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Commentary

Why we *still* don't eat insects: Assessing entomophagy promotion through a diffusion of innovations framework

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ABSTRACT

A Diffusion of Innovations framework is used to review entomophagy, the human consumption of insects, and its promotion. Overemphasis on changing values and unrealistic goals of insects as alternative to meat hampered entomophagy's diffusion. Supply-side developments to fight passive rejection are essential before a majority of consumers will accept insects as food. Marketing insects appropriately or using them as livestock feed will also facilitate diffusion.

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"I can't eat your chocolate-covered ants … the chocolate upsets my stomach" – Groucho Marx

1. Introduction

Insect-eating by humans occurs globally (Ramos-Elorduy, 2009), but remains rare or even taboo in most cultures in the developed world (van Huis, 2013). The question of how to encourage Westerners (referring here as in most of the works cited as Europeans and non-Aboriginal Americans, Canadians, Australians, and New Zealanders) to eat insects [plus some arachnids like scorpions] is a perennial topic of discussion for entomologists and anthropologists alike (DeFoliart, 1999). The discussion is motivated primarily by their high conversion efficiency (ratio of feed consumed to edible product produced), theoretically translating into reduced CO_2 output and reduced water needs per gram of protein relative even to plants (Costa-Neto, 2013; Soares & Forkes, 2014). The message is straightforward: "Eat Insects … Save the Planet" (Martin, 2014). Entomophagy campaigns have focused on raising awareness, with the hope that once people see that insects are edible or taste them for themselves, they will accept the idea and add insects to their diet. This notion is not new: Vincent Holt first raised the question of "Why not eat insects?" in 1885, while coining the word "entomophagy." Insect cookbooks have been around since the seventies (Taylor & Carter, 1976), and the *Food Insects Newsletter* ran from 1988 to 2000 (DeFoliart, Dunkel & Gracer, 2009). Several companies are developing ways to market or present insects for the Western consumer (Fellows, 2014; Sexton, 2014). Entomophagy advocates appear on television and give TED talks (Dicke, 2010), and the United Nations has repeatedly urged greater insect consumption worldwide (van Huis et al., 2013), most recently via an interview with former Secretary General Kofi Annan that appeared in an insect cookbook (van Huis, van Gurp, & Dicke, 2014). The 21st century has seen a rise in the exposure of entomology to people of all ages and backgrounds (DeFoliart et al., 2009). So why are Westerners still not eating bugs?

Significant changes in cultural tastes are not impossible: consider the global sushi boom, where eating raw fish went from peculiar to chic in only a decade and without the concentrated efforts of scientists or politicians (Johnson, 2010). Foods can rise from obscure to popular or at least trendy quite suddenly, as in the recent cases of quinoa, kombucha, acai juice, and goji berries. By contrast, in many aboriginal populations entomophagy is *decreasing*, as the insect-free Western diet gains in popularity among the very cultures inspiring entomophagy advocates (Menzel & D'Aluisio, 1998; Meyer-Rochow & Chakravorty, 2013; Ramos-Elorduy, 1998; Yen, 2008). Despite over a century of work, entomophagy remains exotic. Holt's (1885) question of "Why Not Eat Insects?" may have been rhetorical then, but today deserves an answer.

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A landmark work on "why" certain novel ideas become widely adopted while others languish or remain restricted to a minority of users is the late Everett M. Rogers' *Diffusion of Innovations* first published in 1962 and now in its fifth edition (Rogers, 2003). It describes the innovation-decision process consumers use when presented with new technologies or ideas, the factors needed for innovations to become widely adopted by a population (such as boiling water to prevent disease in a rural Peruvian village or using snowmobiles instead of reindeer in Lapland), reasons diffusion may fail, and the consequences if diffusion succeeds. Cited in thousands of papers, the theory of diffusion of innovations (DoI) is still being used to analyze public health (Harringer et al., 2014; Sundstrom, 2014) and environmental policy (Islam, 2014; Jager, Janssen, & Bockarjova, 2014) campaigns, in addition to product marketing (Roos et al., 2014) including food (Barska, 2014). Thus DoI provides a tested and well-supported method to measure the progress of an innovation's diffusion and a structure on which to design future advocacy efforts (Sexton, 2014).

