=0.05$), above which, acceptability is significant.

Observing instrumental measurements of snack crackers’ hardness (Table 5.4), directionally higher forces were required to deform the products as the proportion of cricket powder increased and wheat-flour decreased. That is, snack crackers became harder. While our instrumental texture analysis was meant to imitate the first incisor bite (related to crispness), it is expected that harder crackers also required more force over time (work) to break down with the molars (related to crunchiness; Tunick *et al.*, 2013) in order to form a bolus. This trend was generally consistent with decreased affective ratings from consumers (Tables 1 and 4).

To more objectively quantify perceptual differences in texture, we turn to d′ estimates derived from 2-AC preference tests (Table 5.3). Preference data provide comparative judgements, and expressing a preference for one item over another (especially when offered a "no preference" option) implies a perceptible difference that exceeds an individual's internal criterion (Lawless & Heymann, 2010). Therefore, Thurstonian 2-AC principles were used to obtain d′ estimates (Ennis & Ennis, 2012a) for snack crackers, where larger d′ values indicate stronger group preferences for the control snack cracker (C0; Table 5.3). A d′ of 1.0 is considered a threshold in psychophysics (O'Mahony & Rousseau, 2003), and will be used here to explain perceived differences (beyond just statistical significance). We will refer to statistically significant results below the d′ threshold of 1.0 as a "shift" in preference.

A significant difference, both practically and statistically, in texture preference (favouring of the cricket-free formulation) was first observed at 20% wheat-flour substitution with a d′ of 1.17 (Table 5.3). Despite similar instrumental hardness (Table 5.4), the difference deviates substantially from that of C15 vs. C0 (d′ = 0.26). This raises belief that an affective threshold was surpassed beyond C15 approaching C20. According to M-CRT methodology, this threshold was estimated at 15.6% cricket powder (Ardoin *et al.*, 2020). Alternatively, this steep change in texture preference, when samples were physically similar (Table 5.4), may be related to a cumulative sensory effect, where each component attribute was penalised for an overall quality deterioration, resulting in all d′ estimates exceeding 1.0 at 20% cricket powder (Table 5.3). Either way, limiting whole-wheat flour replacement to 15% in snack crackers seems practical, without the use of other functional ingredients or technologies to preserve textural quality.

As opposed to other wheat-based products where a softness or tenderness are desired, the thin and rigid nature of snack crackers lends to a compatible application of cricket powder in terms of texture. Increased firmness and decreased volume of breads (de Olivera *et al.*, 2017; Osimani *et al.*, 2018) and reduced tenderness and stickiness of pasta (Biró *et al.*, 2019) have been problems attributed to insect powders used in place of wheat flour. There are also reports of insect powder addition producing instrumentally softer baked products, which was associated with higher moisture content (Haber *et al*, 2019; Pauter *et al.*, 2018). Crackers, on the other hand, are expected to be crispy. However, surpassing a critical threshold of cricket powder, and thus hardness, may reduce perceptions of crispness by decreasing speed of deformation (Tunick *et al.* 2013) from a typical bite.

5.3.3. Flavour

Of the three sensory attributes investigated, liking of flavour was most highly correlated with OL of snack crackers ($r = 0.92$, $p < 0.0001$; Table 5.2b). The strong association between perceptions of flavour and overall quality are evident by tracking their respective hedonic scores (Table 5.1) and acceptability ratings (Figure 5.1) with increasing whole-wheat flour substitution. The acceptor set size for flavour and overall acceptability converged at 60% for C20 (Figure 5.1). Based on a binomial distribution of “yes/no” acceptability responses (n=75, p=0.50), a two-tailed hypothesis test for proportion (H_o: P(“yes”)=0.50, H_a: P(“yes”)≠0.50) would yield a significant result ($\alpha=0.05$) at or above an acceptor set size of 61.3%, “yes” responses. By failing to reach this critical acceptor set size, C20 did not meet consumers’ minimum flavour expectations any more often than expected by chance alone. Flavour of C15, however, did show to be significant acceptability (acceptor set size of 77.3%)- again, pointing to a critical drop-off in quality somewhere between 15% and 20% substitution.

While flavour acceptability remained favourable at up to 15% cricket powder usage, a significant ($\alpha=0.05$) shift in preference occurred by 10% substitution ($d'=0.61$), and its d′ was greater than 1.0 at 20% whole-wheat replacement (Table 5.3). The richness of information obtained from assessing flavour (and other attributes) across multiple affective modalities gives the sensory analyst better insight into a novel ingredient's effects on perceptions of a product. It also requires careful interpretations. In this case, the practical implications of an initial shift in flavour preference at 10% wheat-flour should not be overlooked. This does not imply that the flavour of C10 is objectionable on its own, or that preference shift would be universal, but that flavour may be a barrier to its commercial success. In the U.S. market, where enjoyable and affordable snack options are readily available, it is less likely that consumers would compromise taste or flavour for sustainability (Barton *et al.*, 2020). While appearance may be influential to trial, taste is a major driver of repeat insect consumption (House, 2016). Until insects are appreciated for their own unique sensory character, perceptions of flavour must not deviate from those of familiar foods, lest conditioned taste aversions be reinforced (Deroy *et al.*, 2015). Therefore, we suggest that flavour be the first sensory attribute addressed in further development of the cricket snack cracker model.

It is well understood that insect flavours vary by species, developmental stage, and processing method (Mishyna *et al.*, 2020). Furthermore, the salience of perceived tastes and flavours likely arise from how well (or poorly) the novel ingredient fits within the characteristic flavour profile of the "normal" product. When an unpleasant mismatch occurs, the unusual sensation can be considered an off-flavour or "taint" (Prescott *et al.*, 2005), whereas in another product it may go unnoticed. For example, crickets (*Acheta domesticus*) have been reported to have a meat-like flavour (Sipponen *et al.*, 2018). In a whole-wheat cracker, this may be undesirable and become quite noticeable at higher levels, but in pork pâté, the level of added cricket was negatively correlated with meat flavour intensity (Smarzyński *et al.*, 2019). No attempt was made in our investigation to characterise the off-flavour imparted by cricket powder onto snack crackers, but even without this information, practical limits should be set on its usage (Ardoin *et al.*, 2020).

5.3.4. Overall Sensory Quality

As previously discussed, overall perceptions of each sample were reported last, after focussed evaluations of colour, texture, and flavour across three affective modalities, and were presumably based on an integration of those precepts. This type of deliberate analysis is atypical of everyday snacking situations, but was important to pinpointing differential effects of our novel ingredient on snack crackers. Even with direct questioning, consumers may not be fully aware of why they like or dislike a food or why one option is preferred over the other (Köster, 2003), but it was clear from the obtained data that substituting wheat flour with cricket powder diminished the overall quality of snack crackers (Table 1).

The first statistically significant difference in overall preference was noticed at 15% cricket powder (C15, $d'=0.73$; Table 5.3), and d' easily crossed threshold of 1.0 for C20 ($d'=1.67$). Across sensory attributes, there was a steep decline in acceptability going from C15 to C20 (Figure 5.1). In overall acceptability, a 20% drop (from 80% for C15 to 60% for C20) was observed. As opposed to pushing the limits of insect addition toward an affective breaking approaching 20%, we suggest a more conservative approach to incorporating insects into U.S. diets- one that gradually familiarises consumers with the entomophagy through approachable products. In this way, sensory rejection can be minimised, while consumers may become psychologically acclimated to entomophagy.

In assessments of quality, consumers compare available options to a reference point (other options or previous experience), and score a product based on its performance relative to the reference (Oberhauser & Czaczkes, 2018). For the present analysis, C0 served as a reference point for consumers' direct comparisons (d′ from 2-AC preference tests; Table 5.3) and investigators' indirect comparisons (ANOVA of liking; Table 5.1) of cracker quality. The binomial measure of acceptability was used to compare each product to consumers' minimum expectations for the category (an internal reference), providing an estimate of the size of the pool of potential users (Lawless & Heymann, 2010) within the population sample. A real-world application of this research is to propose a limit on cricket powder usage that accommodates consumers' quality standards for whole-wheat snack crackers.

Because of its relation to behavioural outcomes (Lawless & Heymann, 2010), acceptor set size data were used to calculate a practical range of wheat-flour substitution with cricket powder. Careful consideration was given to the holistic set of results and characteristics of our consumer sample in making the determination. By consenting to participate in the tasting, all 150 subjects expressed willingness to try an insect-containing food. Potential consumers of cricket-containing snack crackers are only expected to represent, at the most, around 60% of U.S. adults (Ardoin & Prinyawiwatkul, 2020). In other studies, college students have shown more openness to entomophagy (Roma *et al.*, 2020). Given our limited population segment and these consumers' relative openness to insect trial, it was important to take even minor deficiencies in sensory quality seriously, to promote repeat consumption and to expand trial to a broader audience who may be more critical of cricket powder's effects.

Therefore, a rejection tolerance threshold (RTT; Ardoin *et al.*, 2020) for cricket powder was estimated to capture 90% overall acceptability of snack crackers ($RTT_{10;}$ Figure 5.2) from the present consumer segment. Equivalently, commensurate with the original terminology, this model allowed for 10% rejection ("no" for acceptability) of the product. More importantly, keeping in mind that consumers' perceptions are neither uniform nor consistent (Köster, 2003), we were interested in a range of cricket powder usage that would reliably contain our desired acceptor set size (from 90% of samples). Thus, a 90% rejection range (RR_{90}; Ardoin *et al.*, 2020) was estimated for wheat-flour substitution with cricket flour in snack crackers (Figure 5.2).

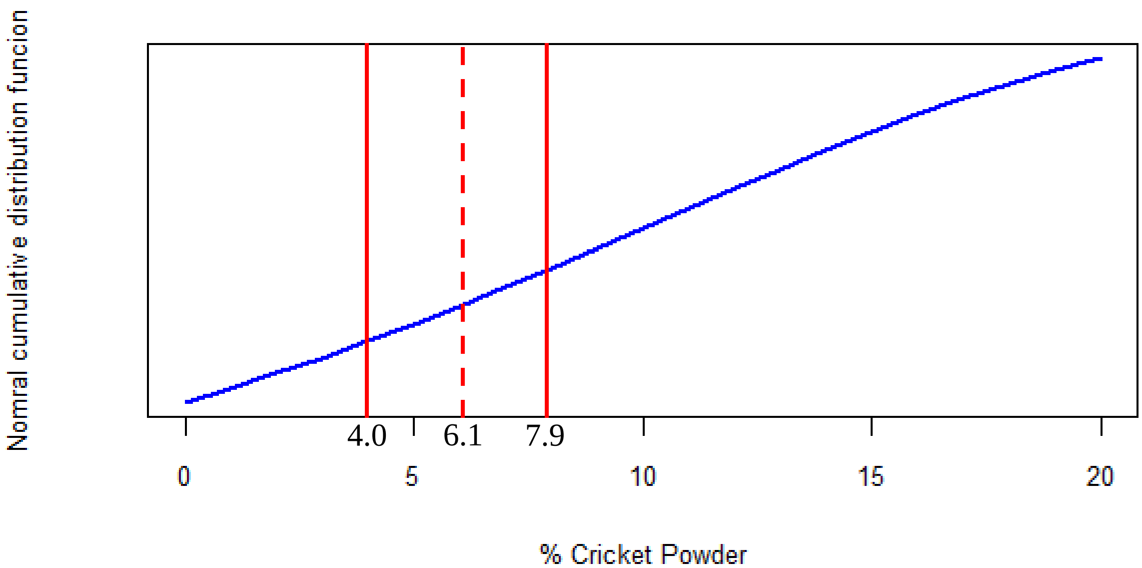

Figure 5.2. Rejction Tolerance Threshold$_{10\%}$ (RTT_{10}) and Rejection Range$_{90\%}$ (RR_{90}) for Cricket Powder in Whole-Wheat Snack Crackers. RTT_{10} was estimated as % cricket powder (represented by the dashed red vertical line) expected to result in 90% overall acceptability (equivalent to a 10% rejection tolerance) of snack crackers, where the cumulative left-tail probability = 0.10 (represented by an area under the blue line). RR_{90} was estimated as the range of x-values (% cricket powder, represented by solid red vertical lines) bounded by 90% fiducial limits around the RTT_{10} estimate.

