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Editorial office

jiff@wageningenacademic.com

Orders and claims

P.O. Box 220
6700 AE Wageningen
The Netherlands
jiff_cr@wageningenacademic.com
Tel: +31 317 476516
Fax: +31 317 453417

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Determinants of willingness to eat insects in the USA and India

M.B. Ruby*, **P. Rozin, and C. Chan**

University of Pennsylvania, Department of Psychology, 3720 Walnut St., Philadelphia, PA 19103-1369, USA; mattruby@psych.upenn.edu

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RESEARCH ARTICLE

Abstract

One of the major, if not the major impediment to large scale increases of human insect consumption, is the strong rejection of insects as food by most of the world's population. In an effort to understand this aversion, we surveyed online samples of adults living in the USA and India to participate in a study on 'attitudes toward food'. A substantial proportion of both Americans (72%) and Indians (74%) were at least willing to consider eating some form of insect food. Men were more willing to try eating insects than were women, especially in the USA. Disgust seems to be the most common reaction of both groups at the prospect of eating insects. The most common perceived benefits of eating insects were related to nutrition and environmental sustainability, and the most common risks related to risk of disease and illness. Both groups find ants the most palatable of a set of seven possible insects, and cockroaches the most unpalatable. In both samples, participants were most amenable to eating low levels of insect flour in a favourite food, and most averse to consuming whole insects. The best predictors of insect acceptance were disgust at the thought of eating insects, beliefs about the benefits of eating insects, sensation seeking, and the enjoyment of telling others about consumption of unusual foods.

Keywords: acceptance, attitudes, culture, disgust, entomophagy

1. Introduction

It has become increasingly clear in the last decade that insects offer a promising way of addressing the global problem of food security. Following up on Holt's 1885 (1992) classic, 'Why not eat insects?', a number of entomologists have written about the advantages of eating insects. DeFoliart (1999), Looy *et al.* (2013), DeFoliart *et al.* (2009), Van Huis *et al.* (2013), Ramos-Elorduy (2009), Paoletti and Dreon (2005), Raubenheimer and Rothman (2013) and Yen (2009) have thoroughly covered the promise of insects as food, from ethnographic, entomological, economic, nutritional, and health perspectives. The entire picture is ably summarised in Van Huis *et al.* (2013). Van Huis *et al.* (2014) have recently published an insect cookbook and Martin (2014) has recently published a trade book on the subject of eating insects. These sources document that many species of insects are nutritious, widely eaten, non-toxic, and abundant, and compared to common domesticated animals, they are more efficient at converting plant to animal calories, have a smaller ecological footprint, are easier to farm, and cause less concern to most people in terms of issues of cruelty in rearing and killing.

There is some encouraging information about the prospects of increased insect consumption. Many human children under two years of age eat insects, and insects are already a favoured food in many regions of the world, especially in parts of Latin America, West Africa, and Southeast Asia. As noted by many of the authors in the reviews cited above, the main reason for rejection of insects as food is likely disgust, but there is no direct evidence for this. Sushi (usually based on raw fish) often elicits disgust in those not familiar with it, but has become extremely popular in the Western world, ranking as the 10th favourite food among Americans (GlobeScan, 2011). As such, it may constitute a model for insect acceptance. Finally, insects generally have a mild, nutty taste, and textures that can be appealing, ranging from crispy to soft.

With respect to insect consumption, one can roughly divide adult humans into four groups. The smallest is people in

the developed world who enjoy and savour insects – these are primarily 'foodies.' The second category is people in the developed world who reject insects (perhaps about 1 billion people). The third is people in the developing world who traditionally consume and value insects (again, perhaps about 2 billion people; Van Huis *et al.*, 2013). The most critical and largest category is people in the developing world who do not consume insects (approximately 4 billion people). This largest group could have the most to gain by including insects in their diet, because many of these people have a diet with either a suboptimal caloric or protein intake (e.g. FAO, 2014). Strategies for increasing insect intake in the two non-consuming groups may be different. It is for this reason that we recruited participants from two very different cultural contexts – India and the USA.

Human food choice

There are four different ways to measure how people respond to a particular food intake, preference, liking, and willingness to try. The first step in introducing a food is willingness to try it, and as many people have never eaten insects before, various elaborations of this measure form the core of the insect acceptance measures that we explore here.

There are two major routes through which new foods become part of a country's or culture's diet. One, top-down, involves initial use by upper-class individuals. The prestige of these groups encourages wider ingestion, especially as the food involved becomes less expensive. The Nordic Food Lab (2014) in Copenhagen, Denmark, takes this approach, by working on recipes designed to make insects delicious. The second route, bottom-up, often involves use by a relatively poor immigrant group, spreading from this origin to a wide range of people in the host country. A prime example of this is pizza, introduced to the USA via Italian immigrants, which has become the favourite food among Americans (GlobeScan, 2011).