Under DoI definitions, entomophagy is a "failed diffusion." The term does not mean no one adopted the innovation, but that adoption never reached or approached universal acceptance in its target population (Rogers, 2003), which is unquestionably the case for Western entomophagy after over a century of promotion (Gracer, 2010). To date, no retrospective works have critically examined entomophagy as an innovation, to see which techniques have been ineffective or untried. Here I present a review of the literature on and the status of entomophagy in the developed world, through the framework of DoI. The goal is to understand why entomophagy failed to diffuse, and to suggest strategies for the future based on addressing the problems identified through the DoI-based analysis.

2. Diffusion of entomophagy

Rogers identifies five essential attributes an innovation needs to diffuse in a society: relative advantage, compatibility, low complexity, trialability, and observability. I examine each of these factors and how they relate to entomophagy, plus whether and how advocacy of the past addressed them. The initial hypotheses were that entomophagy advocacy has focused too highly on some of these factors to the neglect of others, makes false assumptions about how entomophagy truly rates in these attributes, and/or uses inappropriate tactics for the target populations.

2.1. Relative advantage

At a minimum, an innovation must be "perceived as better than the idea it supercedes" (Rogers, 2003). Much of the drive for entomophagy is based on the idea that producing insects requires fewer resources (land area, labor, water, etc) than producing meat, while still providing the same nutrition (Martin, 2014; van Huis et al., 2014). Relative advantage, however, covers more than economic, ecological, or health benefits: it includes social benefits [prestige], convenience, and satisfaction (Rogers, 2003). For the Western consumer, how does entomophagy fare relative to existing food technologies?

Poorly. Certainly eating insects provides no status benefit: even in countries where entomophagy exists, such as Mexico, only the rural, indigenous persons consume insects regularly (de Conconi, 1982). The more wealthy and urban populace looks down on insects as food for the poor or primitive (Costa-Neto, 2013; Ramos-Elorduy, 1998). Worldwide, indigenous persons themselves are increasingly abandoning traditional foods for a Western diet of prepackaged foods, even though it is both ecologically and nutritionally disadvantageous, because it is seen as socially superior (Menzel & D'Aluisio, 1998; Meyer-Rochow & Chakravorty, 2013). This problem of social status cost is compounded in the West: one author asked Thai and Cambodian immigrants to the USA who run specialty food stores that carry insects, whether they eat what they sell. Invariably they reply, "No.… back home, we ate this. Not anymore" (Gracer, 2010).

Furthermore, while insects may be more ecologically friendly sources of protein than larger animals, vegetarianism and veganism are even greener. Other options for reducing food's environmental footprint include the nose-to-tail movement—reducing food waste by consuming every part of already acceptable animals, namely by eating offal (Strong, 2006)—and the new [and even less accepted] field of *in vitro* meat (IVM) grown from stem cells (Sexton, 2014; Tucker, 2014). Also, commercial insect collecting can be environmentally destructive (Johnson, 2010), as in the deforestation associated with the Sago Palm grub harvest or local extirpations of Africa's Mopane Worm (Menzel & D'Alusio, 1998). If the demands of entomophagy are not balanced against the needs of conservationists, via sustainable harvests with appropriate habitat management or with farming, the ecological advantages might be lost (Yen, 2009b). Thus, if one's goal is feeding a growing human population on diminishing land and in the face of climate change (Nadeau, Nadeau, Franklin, & Dunkel, 2014), then promoting non-animal diets, nose-to-tail feeding, or IVM may be better alternatives than entomophagy, as their relative advantages are higher (Tucker, 2014).