The RTT_{10} was estimated at 6.1% cricket powder (Figure 5.2). Consulting the raw data (Figure 5.1), C5 yielded 89.3% overall acceptance, and the acceptor set size shrunk with additional cricket powder. Intuitively, we would have expected the RTT_{10} to fall slightly lower than 5% cricket powder but acknowledge the inherent error involved in model-fitting. The real advantage of this model came from construction of 90% fiducial limits (a RR_{90}) around the RTT_{10} estimate. The resultant RR_{90} (Figure 5.2) predicts that snack crackers containing between

4.0% and 7.9% cricket powder, in place of whole-wheat flour, have a 90% probability of reaching our desired acceptor set size (90% acceptability; RTT_{10}) from similar population samples. Interpreting the fiducial limits (RR_{90}) in both directions: based on repeated sampling, the model gives 95% confidence that snack crackers made with 4% cricket powder will achieve an acceptor set size of at least 90%, as well as 95% confidence that surpassing 7.9% cricket powder will fail to reach this level of overall acceptability.

Proceeding with development of whole-wheat snack crackers using between 4% and 7.9% cricket powder is advisable not only based on overall perceptions, but also after considering the ingredient's effects on individual sensory attributes. Cracker colour became perceptibly darker within this stimulus range (Table 5.4), but lower affective colour ratings (Table 5.1) did not prove detrimental to overall quality. Although instrumental differences in hardness were observed, texture perceptions remained favourable up to at least 15% cricket powder addition. As previously mentioned, flavour was considered to be the most critical attribute for overall cracker quality, but the first observable shift in flavour preference did not occur (Table 5.3) until slightly above our recommended upper of limit of 7.9% cricket powder. Taking a less conservative approach, and therefore conceding smaller (but perhaps more realistic) acceptor set sizes, an RTT_{20} (for overall acceptability) would be estimated at 12.7% cricket powder and an RTT_{30} at 17.5% cricket powder, for the present population sample.

To improve OL of cricket-containing snack crackers, negative effects of the ingredient on colour and flavour quality should first be addressed. As a wheat flour substitute, cricket powder may be more suitable for whole-wheat products, which are inherently darker than those made with refined flour. However, technologies to lighten the colour of snack crackers (or the cricket powder itself), or otherwise align its dark colour with expectations (e.g., chocolate flavour), may be explored. Flavour modification/addition has been shown to improve acceptance of bars made with cricket (Adámek *et al.*, 2018), but requires an understanding of the target audience's preferences. Some cultures may, for example, prefer some optimal level of cricket powder (Castro Delgado *et al.*, 2020), and certain sub-populations within the same culture can exhibit bimodal tendencies in their affective responses toward insects in food (Biró *et al.*, 2019). Within the present sample of U.S. consumers, liking of snack crackers showed a decreasing linear trend, as a function of increasing cricket powder, for colour, flavour, and OL (all $p<0.0001$; Table 5.1). Although some consumers still preferred the cricket-containing samples at up to 20% addition, at this time, it is recommended to appeal to as many early adopters as possible until a potential market for entomophagy develops further. Future studies should take advantage of the proposed rejection range (RR), and look beyond intrinsic sensory quality and into aspects of nutrition (e.g., protein content), price, and external cues (Chonpracha *et al.*, 2020) to optimise snack crackers.

5.4. Conclusions and Future Research

Clear effects of cricket powder on sensory quality of snack crackers were observed. Replacing whole-wheat flour with cricket powder (up to 20%) produced instrumentally darker and harder crackers. Although consumers' evaluations of colour were first to decline (at 5% cricket powder) those changes did not necessarily render products unacceptable after tasting. Ratings of flavour were most closely aligned with overall perceptions, with the first statistically significant changes in flavour liking and preference observed at 10% cricket powder. The thin crispy snack crackers were a fitting vehicle for cricket powder incorporation in terms of texture, with perceptions remaining favourable at up to 15% cricket powder addition. However, by 20% whole-wheat flour substitution, a clear preference for the cricket-free crackers was observed across sensory attributes and overall.

While cricket-containing snack crackers remained “acceptable” at 15% whole-wheat flour substitution, we recommend further research and development of the product using between 4%, and 7.9% cricket powder, based on a 10% rejection tolerance threshold (RTT_{10}) and its associated 90% rejection range (RR_{90}). With an already limited segment of U.S. consumers willing to try insect-based foods, reinforcing positive eating experiences may be crucial for repeat consumption and require a gradual familiarisation with crickets’ unique sensory properties. Therefore, in product concepts such as this one, too little cricket is preferable to too much until its sensory qualities become better appreciated or improved upon.

A question going forward for insect-based product development in the U.S. is to what extent the insect-ingredient’s inherent attributes should be modified or masked rather than showcased to increase familiarity or find complementary sensory profiles. A more holistic understanding of consumers’ wants, in regard to these novel foods, may be further informed by preference mapping techniques and/or conjoint analysis. Continued development of cricket-containing snack crackers would also benefit from descriptive sensory analysis of flavour and validation of the presently observed results in more diverse U.S. population samples.

Chapter 6. Conclusions

It is apparent from the surge in scientific attention given to entomophagy in the early 21st century that the looming challenges facing our global food supply are being taken seriously in the research community, but a sense of urgency to change unsustainable dietary habits has not made its way to the majority of U.S. consumers, especially when it involves compromising taste. Despite the effectiveness of our entomophagy benefit information in changing self-reported intention to try insects in food, the larger body of research suggests that consumers are not willing to trade immediate satisfaction (in the form of familiar tasty foods) for potentially unforeseeable long-term benefits. While it does seem that entomophagy education can play a role in shifting attitudes, this only offers a starting point for helping consumers overcome irrational fears of insect consumption.

High reports of unfamiliarity and poor expectations of sensory quality from consumers who were unwilling to try foods made with insect powder (even in the hypothetical sense) offered valuable insight into a way forward. Through appropriate products- like protein bars, snack crackers, or baked goods- trial can be achieved and sensory data collected. This information can then be used by food scientists to develop better products based on an understanding of insects' sensorial effects in different food matrices. In the process, consumers' first-time tastings may lead to repeat behaviours, as prior insect consumption was a significant predictor of future intentions. Eventually, better products and gradual familiarization among a growing segment of the U.S. population may work synergistically to decrease negative attitudes and emotions toward entomophagy.

In the meantime, the ability of insects-in-food to evoke such strong and measurable responses from consumers can be applied to development of new sensory evaluation methods with broader uses in food research. The newly proposed rejection tolerance threshold (RTT) and rejection range (RR) methodologies provided advantages over previous techniques in terms of practical application (both can be tailored to the aims of the research) and interpretability, and an empirically derived range of values (RR) accounts for the variability inherent to human perception. These results can be valuable to understanding both the ingredient/product (how much of an ingredient to use in a specific application) and the population segment (how tolerant they are to the stimulus). As demonstrated in other research, the study of edible insects is especially amenable to emotional measures (i.e., disgust, sensation seeking) as well.

Based on perceptual data obtained from whole-wheat substitution in snack crackers, color and flavour are central to consumers' determinations of cricket cracker quality. Even in an "invisible" form (powdered), deviations form expected product color (darker) make the insect component again apparent, and may lower expectations of overall quality. On the other hand, the color imparted to tortilla chips by cricket powder prompted rating of *interested* and *adventurous* feelings. In the current early stages of entomophagy introduction, optimizing products for early adopters may mean appealing to the sensation seeking nature of potential consumers.

Still, taste and flavour remain critically important to overall acceptability of insect-containing foods. For this reason, a desensitization to the novel flavour of crickets in familiar products may require incremental exposure over time, which was the justification for a low recommended RTT (10% rejection tolerance) for cricket powder in snack crackers. However, a wide RR (90% confidence interval) allowed for some leeway in cracker formulation to potentially meet goals of cost or nutritional claim within the desired acceptability level. Descriptive sensory analysis would aid further development of this product by characterizing the flavour profile, potentially revealing complementary modification strategies.

Until insect-based foods are comparable in sensory quality to successful products on the U.S. market, other avenues may be exploited to compensate for the quality loss. These may include capitalizing on the high protein content, such is in protein powders or bars, which were both deemed appropriate and may also appeal to healthy-lifestyle consumers. Extrinsic visual cues (e.g., packaging) may also be considered to sway consumers choice at the point of purchase, but insufficient demand may serve as an obstacle for price-competitiveness. Effective insect-inclusive legislation could increase confidence throughout the supply chain, promote entry into the market, and eventually break down barriers to consumption through variety of product options and enhanced feelings of safety. Indeed, governments and food companies play critical roles in developing a viable market for edible insects in the U.S., but consumers will decide its success.

With so many affordable, tasty, and familiar food options available, any move toward entomophagy in the U.S.A. will be a slow one. This does not suggest that the push for change in Americans' dietary habits should desist, but it should proceed patiently during these rudimentary stages of Western entomophagy research. Even the development of acceptable cricket-containing snack crackers, albeit at low addition levels, is a sign of progress guided by previous finding about the "invisible" nature of powders, appropriate products, and methods to set ingredient limits based on sensory quality. Furthermore, the presently employed approaches to understanding U.S. consumers perceptions of edible insects may lend to effective exploration of other novel foods in modern societies.