The two great challenges for insect promoters are to: (1) make them inexpensive, especially for the most critical group, non-insect eaters in developing countries; and (2) make insect consumption more acceptable. The two challenges are related. The bigger the demand, the more likely it is that food companies in the developed world, which have found many ways to make all sorts of foods less expensive (e.g. via breeding, efficient production systems) will turn their efforts to producing palatable and inexpensive insect products. The more they do this, the more people will be inclined to try and adopt them.

Disgust

Disgust is a basic reaction that people have to certain potential foods (Rozin and Fallon, 1987; Rozin *et al.*, 2008). Disgust appears to be uniquely human, and entirely acquired, arising in the period between about two and five years of age. Human infants will put anything into their mouths, including insects and faeces, the universal disgust elicitor. Disgust is not primarily based on the sensory properties of potential foods, but rather it is based on knowledge of the nature or history of a potential food. A person might like the taste of grilled and ground earthworms, if they did not know the source of the food. Once discovering the earthworm origin of this food, the same taste would likely become disgusting.

A basic feature of disgusting entities is that if they contact an otherwise desirable food, they tend to render it inedible, and even disgusting. To take an apt example, if a dead cockroach comes into contact with a favourite food, for most people in the world that food will be rejected. Disgusting entities are contaminating (Rozin *et al.*, 1986).

Around the world, almost all the potential foods that are disgusting, and hence contaminating, are of animal origin (e.g. Angyal, 1941; Fessler and Navarette, 2003; Simoons, 1994). For a typical American, only the cooked muscle tissue of cows, pigs, and lamb is considered edible. Other parts of these animals, such as skins, eyes, or internal organs are considered disgusting, as is the muscle of all other mammals. Almost every animal on earth is disgusting to most Americans. A smaller number, but still the vast majority of animals and animal products, are disgusting to most Chinese. Thus, disgust to insects is not a unique property of insects, as they share this property with almost all animals on earth.

Hedonic reversals, where a substance initially disliked becomes liked, are common in humans, and include chili pepper, coffee, and carbonated beverages (Rozin *et al.*, 2013). Insects are generally considered disgusting, but people can come to enjoy disgusting things. Cheese (decayed milk) is an obvious example in Western cultures, but there are many other examples around the world, for example, the fermented fish sauces that are a basic flavouring in many foods in Southeast Asia.

The present studies

The present study reports results from an online survey of 220 Americans and 179 Indians. We present basic data on willingness to try eating insects, either as insect flour, or as whole insects, incorporated into different dishes. We then assess which insects, in which form (e.g. whole insect, insect flour) elicit the highest acceptance, solicit free responses for reasons for rejecting insects as food, and perceived risks and benefits of eating insects, and finally examine some demographic, trait, and insect-specific factors (e.g. disgust at eating insects) that predict acceptance.

2. Materials and methods

Participants

We recruited a total of 502 people – 200 from the USA and 302 from India, via Amazon.com's MTurk portal (an online, inexpensive, and reliable source of data; Buhrmeister *et al.*, 2011), to take part in a study on 'attitudes toward food'. Participants were paid a modest sum for their time. Although MTurk workers have a broad range of age, education level, and socioeconomic status, MTurk does not provide nationally representative samples. Research suggests that American MTurkers are somewhat younger and more highly educated than the average American, and these differences in age and education are even more pronounced in India. MTurk workers, by definition, have access to an internet connection.

To ensure more representative cross-cultural comparisons, we systematically excluded data from any participants who were not raised in their current country of residence (12 in India, 9 in the USA). To ensure accuracy in responses, we excluded any participants who failed either of two catch questions (70 in India, 12 in the USA). The catch questions were 'Please identify the item in the group that does not belong with the other two (cat, dog, potato)', and 'I would rather eat a piece of fruit than a piece of paper.' Answering cat or dog to the first question, and disagreeing with the second question, counted as an attention check failure. For all analyses in this study, we included participants of all dietary backgrounds. If we limit the analyses to non-vegetarians, the overall pattern of our findings remains unchanged.

The final sample included 220 participants from India (39% women; mean age (M_{age}) = 31.2, standard deviation (SD_{age}) = 9.27; 93% South Asian, 7% other; 54% omnivore, 18% partial vegetarian, 18% vegetarian/vegan; 70% Hindu, 14% Catholic, 10% Muslim; 89% college educated) and 179 participants from the USA (60% women, M_{age}=38.2, SD_{age}=14.2; 79% Caucasian, 9% Black, 5% Asian, 4% Latina/o, 4% other; 87% omnivore, 7% partial vegetarian, 6% vegetarian; 35% Protestant, 30% Atheist/Agnostic, 16% Catholic, 17% other; 52% college educated).