A major disadvantage of entomophagy rarely mentioned in the literature is convenience: commercially available insects are difficult to find (Ramos-Elorduy, 1998; Taylor & Carter, 1976). One might assume this is a non-issue and that the low supply is due to lack of a market, but DoI theory predicts and anthropological studies (Costa-Neto, 2013) suggest that the reverse is true: accessibility drives demand. Aside from the aforementioned specialty stores (Gracer, 2010), few major Western supermarket chain carries unprocessed insects, so would-be entomophages wishing to prepare an insect-based dish must buy their insects at a different location [a pet shop or bait shop] than all the other ingredients, if not online and waiting for the insects to be delivered by mail (Meyer-Rochow & Chakravorty, 2013): a significant loss of convenience. [Note that this is changing: Belgian supermarket groups Delhaize and Carrefour and Dutch supermarket group Jumbo are now carrying insect products]. Most such insect rearing companies primarily cater to pet owners, so their reference in a cookbook runs against the stigma most Westerners associate with eating food meant for animals (Menzel & D'Aluisio, 1998; "The Chef's view…", 1992). In addition, wherever insects are sold (including in the developing world), the price is often higher than for a comparable amount of meat (Ramos-Elorduy, 1998), providing an economic *dis*advantage.

2.2. Compatibility

To successfully diffuse, an innovation must be "consistent with the existing values, past experiences, and needs of potential adopters" (Rogers, 2003). For example, entomophagy advocates rarely target the Middle East, despite its high levels of economic development, as most insects [except certain locusts] are neither halal nor kosher and thus incompatible with local values. Compatibility is the most targeted aspect of insect eating advocacy; changing humanity's mostly negative perceptions of insects has long been a goal of entomologists and entomophages alike (DeFoliart, 1999; Gracer, 2010), and some anthropologists have claimed opening Westerners up to entomophagy would also open them to different cultures and reduce racism and intolerance (Looy, Dunkel, & Wood, 2014). At least for the former, these efforts are largely successful: positive contact with insects and/or

entomophagy events both lead to more positive views of insects overall, and increased stated willingness to eat insects in the future (Lensvelt & Steenbekkers, 2014; Megido et al., 2014).

As for the belief that insects are only food for the poor or primitive (Looy et al., 2014), such values can change. A good example is the lobster: Once considered so unworthy of human consumption that American states had laws limiting how often they could be fed to prisoners at the risk of being cruel, today lobster is considered a delicacy and priced accordingly (Townsend, 2011). In fact, as crustaceans and insects are both arthropods, entomophagy advocates as early as Holt have cited lobsters as evidence that insects are edible and compatible with Western food culture (Gracer, 2010; Holt, 1885), a tactic called "positioning an innovation" (Rogers, 2003).

Compatibility with past experiences is an obstacle, as insects in food are seen as decreasing its value rather than increasing or defining it (Ramos-Elorduy, 1998). For example, the USA has standards on how many insect parts a packaged food item can contain before it is considered contaminated and inedible (Food and Drug Administration, 2010). [Note that contaminants are defined by intent: if a package is supposed to contain insects, like the worm in a mescal bottle, then it is acceptable assuming it is not otherwise adulterated, (Brickey Jr., 1989)]. Food in economically advanced regions is increasingly divorced from the environment in which it grows. Consider how difficult it is to market blemished fruits to Westerners, and the high environmental cost of insecticides and other treatments necessary to produce the flawless fruits and vegetables sold in supermarket produce sections (Sexton, 2014). The cliché of a "worm in the apple" has become an anachronism, as most Americans and Europeans today will never experience biting into an apple and finding a live insect. The idea that the same creature seen as a pest in the garden should be seen as an ingredient in the kitchen may be too much for some to [literally and figuratively] swallow (Costa-Neto, 2013). The physical appearance of insects is thus not compatible with Western notions of the appearance of "food" (Tucker, 2014).

Entomophagy advocates are quite aware of this, however: In the first published insect cookbook for the West, all 85 recipes disguise the insect so it is completely unrecognizable (Taylor & Carter, 1976). Commercial strategies used to focus on deep-frying or chocolate-dipping (Food Insect News Letter, 1993; Gahukar, 2011) but today the source is disguised by using insect meal rather than whole insects. Panels and taste tests have confirmed that consumers greatly prefer not seeing the insect in their food (Megido et al., 2014; Tranter, 2013), which is critical given that sensory appeal trumps ecological concerns in changing how and what people eat (Tucker, 2014).