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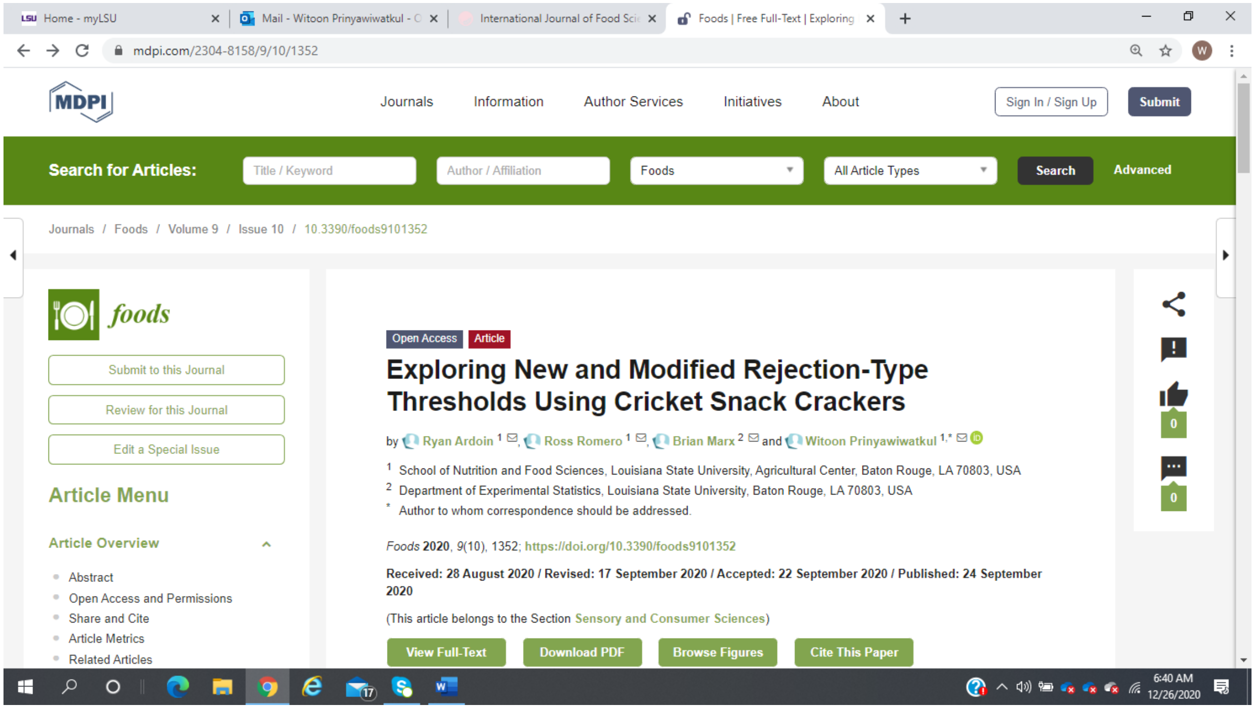
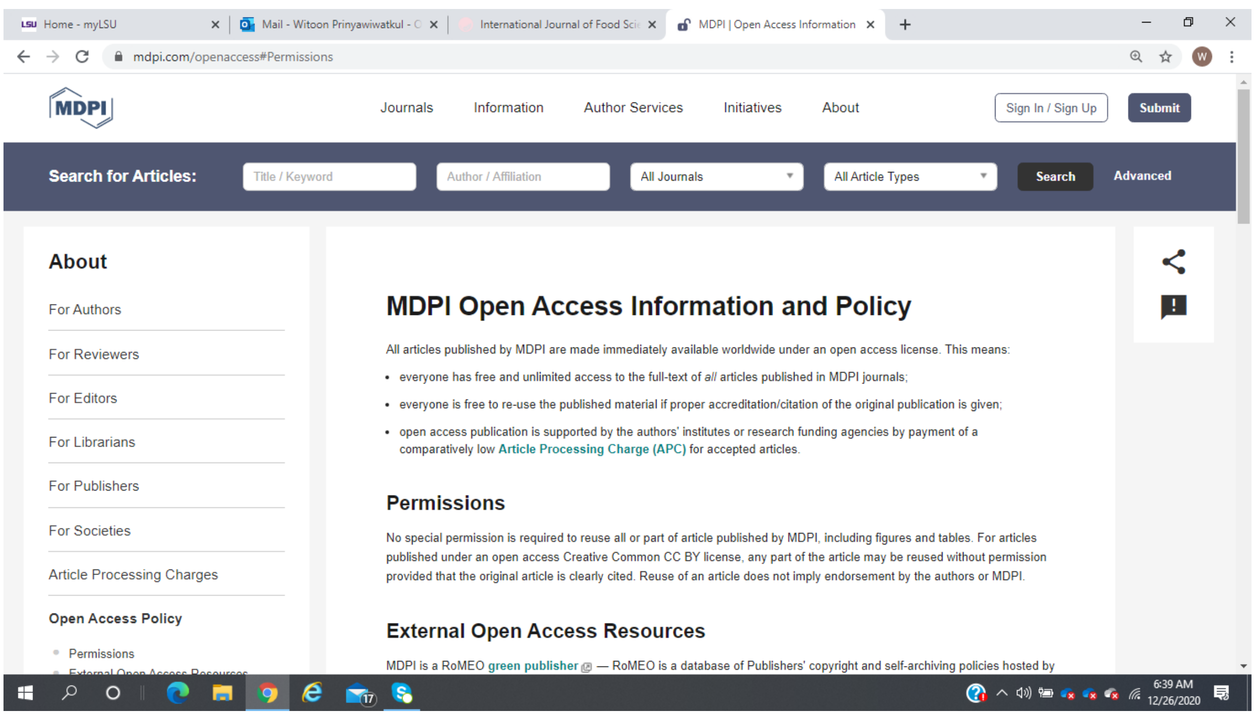
A.2.2. Chapter 4





APPENDIX B. SUPPLEMENTARY MATERIAL FOR CHAPTER 3

B.1. Consent Form (text)

If you agree to participate in this survey based on the terms below, select "I agree to participate." at the bottom of this page.

<u>Consent to Participate in Survey</u>

The objective of the present research is to collect data on consumer attitudes toward foods and beverages containing insect protein powder.

Participation is entirely voluntary and the respondent may withdraw consent and exit the survey at any time without penalty.

Participation entails minimal risk. Participants will be asked to answer a series of questions about food choice.

All responses are anonymous. Results of this study will not be released in any individually identifiable form without prior consent unless required by law.

Additional questions regarding this study should be directed to Dr. Witoon Prinyawiwatkul, Professor, School of Nutrition and Food Sciences, Louisiana State University, Agricultural Center at phone number (225) 578-5188.

This research is carried out under the oversight of the Institutional Review Board. Questions or problems regarding these activities should be addressed to Dr. Michael Keenan, Chair of LSU AgCenter IRB at 578-1708.

B.2. S1 Questionnaire Excerpt

Are you at least 18 years of age?

○ Yes

○ No

Have you lived in the United States of America for the last three years?

- Yes
- No

If not the United States, in which Country do you primarily reside?

____

Gender:

- Male
- Female

Would you try food, beverage or snacks containing insect protein powder?

- Yes
- Maybe not
- No

Why not? Please select all that apply.
Concerns about:

- ☐ Appearance
- ☐ Cultural or religious beliefs
- ☐ Negative emotions (boredom, disgust, fear, guilt, worry etc.)
- ☐ Nutrition
- ☐ Odor/aroma
- ☐ Price
- ☐ Safety
- ☐ Social acceptability
- ☐ Taste
- ☐ Texture/mouthfeel
- ☐ Unfamiliarity with insects as a food source

Do you make consumption decisions based on **sustainability** of the food source?

- ○ Yes
- ○ No

Do you make consumption decisions based on **environmental factors** (such as chemical use, greenhouse gas emissions, land usage, pollution, waste production) associated with the food source?

- Yes
- No

Are you typically willing to try new foods?

- Yes
- No

Have you ever eaten food containing insect as an ingredient?

- Yes
- No

Would you be willing to try food containing edible insect as an ingredient again?

- Yes
- No

Would you be willing to try food containing insect as an ingredient?

- Yes
- No

Would you try **BREAD** containing insect protein powder as an ingredient?

- ◯ Yes
- ◯ Maybe not
- ◯ No

Why not? Please select the top 3 reasons.
Concerns about:

- ☐ Appearance
- ☐ Cultural or religious beliefs
- ☐ Negative emotions (boredom, disgust, fear, guilt, worry etc.)
- ☐ Nutrition
- ☐ Odor/aroma
- ☐ Price
- ☐ Safety
- ☐ Social acceptability
- ☐ Taste
- ☐ Texture/mouthfeel
- ☐ Unfamiliarity with insects as a food source
- ☐ I do not eat this product.

B.3. S2 Questionnaire Excerpt

Edible insects are safe to eat and are considered a sustainable source of high quality protein and other nutrients. Edible insect production has less negative environmental impact than traditional livestock production. An estimated 2 billion people worldwide consume edible insects. Knowing this, would you try the following foods containing insect protein powder?

Bread	○ Yes	○ Maybe not	○ No
Butter or Spread	○ Yes	○ Maybe not	○ No
Cake	○ Yes	○ Maybe not	○ No
Candy bar	○ Yes	○ Maybe not	○ No
Cheese	○ Yes	○ Maybe not	○ No
Chicken nuggets	○ Yes	○ Maybe not	○ No
Chips or Snack crackers	○ Yes	○ Maybe not	○ No
Cookies	○ Yes	○ Maybe not	○ No
Crab cake	○ Yes	○ Maybe not	○ No
Doughnut or Pastry	○ Yes	○ Maybe not	○ No
Fish sticks	○ Yes	○ Maybe not	○ No
Fruit juice or Fruit drink	○ Yes	○ Maybe not	○ No
Gummi candy	○ Yes	○ Maybe not	○ No

Hamburger	○ Yes	○ Maybe not	○ No
Hard candy, Sucker, or Lollipop	○ Yes	○ Maybe not	○ No
Hot dog or Sausage	○ Yes	○ Maybe not	○ No
Ice cream	○ Yes	○ Maybe not	○ No
Milkshake	○ Yes	○ Maybe not	○ No
Muffin	○ Yes	○ Maybe not	○ No
Omelette or Quiche	○ Yes	○ Maybe not	○ No
Pasta	○ Yes	○ Maybe not	○ No
Protein bar or Energy bar	○ Yes	○ Maybe not	○ No
Protein shake	○ Yes	○ Maybe not	○ No
Pudding or custard	○ Yes	○ Maybe not	○ No
Smoothie	○ Yes	○ Maybe not	○ No
Sports drink	○ Yes	○ Maybe not	○ No
Tortilla	○ Yes	○ Maybe not	○ No
Trail mix	○ Yes	○ Maybe not	○ No
Vegetable juice	○ Yes	○ Maybe not	○ No
Yogurt	○ Yes	○ Maybe not	○ No

B.4. SAS Code

B.4.1. Willingness to Try (example)

```
Proc freq;
      Table Bread;
run;
```

B.4.2. Stuart Maxwell Test (example)

```
%MACRO gMcNemar(DSIN = , /* INPUT DATASET*/
ROWV = , /* ROW VARAIBLE NAME */
COLV = , /* COLUMN VARIABLE NAME */
COUNT = ); /* CELL COUNT VARIABLE NAME OF R X R SQUARE TABLE*/
PROC FREQ DATA = &DSIN NOPRINT;
WEIGHT &COUNT;
TABLES &ROWV * &COLV /OUT = FREQ (DROP = PERCENT);
PROC SUMMARY DATA = FREQ;
CLASS &ROWV &COLV;
FREQ COUNT;
OUTPUT OUT = FREQ1 (WHERE = (_TYPE_ > 0 ));
%GLOBAL LEVEL;
PROC SQL NOPRINT;
SELECT MAX(&ROWV) INTO: LEVEL
FROM FREQ1;
QUIT;
DATA TEMP1 (DROP = &ROWV RENAME = (RC = CT) )
TEMP2 (DROP = &COLV RENAME = (RC = RT) ) TEMP3;
SET FREQ1 (DROP = _TYPE_ RENAME = (_FREQ_ = RC) );
IF &ROWV = . AND &COLV NE . THEN OUTPUT TEMP1;
IF &ROWV NE . AND &COLV = . THEN OUTPUT TEMP2;
IF &ROWV NE . AND &COLV NE . THEN OUTPUT TEMP3;
PROC SORT DATA = TEMP1;
BY &COLV;
PROC SORT DATA = TEMP3;
BY &COLV;
DATA TEMP13;
MERGE TEMP3 TEMP1;
BY &COLV;
PROC SORT DATA = TEMP2;
BY &ROWV;
PROC SORT DATA = TEMP13;
BY &ROWV;
DATA TEMP123;
MERGE TEMP13 TEMP2;
BY &ROWV;
IF &ROWV = &COLV THEN VIJ = RT + CT - 2*RC;
DIFF = &ROWV - &COLV;
IF DIFF > 0 THEN SEQ = COMPRESS(&ROWV||&COLV);
ELSE SEQ = COMPRESS(&COLV||&ROWV);
PROC SORT DATA = TEMP123;
BY SEQ;
PROC SQL NOPRINT ;
CREATE TABLE TEMP4 AS
SELECT SEQ, (-1)*SUM(RC) AS VIJ
```

```
FROM TEMP123
WHERE DIFF NE 0
GROUP BY SEQ
ORDER BY SEQ;
QUIT;
DATA TEMP4 (DROP = I);
SET TEMP4;
DO I = 1 TO 2;
OUTPUT;
END;
DATA TEMP1234 (KEEP = &ROWV &COLV VIJ);
MERGE TEMP123 TEMP4;
BY SEQ;
IF &ROWV < &LEVEL AND &COLV < &LEVEL;
PROC SORT DATA = TEMP1234;
BY &COLV &ROWV ;
PROC SORT DATA = TEMP1 OUT = TEMP1_1(RENAME = (&COLV = &ROWV));
BY &COLV;
DATA RC;
MERGE TEMP2 TEMP1_1;
BY &ROWV;
D = RT - CT;
IF &ROWV < &LEVEL;
PROC IML;
USE TEMP1234;
READ ALL VAR{VIJ} INTO A;
X = J(&LEVEL - 1,&LEVEL - 1,0); /* CREATE A COLUMN MATRIX OF 1'S */
%DO I = 1 %TO (&LEVEL - 1);
X[,&I] = A[(&LEVEL - 1)*&I - (&LEVEL - 2) : (&LEVEL - 1)*&I, 1];
%END;
INVX = INV(X);
CLOSE TEMP1234;
USE RC;
READ ALL VAR{D} INTO DIJ;
GMN = DIJ` * INVX * DIJ;
DF = &LEVEL - 1;
QCHI95 = CINV(0.95,(&LEVEL - 1));
QCHI99 = CINV(0.99,(&LEVEL - 1));
PROBCHI = 1 - PROBCHI(GMN, (&LEVEL - 1));
PRINT GMN DF PROBCHI, QCHI95 QCHI99;
PROC DATASETS NOLIST KILL LIBRARY = WORK MEMTYPE = ALL;
QUIT;
%MEND;

******Talbe cells ij are (1)MaybeNot (2)No (3)Yes******;

data work.Bread;
      input r c count @@;
      cards;
1 1 54 1 2 7 1 3 32
2 1 22 2 2 99 2 3 18
3 1 11 3 2 1 3 3 358
;
%gMcNemar(dsin = work.bread, rowv = r, colv = c, count = count);
run;
```