Willingness to eat insects

In addition to basic demographics, participants indicated their willingness to eat insects in different dishes, incorporated either as insect flour, or whole. Given the cross-cultural nature of this study, we tried to create a set of items that could be used in both India and the USA. For all items, participants were told 'assume there is no risk of toxicity or infection from consuming insects, as they have been heat-sterilised and certified safe to eat.'

Participants viewed a colour picture of mealworms, with the caption: 'Mealworms are the larvae of a species of beetle and have the following appearance. Mealworm flour is a powder made from roasted (heat sterilised and non-toxic) mealworms. The flour has a mild taste.' Participants were shown a photograph of a chocolate chip cookie and *paratha* (an Indian flatbread), and were asked: 'What is the highest % mealworm flour you would be comfortable tasting in the following cookie/*paratha*?'. The choices offered were 0%, 0.1%, 1%, 5%, 10% and ≥25%. The third item was personalised: 'What is the highest level of mealworm flour that you would be willing to taste when incorporated into a favourite dish of yours?'.

Participants were then shown photographs of: (1) tacos with grasshoppers clearly displayed inside; (2) a *dosa* (an Indian crepe made of rice and lentil flour), rolled up with a (non-visible, but verbally described) filling of potatoes and grasshoppers; and (3) six transparent commercial lollipops, half containing a mealworm and half containing a grasshopper. For each food, participants were asked: 'How willing would you be to taste …?' The possible answers were on a five point scale: 1: I would never eat it under any conditions; 2: I would eat it only if my survival depended on it; 3: I am unsure if I would ever consume it; 4: I could be persuaded to consume it; 5: I would be glad to consume it.

Encouraging insect eating

One could favour insect eating as a social policy without personally being willing to try it, which we call 'encouragement'. Participants responded to the following two questions, rated on a standard 7-point agree-disagree scale: 'We should encourage research on insects as food', and 'We should support programs designed to encourage people to consume insects'.

Form and species preferences

A major way to promote insect eating is to make the object of choice as appealing as possible. To this end, we asked questions about the most acceptable insect species to use and the most acceptable form of preparation. Participants ranked their willingness to eat insects in four different forms: whole insects prepared alone, insects chopped into tiny pieces, insects blended into a puree, and insects as insect flour. Next, from a list of seven insects – ant, cockroach, mealworm, cricket/grasshopper, caterpillar, and beetle – participants ranked their willingness to eat them: (1) plain (heat-sterilised); and, separately, (2) ground into insect flour and baked into a cookie (2% of total cookie weight).

Free responses

All participants were asked: 'If you have not been willing to consume a food with ANY insect flour in it, please indicate

your reasons'. Responses were coded as being in any of five categories (the remainder categorised as 'other'; USA 5%, India 4%). Next, all participants were asked: 'To the best of your knowledge, list any benefits you see associated with insect eating'. Responses were coded as being in any of six categories, or 'no benefits' (the remainder coded as 'other'; USA 11%, India 3%). Lastly, all participants were asked: 'To the best of your knowledge, list any risks you see associated with insect eating'. Responses were coded as being in any of seven categories, or 'no risks' (the remainder coded as 'other'; USA 2%, India 5%).

For all three questions, the same participant's response could be classified in more than one category (e.g. 'insects are nutritious and sustainable' was coded as both 'nutritional' and 'environmental').

Specific beliefs and attitudes about insect consumption

Respondents were given a series of 9 statements, in random order, and asked to rate each on a standard 7-point agree/disagree scale (see items in Table 4, organised conceptually).

One item measures the belief that eating insects is disgusting. Three items have to do with the risks of insect consumption (risk of disease, presence of microbes and toxins). Two items pertain to the benefits of eating insects (nutritional and environmental). Two items ask about ethics (whether killing insects is immoral, and whether they feel pain). One item measures the idea that it is not natural for humans to eat insects.

Psychological scales

Participants were given a number of Likert-type scales that we predicted would be related to willingness to try eating insects. The food neophobia scale (Pliner and Hobden, 1992) assesses degree of rejection of new foods or discomfort one faces with the prospect of eating them. It consists of ten items (e.g. 'If I don't know what is in a food, I won't try it'). The disgust sensitivity scale (Haidt *et al.*, 1994) is the most widely used measure of disgust sensitivity. We used the core disgust subscale, which focuses on disgust related to offensive foods and bodily substances (e.g. 'If I see someone vomit, it makes me sick to my stomach'). The brief sensation seeking scale (Hoyle *et al.*, 2002) assesses individual differences in disinhibition, experience seeking, susceptibility to boredom, and tendency to seek thrill and adventure, on a 5-point agree-disagree scale (e.g. 'I would like to take off on a trip with no pre-planned routes or timetables'. The domain-specific risk taking scale (Blais and Weber, 2006) is a measure of likelihood of engagement in risky activities. We focused on six items that assess recreational risk-taking (e.g. 'bungee jumping off a tall bridge').