One environmental issue that does heavily influence diet is conservation: consumers will not eat insects they fear are endangered (Tucker, 2014). Consider Reese Finer Foods, an American company that in the 1960's readily sold small tins of roasted, chocolate covered, or "French fried" ants, grasshoppers, bees, and silkworms (DeFoliart, 1988). In addition, they sold canned frog legs, smoked whale-meat, and BBQ snakemeat, as well as antelope, elephant, hippo, iguana, lion, tiger, etc., procured from zoos when an animal died naturally. Despite the sources, environmentalists became critical of Reese products following passage of the Federal Endangered Species Act of 1969 and similar legislation. By 1971, the "oddball" items were discontinued, including the insects ("Remember those…," 1993). Reese items became incompatible with increasingly conservation-minded American consumers, although it is worth noting that the canned insects never sold well and even entomophagy enthusiasts admitted they tasted poorly (DeFoliart, 1988).

Compatibility with need is another problem, as it presumes a need exists. Insects do fill a need in developing nations as an inexpensive source of protein; cricket meal tortillas have been advocated to fight protein deficiency in rural Mexico (Gahukar, 2011), as have processed termites and lake flies around Lake Victoria (Ayieko, Oriaro, & Nyambuga, 2010). Some use this food security angle to market entomophagy to Westerners (Yen, 2009a), but the West is not lacking for cheap protein. Instead, overnutrition *à la* the obesity epidemic is the most pressing dietary concern (Kearney, 2010; Shaw, 2014). Since insects in the Western diet are not "needed", they should therefore be classified with other optional foods: as luxuries/delicacies, condiments, non-essential dietary supplements, or snacks (DeFoliart, 1988; 1989; Fellows, 2014). This is not a uniquely Western issue: the more urban and wealthier populations in nations with otherwise long insectivorous traditions also see insects as novelty food (de Conconi, 1982).

The underlying assumption behind these efforts is that changing how people value insects will drive up demand for insects as food, which will motivate food retailers to increase supply. However, the history of food innovations suggests the chain actually goes in the opposite direction. Consider once more the American lobster. Its rise in acceptance is largely due to the invention of the lobster smack, a novel boat that allowed lobsters to be transported alive across large distances. Increased supply to remote areas, including Europe, increased the population of potential early adopters of "lobster-phagy" with access to the food, increasing demand (Townsend, 2011). As lobster eating became more visible, its status improved until society's view of the practice reversed completely. If this pattern is universal, increasing supply of an innovative food might change social values faster than attempting to change these values directly.

2.3. Complexity

Complexity is "the degree to which an innovation is perceived as relatively difficult to understand and use." Unlike the other attributes, it is negatively correlated to the successful adoption of an innovation. For the usage of insects in the kitchen, most complexity issues are easily overcome by use of a cookbook, although the dearth of freely available insect recipes online outside of these cookbooks is a problem: As of January 2015, food.com had more recipes using pine needles or whale meat than crickets or mealworms, and more recipes for horsemeat or jellyfish than for cicadas, their most popular insect.

While the primary, relative advantage argument for entomophagy is as a substitute for meat, their culinary uses are quite different. Insects may require less water per gram of protein produced than livestock or even soy (Dicke, 2010), but they cannot be cooked in the same way: Tofurkey exists, but cricket brisket is impossible. Their small size and often hard exoskeletons make insects less compatible with recipes calling for large cuts of meat than with recipes calling for nuts or other forms of savory crunch (Ramos-Elorduy, 1998), limiting their usage relative to vegan meat substitutes like Portabello mushrooms, Quorn, or tempeh (Lensvelt & Steenbekkers, 2014). The closest insects come to conventional meat is their similarity to seafood; boiled grasshoppers and cicadas turn a familiar red like boiled crustaceans, and aquatic insect larvae taste enough like fish to be usable in *ceviche* (Ramos-Elorduy, 1998). However, small or chopped insects can be easily incorporated into recipes that are open to improvisation, such as to stir-fries, pizzas, tacos, and baked desserts (DeFoliart, 1990; Gahukar, 2011; Gordon, 1998). Likewise, ground insect meal in a 50/50 ratio with grain flour bakes and behaves similarly to all-flour doughs, but with higher protein. In this way, insects can be incorporated with little effort

and marketed as a supplement to increase the protein/carbohydrate ratio of baked goods.