B.4.3. McNemar's Test (example)

```
Proc freq;
      table Bread*Bread2/agree expected norow nocol nopercent;
run;
```

B.4.4. Cumulative Logistic Regression

```
Proc logistic data=work.Logit descending;
      model GWTT = Gender Openness Prior / aggregate scale=none;
run;

Proc genmod data=work.Logit descending;
      model GWTT = Gender Openness Prior / type3 dist=multinomial link=clogit
      aggregate;
run;
```

APPENDIX C. SUPPLEMENTARY MATERIAL FOR CHAPTER 4 AND CHAPTER 5

C.1. Consent Form (text)

I, ____________________, agree to participate in the research entitled "Consumer Perceptions of Whole Wheat Crackers containing Cricket Protein" which is being conducted by Witoon Prinyawiwatkul of the School of Nutrition and Food Sciences at Louisiana State University Agricultural Center, (225) 578-5188.

I understand that participation is entirely voluntary and whether or not I participate will not affect how I am treated on my job. I can withdraw my consent at any time without penalty or loss of benefits to which I am otherwise entitled and have the results of the participation returned to me, removed from the experimental records, or destroyed. One hundred-fifty consumers will participate in this research. For this particular research, about 5-10 minute participation will be required for each consumer.

The following points have been explained to me:

1. In any case, it is my responsibility to report prior to participation to the investigator any food allergies I may have.

2. The reason for this research is to evaluate consumer perceptions of crackers containing cricket protein. The benefit that I may expect from it is a satisfaction that I have contributed to solution and evaluation of problems relating to such examinations.

3. The procedures are as follows: four coded samples will be placed in front of me, and I will evaluate them by normal standard methods and indicate my evaluation on the online questionnaire. All procedures are standard methods as published by the American Society for Testing and Materials and the Sensory Evaluation Division of the Institute of Food Technologists.

4. Participation entails minimal risk: **The only risk may be an allergic reaction to shellfish, wheat, sugar, corn starch, salt, baking powder or canola oil.** However, because it is known to me beforehand that all those foods and ingredients are to be tested, the situation can normally be avoided.

5. The results of this study will not be released in any individual identifiable form without my prior consent unless required by law.

6. The investigator will answer any further questions about the research, either now or during the course of the project.

The study has been discussed with me, and all of my questions have been answered. I understand that additional questions regarding the study should be directed to the investigator listed above. In addition, I understand the research at Louisiana State University AgCenter that involves human participation is carried out under the oversight of the Institutional Review Board. Questions or problems regarding these activities should be addressed to Dr. Michael Keenan of LSU AgCenter at 578-1708. I agree with the terms above.

If you agree to participate in this study, please type your name below.

C.2. Questionnaire (example of one possible serving combination)

Gender

- ○ Female
- ○ Male

In what year were you born?

____

<u>Without tasting,</u>
How do you like the color of **Sample 592**?

- ○ Dislike extremely
- ○ Dislike very much
- ○ Dislike moderately
- ○ Dislike slightly
- ○ Neither like nor dislike
- ○ Like slightly
- ○ Like moderately
- ○ Like very much
- ○ Like extremely

Is the color of **Sample 592** acceptable?

- Yes
- No

Page Break

Please taste sample 592.
How do you like the overall texture of **Sample 592**?

- Dislike extremely
- Dislike very much
- Dislike moderately
- Dislike slightly
- Neither like nor dislike
- Like slightly
- Like moderately
- Like very much
- Like extremely

Is the texture of **Sample 592** acceptable?

- Yes
- No

How do you like the overall flavor of **Sample 592**?

- Dislike extremely
- Dislike very much
- Dislike moderately
- Dislike slightly
- Neither like nor dislike
- Like slightly
- Like moderately
- Like very much
- Like extremely

Is the flavor of **Sample 592** acceptable?

- Yes
- No

Page Break

Overall, how do you like **Sample 592**?

- ◯ Dislike extremely
- ◯ Dislike very much
- ◯ Dislike moderately
- ◯ Dislike slightly
- ◯ Neither like nor dislike
- ◯ Like slightly
- ◯ Like moderately
- ◯ Like very much
- ◯ Like extremely

Is **Sample 592** acceptable?

- ◯ Yes
- ◯ No

Page Break

Without tasting,
How do you like the color of **Sample 385**?

- ◯ Dislike extremely
- ◯ Dislike very much
- ◯ Dislike moderately
- ◯ Dislike slightly
- ◯ Neither like nor dislike
- ◯ Like slightly
- ◯ Like moderately
- ◯ Like very much
- ◯ Like extremely

Is the color of **Sample 385** acceptable?

- ◯ Yes
- ◯ No

Page Break

Please taste sample 385.

How do you like the overall texture of **Sample 385**?

- ○ Dislike extremely
- ○ Dislike very much
- ○ Dislike moderately
- ○ Dislike slightly
- ○ Neither like nor dislike
- ○ Like slightly
- ○ Like moderately
- ○ Like very much
- ○ Like extremely

Is the texture of **Sample 385** acceptable?

- ○ Yes
- ○ No

How do you like the overall flavor of **Sample 385**?

- ◯ Dislike extremely
- ◯ Dislike very much
- ◯ Dislike moderately
- ◯ Dislike slightly
- ◯ Neither like nor dislike
- ◯ Like slightly
- ◯ Like moderately
- ◯ Like very much
- ◯ Like extremely

Is the flavor of **Sample 385** acceptable?

- ◯ Yes
- ◯ No

Page Break

Overall, how do you like **Sample 385**?

- Dislike extremely
- Dislike very much
- Dislike moderately
- Dislike slightly
- Neither like nor dislike
- Like slightly
- Like moderately
- Like very much
- Like extremely

Is **Sample 385** acceptable?

- Yes
- No

Page Break

Which sample do you prefer **in terms of color**?

- Sample 592
- Sample 385
- No preference

Which sample do you prefer **in terms of texture**?

- Sample 592
- Sample 385
- No preference

Which sample do you prefer **in terms of taste**?

- Sample 592
- Sample 385
- No preference

Which sample do you prefer **overall**?

- Sample 592
- Sample 385
- No preference

C.3. SAS Code

C.3.1. 2-AC Preference Tests (frequencies)

```
PROC SORT;
      BY Level;
RUN;

PROC FREQ ORDER=INTERNAL;
      TABLES pCOLOR /  SCORES=TABLE;
      TABLES pTEXTURE /  SCORES=TABLE;
      TABLES pTASTE /  SCORES=TABLE;
      TABLES pOL /  SCORES=TABLE;
      BY Level;
RUN;
```

C.3.2. One-Sample T-Tests

```
PROC SORT;
      BY Level;
RUN;

PROC TTEST;
      PLOTS=NONE
      ALPHA=0.05
      H0 =5
      CI = EQUAL;
      VAR Color;
      BY Level;
RUN;

PROC TTEST;
      PLOTS=NONE
      ALPHA=0.05
      H0 =5
      CI = EQUAL;
      VAR Texture;
      BY Level;
RUN

PROC TTEST;
      PLOTS=NONE
      ALPHA=0.05
      H0 =5
      CI = EQUAL;
      VAR Flavor;
      BY Level;
RUN

PROC TTEST;
      PLOTS=NONE
      ALPHA=0.05
      H0 =5
      CI = EQUAL;
      VAR OL;
      BY Level;
```

```
RUN
```

C.3.3. Rejection Ranges

```
Proc probit;
      model OLACC (event='0') = level / inversecl;
run;

Proc probit;
      model OLACC (event='0') = level / inversecl alpha=0.1;
run;
```

C.3.4. MANOVA and Polynomial Contrasts

```
Proc GLM;
      Class LEVEL;
      Model Color Texture Flavor OL = LEVEL;
      contrast 'linear' LEVEL -2 -1 0 1 2;
      contrast 'quadratic' LEVEL 2 -1 -2 -1 2;
      contrast 'cubic' LEVEL -1 2 0 -2 1;
      Manova H=_All_;
run;
```

C.3.5. ANOVAs

```
proc glimmix;
      class obs level;
      model Color = level;
      random obs;
      LSmeans level/pdiff adjust=tukey;
run;

proc glimmix;
      class obs level;
      model Texture = level;
      random obs;
      LSmeans level/pdiff adjust=tukey;
run;

proc glimmix;
      class obs level;
      model Flavor = level;
      random obs;
      LSmeans level/pdiff adjust=tukey;
run;

proc glimmix;
      class obs level;
      model OL = level;
      random obs;
      LSmeans level/pdiff adjust=tukey;
run;
```

C.3.6. Descriptive Discriminant Analysis

```
proc candisc data=work.MANOVA;
      class level;
      var color texture flavor;
run;
```

C.3.7. Correlation Analysis

```
PROC CORR PLOTS=NONE PEARSON VARDEF=DF;
      VAR OL;
      WITH Flavor Texture Color;
RUN;
```

C.4. R Code

C.4.1. Rejection Tolerance Threshold (example)

```
fit1 = glm(OLACC~Level, family=binomial(link="probit"),data=mydata)
alpha=fit1$coef[1]
beta=fit1$coef[2]
mu=-alpha/beta
sig=1/abs(beta)
L=0
U=20
seq=seq(L,U)
den=dnorm(seq,mu,sig)
summary(fit1)
plot(seq,den,type='l',col="blue",lwd=2, yaxt="none", xlab="", ylab="")
par(ps = 10, cex = 1)
abline(v=15.3, col="red", lty=1, lwd=2)
abline(v=13, col="red", lty=2, lwd=2)
abline(v=18.4, col="red", lty=2, lwd=2
```

C.4.2. D-Prime Estimation (example)

```
> #color 5%
> fit<-twoAC(c(40,13,22))
> fit

> #color 10%
> fit<-twoAC(c(50,8,17))
> fit

> #color15%
> fit<-twoAC(c(62,4,9))
> fit

> #color 20%
> fit<-twoAC(c(64,4,7))
> fit
#Using sensR package
```

APPENDIX D. APPROVAL FOR USE OF HUMAN SUBJECTS

LSU AgCenter Institutional Review Board (IRB)
Dr. Michael J. Keenan, Chair
School of Human Ecology
209 Knapp Hall
225-578-1708
mkeenan@agctr.lsu.edu

Application for Exemption from Institutional Oversight

All research projects using living humans as subjects, or samples or data obtained from humans must be approved or exempted in advance by the LSU AgCenter IRB. This form helps the principal investigator determine if a project may be exempted, and is used to request an exemption.