Participants also rated their 'political orientation regarding social issues' (from 1 very liberal to 7 very conservative), and rated their religiosity (from 1 not at all, to 6 extremely). In addition, because we think that, for some people, part of the motivation for doing things like eating insects or bungee jumping is that after engaging in unusual or risky activities, they enjoy telling others about these experiences; we asked: 'In the past, I have enjoyed telling other people that I have eaten strange or unusual foods'. Response options were: '1: never; 2: rarely; 3: sometimes; 4: frequently'.

Statistical analyses

All statistical analyses were conducted in SPSS version 21 (IBM Corp., Armonk, NY, USA). Due to our large number of analyses and large sample size, for all inferential tests, we set a *P*-level of 0.01 as the threshold for statistical significance.

3. Results

Willingness to eat foods containing insect flour

Scores on willingness to eat the dishes containing insect flour (cookie, *dosa*, favourite dish) had high internal consistency (Cronbach's $\alpha>0.90$ for both countries). Because of this high internal consistency, we averaged the percentages given by each participant to form a composite measure of acceptable level of insect flour, and conducted a 2 (country) × 2 (gender) ANOVA on acceptable flour level.

The effect of gender was significant: $F(1, 392)=13.88$, $P<0.001$, Cohen's d=0.30, such that men (M=5.52%) reported a higher acceptance percentage insect flour than did women (M=3.47%). The effect of country was not significant: $F(1, 392)=2.68$, $P=0.10$, d=0.17, but the interaction of gender and country was: $F(1, 392)=13.79$, $P<0.001$. Examining simple effects within each country revealed that there was a significant gender difference among Americans, $F(1, 175)=22.18$, $P<0.001$, d=0.73, but not among Indians, $F(1, 217)=0.00$, $P=0.99$, d=0.00 (see Figure 1 for group scores).

If we instead compute and analyse a composite from the raw 1-6 scale, the results are not substantively changed, save that the interaction of gender and country becomes marginally significant. Given that the percentage scores are more interpretable, we present the analyses done using them.

Another way to examine differences is with the percentage of people willing to taste any of the three items with any amount of insect flour; 65% of American women were willing, as were 78% of American men, 60% of Indian women and 74% of Indian men.

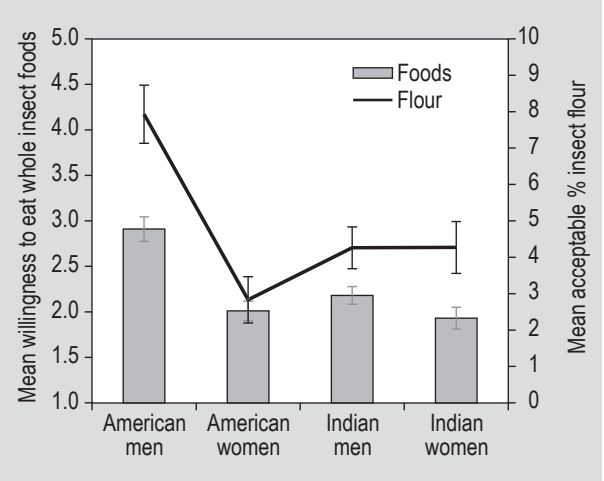

Figure 1. Willingness to eat foods made with insect flour and whole insects. Mean willingness to eat whole insect foods indicates the mean of participants' willingness to eat three foods containing insects (tacos, *dosas*, and lollipops) on a scale of 1: I would never eat it under any conditions; 2: I would eat it only if my survival depended on it; 3: I am unsure if I would ever consume it; 4: I could be persuaded to consume it; and 5: I would be glad to consume it. Mean acceptable % insect flour indicates the mean of the highest % mealworm flour participants would be comfortable tasting in three foods (chocolate chip cookie, *paratha*, favourite dish) answered on a scale of 0%, 0.1%, 1%, 5%, 10%, 25% or more. For both measures, valid n=69 USA men; n=108 USA women; n=133 Indian men; n=86 Indian women.)

Willingness to eat foods containing whole insects

As with the foods containing insect flour, the composite of these three items displayed high internal consistency (USA α=0.92; India α=0.81), so we averaged the items together into a composite of willingness to eat foods made with whole insects, and conducted a 2 (country) × 2 (gender) ANOVA on willingness to eat foods made with whole insects.

The effect of gender was significant, $F(1, 392)=25.13$, $P<0.001$, d=0.41, such that men (M=2.43) were more willing than were women (M=1.97). The effect of country was significant, $F(1, 392)=12.10$, $P<0.001$, d=0.24, such that Americans (M=2.36) were more willing than were Indians (M=2.09). These effects were qualified by a significant interaction of gender and country, $F(1, 392)=5.14$, $P<0.01$. Examining simple effects within each country revealed that there was a significant gender difference among Americans, $F(1, 175)=18.74$, $P<0.001$, d=0.82, but not among Indians, $F(1, 217)=2.66$, $P=0.10$, d=0.23 (see Figure 1 for group scores).