- Applicant, please fill out the application in its entirety and include the completed application as well as parts A-E, listed below, when submitting to the LSU AgCenter IRB. Once the application is completed, please submit the original and one copy to the chair, Dr. Michael J. Keenan, in 209 Knapp Hall.

- A Complete Application Includes All of the Following:
  (A) The original and a copy of this completed form and a copy of parts B through E.
  (B) A brief project description (adequate to evaluate risks to subjects and to explain your responses to Parts 1 & 2)
  (C) Copies of all instruments and all recruitment material to be used.
    - If this proposal is part of a grant proposal, include a copy of the proposal.
  (D) The consent form you will use in the study (see part 3 for more information)
  (E) Beginning January 1, 2009: Certificate of Completion of Human Subjects Protection Training for all personnel involved in the project, including students who are involved with testing and handling data, unless already on file with the LSU AgCenter IRB.
  Training link: (http://grants.nih.gov/grants/policy/hs/training.htm)

1) Principal Investigator: Witoon Prinyawiwatkul **Rank:** ________ **Student?** Y/(N)
School: **Nutrition and Food Sciences** **Ph:** 8-5188 **E-mail:** wprinya@lsu.edu
2) Co-Investigator(s): please include department, rank, phone and e-mail for each

- If student as principal or co-investigator(s), please identify and name supervising professor in this space

3) Project Title: Consumer research on products containing edible insects
4) Grant Proposal?(yes or (no) ____ **If Yes, Proposal Number and funding Agency** ________
Also, if Yes, either: **this application completely matches the scope of work in the grant Y/N**__
OR
more IRB applications will be filed later Y/N___
5) Subject pool (e.g. Nutrition Students) **LSU faculty, staff, students, and off-campus consumers**

- Circle any **"vulnerable populations" to be used:** (children<18, the mentally impaired, pregnant women, the aged, other). Projects with incarcerated persons cannot be exempted. **NONE**

6) PI signature ________ ****Date** 3/12/2018 (no per signatures)
****I certify that my responses are accurate and complete.** If the project scope or design is later changed I will resubmit for review. I will obtain written approval from the Authorized Representative of all non-LSU AgCenter institutions in which the study is conducted. I also understand that it is my responsibility to maintain copies of all consent forms at the LSU AgCenter for three years after completion of the study. If I leave the LSU AgCenter before that time the consent forms should be preserved in the Departmental Office.

Committee Action: Exempted ✓ Not Exempted ____ **IRB#** HE 18-9
Reviewer Michael Keenan **Signature** Michael Keenan **Date** 3-19-2018

APPROVED BY
LSU AG CENTER
IRB AS HE18-9
ON 3-19-2018

Research Consent Form

I, ________________________, agree to participate in the study entitled "Consumer Acceptance of Products Containing Edible Insect Protein" which is being conducted by Witoon Prinyawiwatkul, Professor, the School of Nutrition and Food Sciences at Louisiana State University, Agricultural Center, phone number (225) 578-5188.

I understand that participation is entirely voluntary and whether or not I participate will not affect how I am treated at my job. I can withdraw my consent at any time without penalty or loss of benefits to which I am otherwise entitled and have the results of my participation returned to me, removed from the experimental records, or destroyed. Up to 2000 consumers will participate in this research. For this particular study, participation will take about 5-10 minutes per consumer.

The following points have been explained to me:

1. In any case, it is my responsibility to report any food allergies I may have prior to participation to the investigator.

2. The purpose of this research is to gather information on sensory characteristics and purchase intent of new food products. The benefit I may expect from participation is the satisfaction that I have contributed to scientific understanding in the realms of nutrition and food product development.

3. The procedures are as follows: food samples will be placed in front of me, and I will evaluate them and indicate my perceptions via an associated questionnaire. All procedures are standard methods as published by the American Society for Testing and Materials and the Sensory Evaluation Division of the Institute of Food Technologists.

4. Participation entails minimal risk: The only potential risk to consider is that of an allergic reaction to common food ingredients: Edible Insect Protein. However, because it is known to me beforehand that the food to be tested contains these ingredients, the situation can normally be avoided.

5. The results of this study will not be released in any individual identifiable form without my prior consent unless required by law.

6. The investigator will answer any further questions about the research, either now or during the course of the project.

The study has been discussed with me, and all of my questions have been answered. I understand that additional questions regarding the study should be directed to the investigator listed above. In addition, I understand research at the Louisiana State University Agricultural Center involving human participation is carried out under the oversight of the Institutional Review Board. Questions or problems regarding these activities should be addressed to Dr. Michael Keenan, Chair of LSU AgCenter IRB, (225)578-1708. I have read and acknowledge the terms above and voluntarily agree to participate in this research.

________________________ ________________________
Signature of Investigator Signature of Participant

Witness: ________________ Date: ________________________

LSU AgCenter Institutional Review Board (IRB)
Dr. Michael J. Keenan, Chair
School of Nutrition & Food Sciences
209 Knapp Hall
225-578-1708
mkeenan@agctr.lsu.edu

Application for Exemption from Institutional Oversight

All research projects using living humans as subjects, or samples or data obtained from humans must be approved or exempted in advance by the LSU AgCenter IRB. This form helps the principal investigator determine if a project may be exempted, and is used to request an exemption.

- Applicant, please fill out the application in its entirety and include the completed application as well as parts A-E, listed below, when submitting to the LSU AgCenter IRB. Once the application is completed, please submit the original and one copy to the chair, Dr. Michael J. Keenan, in 209 Knapp Hall.

- A Complete Application Includes All of the Following:
  (A) The original and a copy of this completed form and a copy of parts B through E.
  (B) A brief project description (adequate to evaluate risks to subjects and to explain your responses to Parts 1 & 2)
  (C) Copies of all instruments and all recruitment material to be used.
    - If this proposal is part of a grant proposal, include a copy of the proposal.
  (D) The consent form you will use in the study (see part 3 for more information)
  (E) Beginning January 1, 2009: Certificate of Completion of Human Subjects Protection Training for all personnel involved in the project, including students who are involved with testing and handling data, unless already on file with the LSU AgCenter IRB.
  Training link: (http://grants.nih.gov/grants/policy/hs/training.htm)

1) Principal Investigator: Dr. Witoon Prinyawiwatkul **Rank:** Professor **Student? Y/N** NO
Dept: School of Nutrition & Food Sciences **Ph:** (225)578-5188
E-mail: wprinya@lsu.edu
2) Co-Investigator(s): please include department, rank, phone and e-mail for each
- If student as principal or co-investigator(s), please identify and name supervising professor in this space
  - Ashley Gutierrez, Research Associate, School of Nutrition & Food Sciences
  - (225)578-5423, agutierrez@agcenter.lsu.edu

3) Project Title: Consumer Acceptance and Perception of New and Healthier Food Products
4) Grant Proposal?(yes or no) NO **If Yes, Proposal Number and funding Agency**___
Also, if Yes, either: **this application completely matches the scope of work in the grant Y/N**__

OR

more IRB applications will be filed later Y/N___
5) Subject pool (e.g. Nutrition Students) **LSU Faculty, Staff, Students and off-campus consumers**
- Circle any **"vulnerable populations" to be used:** (children<18, the mentally impaired, pregnant women, the aged, other). Projects with incarcerated persons cannot be exempted.

6) PI signature [signature] ****Date** 8/23/18 (no per signatures)
****I certify that my responses are accurate and complete.** If the project scope or design is later changed I will resubmit for review. I will obtain written approval from the Authorized Representative of all non-LSU AgCenter institutions in which the study is conducted. I also understand that it is my responsibility to maintain copies of all consent forms at the LSU AgCenter for three years after completion of the study. If I leave the LSU AgCenter before that time the consent forms should be preserved in the Departmental Office.

Committee Action: Exempted ✓ Not Exempted ___ **IRB#** HE18-22
Reviewer Michael Keenan **Signature** Michael Keenan **Date** 9-5-2018

APPROVED BY
LSU AG CENTER
IRB AS HE18-22
ON 9-5-2018

Research Consent Form (EXAMPLE)

I, ______________________, agree to participate in the research entitled "Consumer Acceptance and Perception of New and Healthier Food Products" which is being conducted by Dr. Witoon Prinyawiwatkul, Professor of the School of Nutrition and Food Sciences at Louisiana State University, Agricultural Center, phone number (225) 578-5188.

I understand that participation is entirely voluntary and whether or not I participate will not affect how I am treated on my job. I can withdraw my consent at any time without penalty or loss of benefits to which I am otherwise entitled and have the results of the participation returned to me, removed from the experimental records, or destroyed. Up to 300 consumers will participate in this research. For this particular research, about 15-20 minutes participation will be required for each consumer.

The following points have been explained to me:

1. In any case, it is my responsibility to report prior to participation to the investigator any food allergies I may have.

2. The reason for the research is to gather information on sensory acceptability, emotion and purchase intent of new and healthier food products. The benefit that I may expect from it is a satisfaction that I have contributed to quality improvement of these products.

3. The procedures are as follows: 3-5 coded samples will be placed in front of me, and I will evaluate them by normal standard methods and indicate my evaluation on score sheets. All procedures are standard methods as published by the American Society for Testing and Materials and the Sensory Evaluation Division of the Institute of Food Technologists.

4. Participation entails minimal risk: The only risk which can be envisioned is that of an allergic reaction toward common food ingredients [red beans, bell pepper, onion, garlic, celery, thyme, cayenne pepper, bay leaf, pork products, rice and rice products, milk and dairy products, yogurt or fermented milk products, peanuts, mayonnaise products, wheat flour, tapioca flour, eggs, table sugar, vanilla, soy products, sweet potato, salt (sodium chloride) and salt substitute (potassium chloride and common amino acids such as glycine and lysine), and plain unsalted crackers]. However, because it is known to me beforehand that the food to be tested contains common food ingredients, the situation can normally be avoided.

5. The results of this study will not be released in any individual identifiable form without my prior consent unless required by law.

6. The investigator will answer any further questions about the research, either now or during the course of the project.

The study has been discussed with me, and all of my questions have been answered. I understand that additional questions regarding the study should be directed to the investigator listed above. In addition, I understand the research at Louisiana State University, Agricultural Center, which involves human participation, is carried out under the oversight of the Institutional Review Board. Questions or problems regarding these activities should be addressed to Dr. Michael Keenan, Chair of LSU AgCenter IRB, (225) 578-1708. I agree with the terms above and acknowledge.

______________________ ______________________
Signature of Investigator Signature of Participant

Witness: ______________ Date: ______________

LIST OF REFERENCES

Adámek, M., Adámková, A., Mlček, J., Borkovcová, M. & Bednářová, M. (2018). Acceptability and sensory evaluation of energy bars and protein bars enriched with edible insect. *Potravinarstvo Slovak Journal of Food Sciences*, **12**(1), 431-437.

Agresti, A. (2019). *An Introduction to Categorical Data Analysis* (3rd ed). Pp. 167-169, 228-229. New Jersey, USA: John Wiley & Sons Inc.

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes*, **50**(2), 179-211.

Akoglu, H. (2018). User's guide to correlation coefficients. *Turkish Journal of Emergency Medicine*, **18**(3), 91-93.

Akullo, J., Nakimbugwe, D., Obaa, B. B., Okwee-Acai, J. & Agea, J. G. (2018). Development and quality evaluation of crackers enriched with edible insects. *International Food Research Journal*, **25**(4), 1592-1599.

Alemu, M. H. & Olsen, S. B. (2018). Can a repeated opt-out reminder mitigate hypothetical bias in discrete choice experiments? An application to consumer valuation of novel food products. *European Review of Agricultural Economics*, **45**(5), 749-782.

Ammann, J., Hartmann, C. & Siegrist, M. (2018). Development and validation of the food disgust picture scale. *Appetite*, **125**, 367-379.

Ardoin, R. & Prinyawiwatkul, W. (2020). Product appropriateness, willingness to try, and perceived risks of foods containing insect protein powder: A survey of US consumers. *International Journal of Food Science &. Technology*, **55**(9), 3215-3226.

Ardoin, R., Gao, Y., Gurdian, C. & Prinyawiwatkul,W. (2019). Insect as a new food source. *Louisiana Agriculture*, **6**(4), 28-29.

Ardoin, R., Romero, R., Marx, B. & Prinyawiwatkul, W. (2020). Exploring new and modified rejection-type thresholds using cricket snack crackers. *Foods*, **9**(10), 1352.

Baker, M. A., Shin, J. T. & 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**(2), 94-112.

Baldi, A. & Gottardo, D. (2017). Livestock production to feed the planet: Animal protein: A forecast of global demand over the next years. *Relations*, **5**(1), 65.

Balzan, S., Fasolato, L., Maniero, S. & Novelli, E. (2016). Edible insects and young adults in a north-east Italian city an exploratory study. *British Food Journal*, **118**(2), 318-326.

Barsics, F., Megido, R.C., Brostaux, Y., Barsics, C., Blecker, C., Haubruge, E. & Francis, F. (2017). Could new information influence attitudes to foods supplemented with edible insects? *British Food Journal*, **119**(9), 2027-2039.

Bartkowicz, J. & Babicz-Zielińska, E. (2020). Acceptance of bars with edible insects by a selected group of students from Tri-City, Poland. *Czech Journal of Food Sciences*, **38**(3), 192-197.

Barton, A., Richardson, C. D. & McSweeney, M. B. (2020). Consumer attitudes toward entomophagy before and after evaluating cricket (*Acheta domesticus*)-based protein powders. *Journal of Food Science,* **85**(3), 781-788.

Batat, W. & Peter, P. (2020). The healthy and sustainable bugs appetite: Factors affecting entomophagy acceptance and adoption in Western food cultures. *Journal of Consumer Marketing*, **37**(3), 291-303.

Batat, W., Peter, P. C., Vicdan, H., Manna, V., Ulusoy, E., Ulusoy, E. & Hong, S. (2017). Alternative food consumption (AFC): Idiocentric and allocentric factors of influence among low socio-economic status (SES) consumers. *Journal of Marketing Management*, **33**(7-8), 580-601.

Belluco, S., Halloran, A. & Ricci, A. (2017). New protein sources and food legislation: The case of edible insects and EU law. *Food Security*, **9**(4), 803-814.

Belluco, S., Losasso, C., Maggioletti, M., Alonzi, C., Ricci, A. & Paoletti, M. G. (2015). Edible insects: a food security solution or a food safety concern? *Animal Frontiers*, **5**(2), 25-30.

Berger, S., Bärtsch, C., Schmidt, C., Christandl, F. & Wyss, A. M. (2018). When Utilitarian claims backfire: Advertising content and the uptake of insects as food. *Frontiers in Nutrition*, **5**(88).

Berger, S., Christandl, F., Bitterlin, D. & Wyss, A. M. (2019). The social insectivore: Peer and expert influence affect consumer evaluations of insects as food. *Appetite*, **141**, 104338.

Biró, B., Fodor, R., Szedljak, I., Pásztor-Huszár, K. & Gere, A. (2019). Buckwheat-pasta enriched with silkworm powder: Technological analysis and sensory evaluation. *LWT*, **116**, 108542.

Braun, V., Rogeaux, M., Schneid, N., O'Mahony, M. & Rousseau, B. (2004). Corroborating the 2-AFC and 2-AC Thurstonian models using both a model system and sparkling water. *Food Quality and. Preference,* **15**(6), 501-507.

Brown, S. A., Venkatesh, V., Kuruzovich, J., & Massey, A. P. (2008). Expectation confirmation: An examination of three competing models. *Organizational Behavior and Human Decision Processes*, **105**(1), 52-66.

Caparros Megido, R. C., Gierts, C., Blecker, C., Brostaux, Y., Haubruge, É., Alabi, T. & Francis, F. (2016). Consumer acceptance of insect-based alternative meat products in Western countries. *Food Quality and Preference*, **52**, 237-243.

Caparros Megido, R., Sablon, L., Geuens, M., Brostaux, Y., Alabi, T., Blecker, C., Drugmand, D., Haubruge, E. & Francis, F. (2014). Edible insects acceptance by Belgian consumers: Promising attitude for entomophagy development. *Journal of Sensory Studies*, **29**(1), 14-20.

Carabante, K. M., Ardoin, R., Scaglia, G., Malekian, F., Khachaturyan, M., Janes, M. E. & Prinyawiwatkul, W. (2018). Consumer acceptance, emotional response, and purchase intent of rib-eye steaks from grass-fed steers, and effects of health benefit information on consumer perception. *Journal of Food Science*, **83**(10), 2560- 2570.

Carcea, M. (2020). Quality and nutritional/textural properties of durum wheat pasta enriched with cricket powder. *Foods*, **9**(9), 1298.

Carretié, L., Mercado, F., Tapia, M. & Hinojosa, J. A. (2001). Emotion, attention, and the 'negativity bias', studied through event-related potentials. *International Journal of Psychophysiology*, **41**(1), 75-85.

Castro Delgado, M., Chambers IV, E., Carbonell-Barrachina, A., Noguera Artiaga, L., Vidal Quintanar, R. & Burgos Hernandez, A. (2020). Consumer acceptability in the USA, Mexico, and Spain of chocolate chip cookies made with partial insect powder replacement. *Journal of Food Science*, **85**(6), 1621-1628.

Castro, M. & Chambers IV, E. (2019). Willingness to eat an insect based product and impact on brand equity: A global perspective. *Journal of Sensory Studies*, **34**(2), e12486.

Chapman, K. W. & Lawless, H. T. (2015). Sources of error and the no-preference option in dairy product testing. *Journal of. Sensory Studies*, **20**(5), 454-468.

Chonpracha, P., Ardoin, R., Gao, Y., Waimaleongora-ek, P., Tuuri, G. & Prinyawiwatkul, W. (2020). Effects of intrinsic and extrinsic visual cues on consumer emotion and purchase intent: A case of ready-to-eat salad. *Foods*, **9**(4), 396.

Christensen, R. H. B., Lee, H. S. & Brockhoff, P. B. (2015). Estimation of the Thurstonian model for the 2-AC protocol. *Food Quality and Preference*, **24**(1), 119-128.

Cicatiello, C., De Rosa, B., Franco, S. & Lacetera, N. (2016). Consumer approach to insects as food: barriers and potential for consumption in Italy. *British Food Journal*, **118**(9), 2271-2286.

Cicatiello, C., Vitali, A. & Lacetera, N. (2020). How does it taste? Appreciation of insect-based snacks and its determinants. *International Journal of Gastronomy and Food Science*, **21**, 100211.

Cito, A., Botta, M., Francardi, V. & Dreassi, E. (2017). Insects as source of angiotensin converting enzyme inhibitory peptides. *Journal of Insects as Food and Feed*, **3**(4), 231-240.

Cochran, W. G. & Cox, G. M. (1992) *Experimental designs*, 2nd ed. Pp. 640. New York, U.S.A.: John Wiley & Sons, Inc.

[CURIA] The Court of Justice of the European Union. (2020). URL curia.europa.eu/juris/document/document_print.jsf?docid=231847&text=&dir=&doclang=EN&part=1&occ=first&mode=lst&pageIndex=0&cid=7643. Accessed 12/03/2020.

de Carvalho, R. J., de Souza Pedrosa, G. T., Chaves, M. G., de Sousa, J. M. B., de Souza, E. L., Pagán, R. & Magnani, M. (2019). Determination of sensory thresholds of *Mentha piperita* L. essential oil in selected tropical fruit juices and efficacy of sensory accepted concentrations combined with mild heat to inactivate foodborne pathogens. *International. Journal of Food Science & Technology*, **54**(6), 2309-2318.

de Castro, R. J. S., Ohara, A., dos Santos Aguilar, J. G. & Domingues, M. A. F. (2018). Nutritional, functional and biological properties of insect proteins: Processes for obtaining, consumption and future challenges. *Trends in Food Science & Technology*, **76**, 82-89.

de Oliveira, L. M., da Silva Lucas, A. J., Cadaval, C. L. & Mellado, M. S. (2017). Bread enriched with flour from cinereous cockroach (*Nauphoeta cinerea*). *Innovative Food Science & Emerging Technologies*, **44**, 30-35.

Delicato, C., Schouteten, J. J., Dewettinck, K., Gellynck, X. & Tzompa-Sosa, D. A. (2020). Consumers' perception of bakery products with insect fat as partial butter replacement. *Food Quality and Preference*, **79**, 103755.

de-Magistris, T., Pascucci, S. & Mitsopoulos, D. (2015). Paying to see a bug on my food. *British Food Journal*, **117**(6), 1777-1792.

Deroy, O., Reade, B. & Spence, C. (2015). The insectivore's dilemma, and how to take the West out of it. *Food Quality and Preference*, **44**, 44-55.

Domjan, M. (2018). Introduction to food neophobia: Historical and conceptual foundations. In S. Reily (Ed.), *Food Neophobia: Behavioral and Biological Influences* (pp. xv-xxx). Sawston, England: Woodhead Publishing.

Elhassan, M., Wendin, K., Olsson, V. & Langton, M. (2019). Quality aspects of insects as food—nutritional, sensory, and related concepts. *Foods*, **8**(3), 95.

Elzerman, J. E., Hoek, A. C., Van Boekel, M. A. & Luning, P. A. (2011). Consumer acceptance and appropriateness of meat substitutes in a meal context. *Food Quality and Preference*, **22**(3), 233-240.

Ennis, D. M. & Collins, J. (1980). The distinction between discrimination and splitting in paired testing. *Phillip Morris Technical Report*, 80-233.

Ennis, D. M. & Ennis, J. M. (2012a). Accounting for no difference/preference responses or ties in choice experiments. *Food Quality and Preference*, **23**(1), 13-17.

Ennis, D. M., Rousseau, B. & Ennis, J. M. (2017). *Tools and Applications of Sensory and Consumer Science*. Pp. 187. Virginia, U.S.A.: The Institute for Perception.

Ennis, J. M. & Ennis, D. M. (2012b). A comparison of three commonly used methods for treating no preference votes. *Journal of Sensory Studies*, **27**(2), 123-129.

Fahrmeir, L., Kneib, T., Lang, S. & Marx, B. (2013). *Regression*: *Models, methods and applications.* Pp. 698. Heidelberg, Germany: Springer-Verlag Berlin Heidelberg.

Fechner, G. T., Howes, D. H. & Boring, E. G. (1966). *Elements of psychophysics* (Vol. 1). Pp. 286. New York, U.S.A.: Holt, Rinehart and Winston.

Fuentes, S., Wong, Y. Y. & Gonzalez Viejo, C. (2020). Non-invasive biometrics and machine learning modeling to obtain sensory and smotional responses from panelists during entomophagy. *Foods*, **9**(7), 903.

Gaby, J. M., Bakke, A. J., Baker, A. N., Hopfer, H. & Hayes, J. E. (2020). Individual differences in thresholds and consumer preferences for rotundone added to red wine. *Nutrients*. **12**(9), 2522.

Galesic, M. & Bosnjak, M. (2009). Effects of questionnaire length on participation and indicators of response quality in a web survey. *Public Opinion Quarterly*, **73**(2), 349-360.

Gamba, M. M., Lima Filho, T., Della Lucia, S. M., Vidigal, M. C. T. R., Simiqueli, A. A. & Minim, V. P. R. (2020). Performance of different scales in the hedonic threshold methodology. *Journal of. Sensory Studies*, e12592.