Examining those who indicated a reasonable possibility of consumption, a score of 3 ('I am unsure if I would ever consume it') or higher, for any of the three items, 40% of American women were open to the possibility, as were 65% of American men, 36% of Indian women and 52% of Indian men.

Our whole insect and flour composite measures correlate highly (USA r=0.68, India r=0.46), suggesting that they measured a similar attitude toward eating insects.

Encouraging insect eating

The two items ('We should encourage research on insects as food', and 'We should support programs designed to encourage people to consume insects') were highly correlated (USA r=0.85; India r=0.84). We computed the mean of the two items and used it as an encouragement score. We conducted a 2 (country) × 2 (gender) ANOVA on encouragement. The effect of gender was significant, $F(1, 392)=8.94$, $P<0.01$, d=0.32, such that men (M=3.93) believed that insect eating should be encouraged more than did women (M=3.35). There was neither a significant country difference ($P=0.62$), nor a significant interaction ($P=0.87$) of country and gender.

Almost half of participants endorsed supporting research and over 25% (more in the USA) supported programs to encourage ingestion.

Form and species preferences

In the USA, people most preferred eating insects as insect flour, followed by puree, then closely by chopped, with whole clearly least preferred. People were most positive about eating whole ants and crickets/ grasshoppers, and most negative about eating cockroaches.

In India, insect puree and flour were most preferred, followed by chopped, and finally whole. People were most positive about eating ants and flies, and most negative about eating cockroaches. For all means, standard deviations, and significant differences, see Table 1.

Free responses: rejection

In the USA, the most common reason for total rejection of insects as food was disgust (57%), followed by considering insects an inappropriate/unfamiliar food (19%), and dislike of their sensory properties (12%). In India, the most common reason provided was also disgust (38%), followed by sensory dislike (31%), considering insects an inappropriate/unfamiliar food (17%), and considering them to be animals and therefore having reservations about killing/eating them (13%). For full results, see Table 2.

Table 1. Preferred forms and species of insects as food. This table indicates mean ranked willingness (and standard deviation) to eat different forms of insect food, and insect species (whole, and as flour). Means that do not share the same superscripts differ at *P*<0.01.

	Rank	
	USA (n=177)	India (n=219)
Form		
Flour	1.66 (0.94) [a]	2.30 (1.10) [a]
Puree	2.41 (0.98) [b]	2.26 (1.07) [a]
Chopped	2.53 (0.81) [b]	2.51 (1.03) [b]
Whole	3.40 (1.00) [c]	2.90 (1.17) [c]
Plain insect		
Ant	2.25 (1.63) [a]	2.92 (2.15) [a]
Cricket/grasshopper	3.06 (1.81) [b]	3.90 (1.81) [b]
Beetle	4.01 (1.54) [c]	3.96 (1.76) [b]
Mealworm	4.20 (1.86) [c]	4.32 (2.00) [bc]
Caterpillar	4.22 (1.58) [c]	4.51 (1.74) [bc]
Fly	4.35 (1.68) [c]	3.45 (1.90) [ab]
Cockroach	5.91 (1.80) [d]	4.84 (2.03) [c]
Insect flour		
Ant	2.47 (1.78) [a]	2.73 (2.05) [a]
Cricket/grasshopper	3.22 (1.89) [b]	4.00 (1.83) [bc]
Beetle	4.08 (1.50) [c]	4.04 (1.70) [bc]
Mealworm	4.07 (1.94) [c]	4.11 (2.07) [bc]
Caterpillar	4.01 (1.54) [c]	4.43 (1.84) [cd]
Fly	4.30 (1.83) [c]	3.65 (1.78) [b]
Cockroach	5.85 (1.78) [d]	4.94 (2.04) [d]

Free responses: benefits

In the USA, the most common perceived benefit of eating insects was nutrition (66%), followed at a much lower rate by abundance/availability of insects (16%), low cost (14%), and low environmental impact (10%); 18% of participants said that there were no benefits to eating insects. In India, the most common perceived benefit was also nutrition (32%), followed at a much lower rate by general health (17%); 40% perceived that there were no benefits to eating insects. For full results, see Table 3.

Free responses: risks

In the USA, the most common perceived risk of eating insects was microbes/disease (51%), followed to a much smaller extent by disgust (19%), then poisons/toxins (11%); 17% of the sample perceived no risks of eating insects. In India, the most common perceived risks of eating insects were disgust (23%), poisons/toxins (22%), microbes/disease (22%), and general health risk (19%); 13% of the sample perceived no risks of eating insects. For full results, see Table 3.