Gere, A., Székely, G., Kovács, S., Kókai, Z. & 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. & 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.

González, C. M., Garzón, R. & Rosell, C. M. (2019). Insects as ingredients for bakery goods. A comparison study of *H. illucens*, *A. domestica* and *T. molitor* flours. *Innovative Food Science & Emerging Technologies*, **51**, 205-210.

Haber, M., Mishyna, M., Martinez, J. I. & Benjamin, O. (2019). The influence of grasshopper (*Schistocerca gregaria*) powder enrichment on bread nutritional and sensorial properties. *LWT*, **115**, 108395.

Halloran, A., Flore, R., Vantomme, P. & Roos, N. (Eds.). (2018). *Edible Insects in Sustainable Food Systems*. Pp. vii. Cham, Switzerland: Springer.

Halloran, A., Vantomme, P., Hanboonsong, Y. & Ekesi, S. (2015). Regulating edible insects: The challenge of addressing food security, nature conservation, and the erosion of traditional food culture. *Food Security*, **7**(3), 739-746.

Hamerman, E. J. (2016). Cooking and disgust sensitivity influence preference for attending insect-based food events. *Appetite*, **96**, 319-326.

Hartmann, C. & Siegrist, M. (2016). Becoming an insectivore: Results of an experiment. *Food Quality and Preference*, **51**, 118-122.

Hartmann, C. & Siegrist, M. (2017). Consumer perception and behaviour regarding sustainable protein consumption: A systematic review. *Trends in Food Science & Technology*, **61**, 11-25.

Hartmann, C. & Siegrist, M. (2018). Development and validation of the Food Disgust Scale. *Food Quality and Preference*, **63**, 38-50.

Hartmann, C., Ruby, M. B., Schmidt, P. & Siegrist, M. (2018). Brave, health-conscious, and environmentally friendly: Positive impressions of insect food product consumers. *Food Quality and Preference*, **68**, 64-71.

Hénault-Ethier, L., Marquis, D., Dussault, M., Deschamps, M. H. & Vandenberg, G. (2020). Entomophagy knowledge, behaviours and motivations: the case of French Quebeckers. *Journal of Insects as Food and Feed*, **6**(3), 245-259.

Holt, V. M. (1885). *Why Not Eat Insects?* London, England: Field & Tuer.

House, J. (2016). Consumer acceptance of insect-based foods in the Netherlands: Academic and commercial implications. *Appetite*, **107**, 47-58.

Huberty, C. J. & Olejnik, S. (2006). *Applied MANOVA and Discriminant Analysis*, 2nd ed. Pp. 30-31. New Jersey, U.S.A.: John Wiley & Sons, Inc.

Iannuzzi, E., Sisto, R. & Nigro, C. (2019). The willingness to consume insect-based food: An empirical research on Italian consumers. *Agricultural Economics*, **65**(10), 454-462.

[IFPress] The Institute for Perception. (2010). URL https//4af02ab6-d153-465a-9114-bee006e9f927.filesusr.com/ugd/08eb6e_70ca560bccbe4545be0e86ae0af2e700.pdf. Accessed 12/02/2020.

Jensen, N. H. & 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.

Joseph, P., Searing, A., Watson, C. & McKeague, J. (2020). Alternative proteins: Market research on consumer trends and emerging landscape. *Meat and Muscle Biology*, **4**(2):16, 1-11.

Kauppi, S. M., Pettersen, I. N. & Boks, C. (2019). Consumer acceptance of edible insects and design interventions as adoption strategy. *The International Journal of Food Design*, **4**(1), 39-62.

Kim, H. S., Lee, H. S., O'Mahony, M. & Kim, K. O. (2008). Paired preference tests using placebo pairs and different response options for chips, orange juices and cookies. *Journal of Sensory Studies*, **23**(3), 417-438.

Köster, E. P. (2003). The psychology of food choice: Some often encountered fallacies. *Food Quality and Preference*, **14**(5-6), 359-373.

Köster, E. P. (2009). Diversity in the determinants of food choice: A psychological perspective. *Food Quality and Preference*, **20**(2), 70-82.

Kouřimská, L. & Adámková, A. (2016). Nutritional and sensory quality of edible insects. *NFS Journal*, **4**, 22-26.

Kuttiyatveetil, J. R., Mitra, P., Goldin, D., Nickerson, M. T. & Tanaka, T. (2019). Recovery of residual nutrients from agri-food byproducts using a combination of solid-state fermentation and insect rearing. *International Journal of Food Science & Technology*, **54**(4), 1130-1140.

La Barbera, F., Verneau, F. & Coppola, A. (2019). Entomophagy: A contribution to the understanding of consumer intention. *Quality-Access to Success*, **20**(S2), 329-334.

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.

La Barbera, F., Verneau, F., Videbæk, P. N., Amato, M., & Grunert, K. G. (2020). A self-report measure of attitudes toward the eating of insects: construction and validation of the Entomophagy Attitude Questionnaire. *Food Quality and Preference*, **79**, 103757.

Labrecque, J., Doyon, M., Bellavance, F. & Kolodinsky, J. (2006). Acceptance of functional foods: A comparison of French, American, and French Canadian consumers. *Canadian Journal of Agricultural Economics*, **54**(4), 647-661.

Lacroix, I. M., Dávalos Terán, I., Fogliano, V. & Wichers, H. J. (2019). Investigation into the potential of commercially available lesser mealworm (*A. diaperinus*) protein to serve as sources of peptides with DPP-IV inhibitory activity. *International Journal of Food Science & Technology*, **54**(3), 696-704.

Lähteenmäki-Uutela, A., Grmelova, N., Henault-Ethier, L., Deschamps, M. H., Vandenberg, G. W., Zhao, A., Zhang, Y., Yang, B. & Nemane, V. (2017). Laws of the European Union, United States, Canada, Mexico, Australia, and China. *European Food and Feed Law Review*, **12**(1), 22–36.

Lammers, P., Ullmann, L. M. & 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.

Laureati, M., Proserpio, C., Jucker, C. & Savoldelli, S. (2016). New Sustainable protein sources: Consumers' willingness to adopt insects as feed and food. *Italian Journal of Food Science*, **28**(4), 652-668.

Lawless, H. T. & Heymann, H. (2010) *Sensory Evaluation of Food: Principles and Practices*, 2nd ed. New York, U.S.A.: Springer Science + Business Media.

Le Goff, G. & Delarue, J. (2017). Non-verbal evaluation of acceptance of insect-based products using a simple and holistic analysis of facial expressions. *Food Quality and Preference*, **56**, 285-293.

Lenglet, F. (2018). FNS or the Varseek-scale? Proposals for a valid operationalization of neophilia. *Food Quality and Preference*, **66**, 76-84.

Lima Filho, T., de Souza, L. B. A., Della Lucia, S. M., Minim, L. A. & Minim, V. P. R. (2020). The hedonic thresholds methodology varying two stimuli: extending the range of sensory threshold applications. *Food Quality and Preference*, **86**, 104003.

Lima Filho, T., Della Lucia, S. M., Minim, L. A., da Silva, R. D. C. D. S. N., da Silva, A. N. & Minim, V. P. R. (2017). Validation of the hedonic threshold methodology in determining the compromised acceptance threshold. *Journal of. Sensory Studies*, **32**(2), e12255.

Lima Filho, T., Della Lucia, S. M., Minim, L. A., Gamba, M. M., Lima, R. M. & Minim, V. P. R. (2019). Directional hedonic thresholds for sodium concentration in hamburger. *Food Quality and. Preference*, **78**, 103722.

Lima Filho, T., Della Lucia, S. M., Scolforo, C. Z., Lima, R. M., Carneiro, J. C. S., Pinheiro, C. J. G., Junior, J. L. P. & Minim, V. P. R. (2014). Consumer rejection threshold for strawberry radiation doses. *Innovative Food Science & Emerging Technologies*, **23**, 194-198.

Lima Filho, T., Minim, V. P. R., dos Santos Navarro, R. D. C., Della Lucia, S. M. & Minim, L. (2015). A. methodology for determination of two new sensory thresholds: Compromised acceptance threshold and rejection threshold. *Food Research International*,**76**, 561-566.

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.

Looy, H. & Wood, J. R. (2006). Attitudes toward invertebrates: Are educational "bug banquets" effective? *The Journal of Environmental Education*, **37**(2), 37-48.

Looy, H., Dunkel, F. V. & Wood, J. R. (2014). How then shall we eat? Insect-eating attitudes and sustainable foodways. *Agriculture and Human Values*, **31**(1), 131-141.

Mancini, S., Moruzzo, R., Riccioli, F. & Paci, G. (2019). 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. & Paci, G. (2019b). Factors predicting the intention of eating an insect-based product. *Foods*, **8**(7), 270.

Meilgaard, M. C., Carr, B. T. & Civille, G. V. (2006). *Sensory evaluation techniques*, 4th ed. Florida, U.S.A: CRC press.

Meiselman, H. L., King, S. C. & Gillette, M. (2010). The demographics of neophobia in a large commercial US sample. *Food Quality and Preference*, **21**(7), 893-897.

Melgar-Lalanne, G., Hernández-Álvarez, A. J. & Salinas-Castro, A. (2019). Edible insects processing: Traditional and innovative technologies. *Comprehensive Reviews in Food Science and Food Safety*, **18**(4), 1166-1191.

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.

Methven, L., Xiao, C., Cai, M. & Prescott, J. (2016). Rejection thresholds (RjT) of sweet likers and dislikers. *Food Quality and. Preference*, **52**, 74-80.

Mishyna, M., Chen, J. & Benjamin, O. (2019). Sensory attributes of edible insects and insect-based foods–Future outlooks for enhancing consumer appeal. *Trends in Food Science & Technology*, **95**, 141-148.

Modlinska, K., Adamczyk, D., Goncikowska, K., Maison, D. & Pisula, W. (2020). The effect of labelling and visual properties on the acceptance of foods containing insects. *Nutrients*, **12**(9), 2498.

Montowska, M., Kowalczewski, P. Ł., Rybicka, I. & Fornal, E. (2019). Nutritional value, protein and peptide composition of edible cricket powders. *Food Chemistry*, **289**, 130-138.

Nestrud, M. A., Meiselman, H. L., King, S. C., Lesher, L. L. & Cardello, A. V. (2016). Development of EsSense25, a shorter version of the EsSense Profile®. *Food Quality and Preference*, **48**, 107-117.

Nongonierma, A. B. & FitzGerald, R. J. (2017). Unlocking the biological potential of proteins from edible insects through enzymatic hydrolysis: A review. *Innovative Food Science & Emerging Technologies*, **43**, 239-252.

Oberhauser, F. B. & Czaczkes, T. J. (2018). Tasting the unexpected: Disconfirmation of expectations leads to lower perceived food value in an invertebrate. *Biology Letters*, **14**(9), 20180440.

O'Mahony, M. & Rousseau, B. (2003). Discrimination testing: A few ideas, old and new. *Food Quality and Preference*, **14**(2), 157-164.

Osimani, A., Milanović, V., Cardinali, F., Roncolini, A., Garofalo, C., Clementi, F., Pasquini, M., Mozzon, M., Foligni, R., Raffaelli, N., Zamporlini, F. & Aquilanti, L. (2018). Bread enriched with cricket powder (*Acheta domesticus*): A technological, microbiological and nutritional evaluation. *Innovative Food Science & Emerging Technologies,* **48**, 150-163.

Palmieri, N., Perito, M. A., Macrì, M. C., & Lupi, C. (2019). Exploring consumers' willingness to eat insects in Italy. *British Food Journal*, **121**(11), 2937-2950.

Pambo, K. O., Okello, J. J., Mbeche, R. M., Kinyuru, J. N. & Alemu, M. H. (2018). The role of product information on consumer sensory evaluation, expectations, experiences and emotions of cricket-flour-containing buns. *Food Research International*, **106**, 532-541.

Pauter, P., Różańska, M., Wiza, P., Dworczak, S., Grobelna, N., Sarbak, P. & Kowalczewski, P. Ł. (2018). Effects of the replacement of wheat flour with cricket powder on the characteristics of muffins. *Acta Scientiarum Polonorum Technologia Alimentaria*, **17**(3), 227-233.

Payne, C. L., Scarborough, P., Rayner, M. & 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.

Pennisi, E. (2015). All in the (bigger) family. *Science*, **347**, 220-221.

Pew Research Center (2018). URL https://www.pewresearch.org/st_18-02-27_generations_defined/. Accessed 12/02/2020.

Piha, S., Pohjanheimo, T., Lähteenmäki-Uutela, A., Křečková, Z. & 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. & Hobden, K. (1992). Development of a scale to measure the trait of food neophobia in humans. *Appetite*, **19**(2), 105-120.

Prescott, J., Norris, L., Kunst, M. & Kim, S. (2005). Estimating a "consumer rejection threshold" for cork taint in white wine. *Food Quality and Preference*, **16**(4), 345-349.

Pujols, K. D., Ardoin, R., Chaiya, B., Tuuri, G. & Prinyawiwatkul, W. (2019). Low-sodium roasted peanuts: Effects of salt mixtures (NaCl, KC l and glycine) on consumer perception and purchase intent. *International Journal of Food Science and Technology*, **54**(9), 2754-2762.

R Core Team. *R: A Language and Environment for Statistical Computing*; R Foundation for Statistical Computing: Vienna, Austria, 2019; https://www.R-project.org

Ribeiro, J. C., Cunha, L. M., Sousa-Pinto, B. & Fonseca, J. (2018). Allergic risks of consuming edible insects: A systematic review. *Molecular Nutrition & Food Research*, **62**(1), 1700030.

Ribeiro, J. C., Lima, R. C., Maia, M. R., Almeida, A. A., Fonseca, A. J., Cabrita, A. R. J. & Cunha, L. M. (2019). Impact of defatting freeze-dried edible crickets (*Acheta domesticus* and *Gryllodes sigillatus*) on the nutritive value, overall liking and sensory profile of cereal bars. *LWT*, **113**, 108335.

Roma, R., Ottomano Palmisano, G. & De Boni, A. (2020). Insects as novel food: A consumer attitude analysis through the dominance-based rough set approach. *Foods*, **9**(4), 387.

Roncolini, A., Milanović, V., Cardinali, F., Osimani, A., Garofalo, C., Sabbatini, R., Clementi, F., Pasquini, M., Mozzon, M., Foligni, R., Raffaelli, N., Zamporlini, F., Minazzato, G., Trombetta, M. F., Van Buitenen, A., Van Campenhout, L. & Aquilanti, L. (2019). Protein fortification with mealworm (Tenebrio molitor L.) powder: Effect on textural, microbiological, nutritional and sensory features of bread. *PLOS ONE*, **14**(2), e0211747.

Roosen, J., Marette, S., Blanchemanche, S. & Verger, P. (2007). The effect of product health information on liking and choice. *Food Quality and Preference*, **18**(5), 759-770.

Rozin, P. & Fallon, A. E. (1987). A perspective on disgust. *Psychological Review*, **94**(1), 23.

Ruby, M. B., Rozin, P. & Chan, C. (2015). Determinants of willingness to eat insects in the USA and India. *Journal of Insects as Food and Feed*, **1**(3), 215-225.

Saliba, A. J., Bullock, J. & Hardie, W. J. (2009). Consumer rejection threshold for 1, 8-cineole (eucalyptol) in Australian red wine. *Food Quality and Preference.* **20**(7), 500-504.

Schäufele, I., Albores, E. B. & Hamm, U. (2019). The role of species for the acceptance of edible insects: Evidence from a consumer survey. *British Food Journal*, **12**(9), 2190-2204.

Scherer, K. R. (2005). What are emotions? And how can they be measured? *Social Science Information*, **44**(4), 695-729.

Schlup, Y. & Brunner, T. (2018). Prospects for insects as food in Switzerland: A tobit regression. *Food Quality and Preference*, **64**, 37-46.

Schouteten, J. J., De Steur, H., De Pelsmaeker, S., Lagast, S., Juvinal, J. G., De Bourdeaudhuij, I., Verbeke, W. & Gellynck, X. (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.

Schutz, H. G. & Martens, M. (2001). Appropriateness as a cognitive-contextual measure of food attitudes. In: Frewer, L. J., Risvik, E. & Schifferstein H. (Eds.). *Food, People and Society.* Pp. 247-266. Germany: Springer- Verlag Berlin Heidelberg.

Searchinger, T., Waite, R., Hanson, C., Ranganathan, J., Dumas, P., Matthews, E. & Klirs, C. (2019). *Creating a Sustainable Food Future: A Menu of Solutions to Feed Nearly 10 Billion People by 2050* (final report). Washington, D.C., U.S.A.: World Resources Institute.

Sharma, G. & Bala, R. (Eds.). (2017). *Digital Color Imaging Handbook*. Florida, U.S.A.: CRC Press.

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.

Simpson, J., Carter, S., Anthony, S. H. & Overton, P. G. (2006). Is disgust a homogeneous emotion? *Motivation and Emotion*, **30**(1), 31-41.

Sipponen, M. H., Mäkinen, O. E., Rommi, K., Heiniö, R. L., Holopainen-Mantila, U., Hokkanen, S., Hakala, T. K. & Nordlund, E. (2018). Biochemical and sensory characteristics of the cricket and mealworm fractions from supercritical carbon dioxide extraction and air classification. *European Food Research and Technology*, **244**(1), 19-29.

Smarzyński, K., Sarbak, P., Musiał, S., Jeżowski, P., Piątek, M. & Kowalczewski, P. Ł. (2019). Nutritional analysis and evaluation of the consumer acceptance of pork pâté enriched with cricket powder-preliminary study. *Open Agriculture*, **4**(1), 159-163.

Sogari, G., Bogueva, D. & Marinova, D. (2019a). Australian consumers' response to insects as food. *Agriculture*, **9**(5), 108.

Sogari, G., Menozzi, D. & Mora, C. (2018). Sensory-liking expectations and perceptions of processed and unprocessed insect products. *International Journal on Food System Dynamics*, **9**(4), 314-320.

Sogari, G., Menozzi, D. & Mora, C. (2019b). The food neophobia scale and young adults' intention to eat insect products. *International Journal of Consumer Studies*, **43**(1), 68-76.

Sogari, G., Mora, C., & Menozzi, D. (Eds.). (2019c). *Edible Insects in the Food Sector: Methods, Current Applications and Perspectives*. Pp. 3, 114. Chan, Switzerland: Springer Nature.

Stone, H., Bleibaum, R. N. & Thomas, H. A. (2012). *Sensory Evaluation Practices*. Massachusetts, U.S.A.: Academic Press.

Sukkhown, P., Pirak, T., Chonpracha, P., Ardoin, R. & Prinyawiwatkul, W. (2019). Seafood flavor perception, liking, emotion, and purchase intent of coated peanuts as affected by coating color and hydrolyzed squid peptide powder. *Journal of Food Science*, **84**(6), 1570-1576.

Sun, X. & Yang, Z. (2008). Generalized McNemar's test for homogeneity of the marginal distributions. In *SAS Global forum* (Vol. 382, pp. 1-10).

Swets, J. A. (1961). Is there a sensory threshold? *Science*, **134**(3473), 168-177.

Tan, H. S. G., Fischer, A. R., Tinchan, P., Stieger, M., Steenbekkers, L. P. A. & van Trijp, H. C. (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., Fischer, A. R., van Trijp, H. C. & Stieger, M. (2016). 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., Tibboel, C. J. & Stieger, M. (2017a). 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., Verbaan, Y. T. & Stieger, M. (2017b). How will better products improve the sensory-liking and willingness to buy insect-based foods? *Food Research International*, **92**, 95–105.

Tao, J. & Li, Y. O. (2018). Edible insects as a means to address global malnutrition and food insecurity issues. *Food Quality and Safety*, **2**(1), 17-26.

Thurstone, L. L. (1927). A law of comparative judgment. *Psychological Review*, **34**(4), 273-286.

Toti, E., Massaro, L., Kais, A., Aiello, P., Palmery, M. & Peluso, I. (2020). Entomophagy: A narrative review on nutritional value, safety, cultural acceptance and a focus on the role of food neophobia in Italy. *European Journal of Investigation in Health, Psychology and Education*, **10**(2), 628-643.

Tuccillo, F., Marino, M. G. & Torri, L. (2020). Italian consumers' attitudes towards entomophagy: Influence of human factors and properties of insects and insect-based food. *Food Research International*, **137**, 109619.

Tunick, M. H., Onwulata, C. I., Thomas, A. E., Phillips, J. G., Mukhopadhyay, S., Sheen, S., Liu, C., Latona, N., Pimentel, M. R. & Cooke, P. H. (2013). Critical evaluation of crispy and crunchy textures: A review. *International Journal of Food Properties*, **16**(5), 949-963.

van Huis, A., Van Itterbeeck, J., Klunder, H., Mertens, E., Halloran, A., Muir, G. & Vantomme, P. (2013). *Edible Insects: Future Prospects for Food and Feed Security* (No. 171). Rome, Italy: Food and Agriculture Organization of the United Nations.

Van Thielen, L., Vermuyten, S., Storms, B., Rumpold, B. & Van Campenhout, L. (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.

van Trijp, J. C. M. & Steenkamp, J. E. B. M. (2005). Consumer-oriented new product development: principles and practice. In: Jongen, W. M. F. & Meulenberg, M. T. G. (Eds.). *Innovation in Agri-food Systems*. Pp. 87-124. The Netherlands: Wageningen Academic Publishers.

Vane-Wright, R. I. (1991). Why not eat insects? *Bulletin of Entomological Research*, **81**(1), 1-4.

Vanhonacker, F., Van Loo, E. J., Gellynck, X. & Verbeke, W. (2013) Flemish consumer attitudes towards more sustainable food choices. *Appetite*, **62**, 7-16.

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.

Wardy, W., Jack, A. R., Chonpracha, P., Alonso, J. R., King, J. M. & Prinyawiwatkul, W. (2018). Gluten-free muffins: effects of sugar reduction and health benefit information on consumer liking, emotion, and purchase intent. *International Journal of Food Science & Technology*, **53**(1), 262-269.

Woolf, E., Zhu, Y., Emory, K., Zhao, J. & Liu, C. (2019). Willingness to consume insect-containing foods: A survey in the United States. *LWT*, **102**, 100-105.

Zielińska, E., Baraniak, B. & Karaś, M. (2018). Identification of antioxidant and anti-inflammatory peptides obtained by simulated gastrointestinal digestion of three edible insects species (*Gryllodes sigillatus, Tenebrio molitor, Schistocerca gragaria*). *International Journal of Food Science & Technology*, **53**(11), 2542-2551.

Zielińska, E., Zieliński, D., Karaś, M. & Jakubczyk, A. (2020). Exploration of consumer acceptance of insects as food in Poland. *Journal of Insects as Food and Feed*, **6**(4) 383-392.

Zuckerman, M. (2009). Sensation seeking. In: Leary, M. R. & Hoyle, R. H. (Eds.). *Handbook of Individual Differences in Social Behavior*. Pp. 455-465. New York, U.S.A.: The Guilford Press.

VITA

Ryan Paul Ardoin was born in Lafayette, LA, graduated high school from the Louisiana School for Math Science and the Arts, and subsequently enrolled at Louisiana State University in 2003. Five years after earning a B.S. in Psychology, he returned to LSU to study Food Science and has since found his niche as a food sensory scientist. Upon completion of his doctorate degree, Ryan intends to benefit society through impactful professional research.