Specific beliefs and attitudes about insect consumption

We performed a 2 (country) × 2 (gender) ANOVA on each of the nine insect belief/attitude items (Table 4). With the exception of finding eating insects disgusting, and believing that insects carry harmful microbes, Indians were significantly more negative (*P*<0.01 or better) than Americans. There were no significant gender or interaction

Table 2. Common reasons given for total rejection of insects as food. These figures are based on the number of participants who answered the question 'If you have not been willing to consume a food with any insect flour in it, please indicate your reasons'.

Reason	% Responses		Sample items (first from USA; second from India)
	USA (n=96)	India (n=173)	
Disgust	57	38	'I don't eat insects, and don't want to eat any insects. The thought is just nauseating to me.'; 'I hate insects. They are disgusting.'
Sensory dislike	13	31	'I don't think I would enjoy the taste.'; 'It tastes bad and I do not like it.'
Inappropriateness/unfamiliarity	19	17	'Insects are not consumed in our culture and I am not willing to start now.'; 'It's against our culture.'
Health risks	7	8	'I don't want to catch some disease the insect was carrying.'; 'I don't think it's safe and I'm concerned about my health.'
Animal food/moral	6	13	'Because I believe it's wrong to unnecessarily kill animals.'; 'Since I am from India moreover a vegetarian, I am not willing to take insect or non-vegetarian foods.'

Table 3. Common perceived benefits and risks of insects as food. These figures are based on the number of participants who answered the question 'To the best of your knowledge, list any benefits you see associated with insect eating', and the number of participants who answered the question 'To the best of your knowledge, list any risks you see associated with insect eating'.

Category	% Responses		Sample items (first from USA; second from India)
	USA	India	
Perceived benefits	n=176	n=210	
Nutritional	66	32	'Good amount of protein, low fat.'; 'High protein and nutritional content.'
Abundance/availability	17	3	'Plentiful source.'; 'It is easily available'
Cost	14	2	'Insects are cheaper to raise than say cows.'; 'The price of the food materials would be cheap.'
Environmental	10	2	'It reduces the environmental impact of the commercial meat industry.'; 'Consuming insects will balance the environment.'
Culinary	3	4	'Additional choices for consumption.'; 'May be tasty.'
General health/medical	1	17	'Possible health benefits.'; 'I heard that ants are good for eyes.'
No benefits	18	40	
Perceived risks	n=179	n=205	
Microbes/disease	51	22	'I may get diseases or infections carried by insects.'; 'Any infectious bacteria present.'
Disgust-related	19	23	'Throwing up cause it's so gross.'; 'I may feel like vomiting.'
Poisons/toxins	11	22	'Could be poisonous if you eat the wrong kind.'; 'They are mostly poisonous.'
Sensory dislike	8	4	'The whole insect parts could get stuck in the roof of your mouth.'; 'The taste may not be acceptable/ their texture may be bad.'
Insecticides/chemicals	6	2	'There is a risk they might be contaminated with insecticide.'; 'There may be traces of pesticides on them.'
Allergy	5	7	'Could get sick from having an allergy to the insect.'; 'Eating the insect may cause allergy problems.'
General health risk	3	19	'Depends on health standards of the country.'; 'It will affect our health.'
No risks	17	13	

Table 4. Specific beliefs and attitudes about insects. Scores for each group (USA: n=177; India: n=219) are means (and standard deviations; SD) on a 1-7 (1: strongly disagree; 7: strongly agree) scale. % agree indicates responses above the midpoint of the scale (≥5: slightly agree).

	USA women		USA men		Indian women		Indian men	
	Mean (SD)	% agree	Mean (SD)	% agree	Mean (SD)	% agree	Mean (SD)	% agree
Disgust								
Eating insects is disgusting	5.75 (1.49)	83	5.17 (1.85)	68	5.70 (1.67)	80	5.53 (1.55)	77
Risks								
Eating insects will increase risk of infectious disease	4.38 (1.68)	45	4.04 (1.63)	39	5.48 (1.40)	83	5.19 (1.61)	71
Insects carry harmful microbes	5.05 (1.31)	64	5.12 (1.50)	65	5.44 (1.32)	77	5.44 (1.40)	75
Insects contain harmful toxins	4.66 (1.40)	52	4.29 (1.42)	42	5.36 (1.32)	79	5.41 (1.44)	75
Benefits								
Insects are highly nutritious	4.75 (1.62)	60	4.77 (1.62)	62	3.70 (1.83)	36	4.17 (1.84)	42
Eating insects is good for the environment	3.80 (1.74)	32	4.10 (1.69)	36	3.29 (2.04)	31	3.53 (1.98)	37
Moral								
Killing insects is immoral	2.63 (1.72)	16	2.23 (1.52)	6	4.88 (1.70)	60	4.41 (1.88)	53
Insects are capable of feeling pain	4.71 (1.69)	53	3.99 (1.70)	33	5.50 (1.38)	78	5.45 (1.37)	77
Miscellaneous								
It is not natural for humans to eat insects	4.56 (2.02)	53	4.29 (1.93)	44	5.66 (1.55)	76	5.17 (1.72)	74

effects. Most notably, over 75% of people agreed that eating insects is disgusting, and over 50% agreed that insects were sources of infection, microbes, and toxins, that insects are capable of feeling pain, and that it is not natural for humans to eat insects. The biggest country difference is about 'killing insects is immoral', with which (averaging across gender scores) only 11% of Americans, but 56% of Indians agreed.

Correlates of insect acceptance

The variables that correlated, in the full sample, most highly (r>0.20) with insect acceptance (flour/food) were, in decreasing order: insect disgust (-0.32/-0.42); environmental benefits (0.31/0.35), 'tell others' (0.28/0.34), sensation seeking (0.30/0.29), risk tolerance (0.26/0.24), nutritional benefits (0.28/0.26), not natural (-0.29/-0.32), food neophobia (-0.17/-0.35), disease risk (-0.22/-0.28), core disgust (-0.18/-0.26), microbe risk (-0.19/-0.23) and toxin risk (-0.22/-0.21). Notably, neither social conservatism nor attitudes to the morality of killing insects significantly predicted acceptance.

Multiple regressions

In order to assess the unique predictive value of these variables, we ran a series of stepwise multiple regressions to predict both food acceptance and flour acceptance. We did this for both the total sample, and separately for Indians and Americans. For each set (all, USA, India) we only used predictors that, on their own, correlated at least 0.20 with these measures. We predicted each outcome measure separately with two sets of independent variables: (1) specific beliefs and attitudes about eating insects; and (2) demographics and measures of psychological traits (e.g. food neophobia, sensation seeking), using a cut-off of $P<0.01$. Altogether, we computed 12 regressions (3 samples by 2 types of variables (beliefs vs traits) by 2 acceptance measures; see results in Table 5)

Of the insect-specific beliefs and attitudes, disgust at eating insects was the most consistent predictor, significant in all 6 regressions, followed by perceived environmental benefits (4/6 regressions). No other predictor emerges as significant in half or more of the regressions. For the trait/demographic variables, sensation seeking emerges most reliably for Indians, and 'tell others' emerges most reliably for Americans (see Table 5 for all significant predictors).

4. Discussion

This study is an initial step in understanding people's reactions to insects as food, drawing on internet samples from two very populous countries, the USA and India, both of which have minimal insect consumption. The USA is particularly good at finding efficiencies in manufacturing, and so has the resources to make mass production of insects inexpensive. India has a large number of citizens facing malnourishment (~190 million; FAO, 2014), who could potentially benefit from the availability of insects as food.

Table 5. Stepwise multiple regressions predicting willingness to eat insect flour and whole insects. Flour coefficients are standardised predictors of mean highest acceptable % mealworm flour participants would be comfortable tasting in three foods (chocolate chip cookie, *paratha*, favourite dish). Food coefficients are standardised predictors of mean willingness to eat three foods containing insects (tacos, *dosas*, and lollipops) on a 1-5 scale.

Beliefs/attitudes	Flour (β)	Food (β)	Demographics/traits	Flour (β)	Food (β)
Full sample (n=394)					
Insect disgust	-0.24***	-0.36***	Sensation seeking	0.24***	0.18***
Environmental benefits	0.017**	0.25***	Tell others	0.22***	0.17***
Nutritional benefits	0.015**		Food neophobia		-0.22***
			Core disgust		-0.17***
USA (n=176)					
Insect disgust	-0.35***	-0.51***	Food neophobia		-0.28***
Disease risk	-0.21**		Tell others	0.29***	0.25***
Environmental benefits		0.25***	Gender (male)	0.22**	0.22***
			Risk tolerance	0.21**	0.19**
India (n=218)					
Nutritional benefits	0.29***		Sensation seeking	0.30***	0.30***
Environmental benefits		0.22***			
Insect disgust	-0.16**	-0.22**			
Killing insects immoral	-0.19**				

**$P<0.01$; ***$P<0.001$.

One aim of the present study was to develop valid self-report measures of willingness to try eating insects. We developed two ways of asking this: one uses whole insects in a culinary context, and the other assesses the highest concentration of mealworm flour that would be accepted as a flour replacement in a series of dishes. Scores on these two measures are highly correlated, but to some degree, assess different things. To increase cross-cultural validity, we included a food that was familiar in each of the countries, for both whole insect foods (*dosa* and taco) and insect flour foods (*paratha* and chocolate chip cookie). We found that a substantial minority in each country was willing to try food containing whole insects, and a clear majority was willing to consume a food with very low levels of insect flour. Overall, men were more willing than were women; this difference resulted primarily from the greater willingness among American men. Acceptability of insect flour or whole insects did not depend much on the particular food in which it was presented.

Perhaps the most useful information we report is about what insects people found most acceptable, and in what form. Ants were consistently among the least offensive insects, and cockroaches the most offensive, either whole or as insect flour. Although our data cannot directly address this, a reasonable hypothesis about insect acceptability is probably related to two things: the association of the insect with filth and disease (hence the offensiveness of cockroaches), and its perceived moistness/viscosity, which probably accounts for the fact that the caterpillar and mealworm were not as acceptable as the drier and crunchier ant. The results on preferred preparation were not especially surprising, with flour added to an existing dish rated as most acceptable, and whole insects as least acceptable.

When individuals from both countries explained their total rejection of insect foods containing insect flour, the predominant reason they offered was 'disgust.' The central role of disgust was also confirmed by our finding that the degree of disgust at eating insects emerges consistently as a major predictor of insect acceptance in the multiple regressions. A central role for disgust is confirmed by a more elaborate set of belief and attitude questions about eating insects in another recent study (Ruby, Rozin and Chan, unpublished data). Furthermore, when people are asked to freely associate to the word 'insect', disgust or synonyms of it are frequent free associations in both Indians and Americans (Rozin, Ruby and Chan, unpublished data).

Surprisingly, moral beliefs about eating insects and beliefs about the risks of insect consumption were not substantial predictors of insect acceptance; Indians were more concerned about moral issues around eating insects, perhaps related to Hinduism and the related, much higher, incidence of vegetarianism in India (Ruby, 2012; Spencer, 1993), although this difference remains if one only compares attitudes of American and Indian omnivores.

In both samples, there was higher agreement with statements about the risks (infections, toxins) of insect consumption than the benefits (nutritional, environmental). The predominance of risks is probably factually incorrect, and spread of information about the relative safety of edible insects might encourage their consumption.

Among Indians, higher sensation seeking was a consistent predictor of greater willingness to consume insects, and among Americans, enjoying telling others about having eaten unusual foods also emerges as a substantial and reliable predictor of insect acceptance. In the top-down model for insect acceptance in developed countries, it is seeking such experiences (for example, at high-end modern cuisine restaurants), and communicating the experiences, that may play an important role in moving toward widespread adoption.

This study has clear limitations: all of the information comes via self-report, from only two countries. Although self-reports are often reliable, people are not always able to imagine, for example, exactly what it would be like to be faced with a piece of flatbread with 5% insect flour in it, or a taco with roasted grasshoppers. Furthermore, our insect flour questions considered flour only as an additive, constituting only a very small percentage of the foods in question. Also, the whole insects were presented relatively unadorned, and not fully integrated into a dish. From the top-down perspective, as promoted by the Nordic Food Lab (2014), whole or coarsely chopped insects could be integrated into a dish appealing to both the eye and the mouth. We did not assess reactions to such foods, though our taco and *dosa* achieved some level of integration. Also, when we presented the four forms (whole, chopped, pureed, flour), there was some ambiguity about the context in which the insect might be consumed (e.g. alone or in a soup). In particular, 'flour' could have been conceived of as an additive to an existing dish or as simple consumption of the flour itself.

On the basis of our findings in this paper, we suggest that the people most likely to respond positively to a campaign promoting the nutritional and environmental benefits of insect consumption would be: low in disgust at eating insects, low in trait disgust sensitivity and food neophobia, high in sensation seeking, and inclined to tell others about their unusual eating experiences.

We believe that this is the first systematic study of insect acceptance, and as such it is difficult to relate our findings to a prior literature, though a number of ethnographic and review studies of entomophagy have suggested, correctly as it turns out, that disgust is a critical component of rejection

(e.g. Van Huis *et al.*, 2013). The relevant literature on acquisition for liking of initially aversive foods is presented briefly in the introduction, and is consistent with our findings and suggestions below.

There are many lines of research that can be followed to facilitate insect consumption, and perhaps simultaneously reduce meat consumption:

- Further investigate the basis of insect rejection, particularly disgust, and develop ways to overcome this. It has been shown that people can adapt to disgust, and that it can even become a positive and attractive feature. One may be able to harness disgust as a positive feature of insects, what we call benign masochism (Rozin *et al.*, 2013), in the way that the initial disgust at raw fish (sushi) may actually promote ingestion, or the disgust at rotted milk (cheese) may promote its ingestion.
- Make insects more delicious (Nordic Food Lab, 2014), which may either blunt disgust or engage it as an enhancement, such as with the bee larvae ceviche served at Noma (Copenhagen, Denmark).
- At the other extreme, participants' positive reactions to very low levels of insect flour suggest that a bottom up approach, with gradually increasing concentrations of flour, might be effective. Individuals are likely to adapt to disgust under these conditions.

There is great potential in the development of insects for human consumption, to help address problems of world hunger, environmental sustainability, and animal suffering. We hope that our work adds to this exciting prospect.

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