2.4. Trialability

Trialability is "the degree to which an innovation may be experimented with on a limited basis" (Rogers, 2003). Entomophagy advocates have placed much emphasis on this, hosting insect food fairs and other events where people can taste insects and see for themselves that, yes, insects can be food (DeFoliart et al., 2009). One author estimated one such event happens somewhere in the United States every week (Gracer, 2010). The results of such events are predominantly positive; after eating insects, most people report that they would be open to eating insects again in the future (Lensvelt & Steenbekkers, 2014; Megido et al., 2014; Pitt & Shockley, 2014). Entomophagy literature emphasizes these results, with the assumption that entomophagy would become widely adopted if only more people tried it. Indeed, one need not expose all individuals to entomophagy directly to achieve successful diffusion. Early adopters need to try an innovation for themselves before they add it to their lifestyle, while late adopters can try it vicariously through the early adopters who surround them (Rogers, 2003). So long as they know others have tried it and it works, they will seek out the innovation on their own (Frattini, Bianchi, Massis, & Sikimic, 2013), as in the case of lobster (Townsend, 2011) and tofu (Menzel & D'Aluisio, 1998).

The emphasis given to these trials overlooks a key detail: even if people leave an entomophagy event with a desire to eat insects, they may not have another opportunity. Entomophagy advocates are successfully combating "active rejection" (Rogers, 2003), where a person simply refuses to eat insects, but this strategy has worked too well. As relatively low as it is, demand for insects as food in the West now exceeds supply (Gracer, 2010). Consider Australia's already threatened witchetty grub: the popularity of such "Bush Tucker" among the affluent is so high and wild collection so low in output that artificial grubs made of cheese had to be developed (Yen, 2008). Similarly, a survey of English schoolchildren found a majority of them are already aware of the relative advantages of eating insects and are ready to consume insect products, but they lack access to them (Tranter, 2013). Convenient, inexpensive sources of insects are simply not available in the West, so would-be early adopters of entomophagy are showing "passive rejection." They have no way to add insects to their diet other than waiting for the next insect food festival. Efforts to boost trialability should therefore move from individual consumers and chefs (the demand) to supermarkets and grocery stores (the supply), by putting whole insects or insect meal on the shelves, with recipes printed on the back of the packaging, and making them available to consumers to try on their own time in their own homes on their own terms (again, like lobster). Until such opportunities exist, entomophagy will be limited to the $\leq$2.5% of the population described as "innovators," in this case the restauranteurs and entomologists agreeable to expending the effort essential for acquiring edible insects, without options for the 13.5% that define early adopters (Rogers, 2003), to say nothing of anyone else.

2.5. Observability

The final attribute is defined as "the degree to which the results of an innovation are visible to others" (Rogers, 2003). If we define the result of entomophagy as the reduced resource footprint of a person's diet, then observability is a problem, just as it is for other environmentalism-based innovations (Islam, 2014; Smith, 2014). If, instead, we define the result of entomophagy as a person chewing, swallowing, and approving a dish containing insects, then we enter a richer and, for better or worse, more entertaining field. Entomophagy is a popular topic; far more publicity has been given to eating insects than, for example, eating offal. In addition to hosting entomophagy events at museums and schools [the latter not without controversy], entomophagy advocates are taking to the airwaves, eating insects or insect-based foods on talk shows or promoting the advantages of entomophagy in online videos (Dicke, 2010; Gracer, 2010; Raloff, 2008).

Despite the adage that "there is no such thing as bad publicity," some of these events have done more harm than good. Media appearances of entomophagy must focus on normalization rather than novelty (Looy et al., 2014). Unfortunately, people who eat insects are usually played for a sideshow. Entomophagy is used as a sign of toughness or bravery; Kofi Annan recommended convincing politicians to publicly consume insects "to show how courageous and adventurous, and what leaders they are" (van Huis et al., 2014). Insects even entomophages avoid are eaten as a sport or game, usually raw or alive, as on television shows like "Fear Factor" and "Survivor" (Looy et al., 2014). One such challenge culminated in catastrophe as the champion of a cockroach-consuming contest choked to death on a chuck of chitin (Laboy, 2012). Even respectable advocates of insects can be marginalized in the wrong limelight. Seeing an entomophage alongside a "freegan" who eats from other peoples' garbage, right after a segment on pica, a psychiatric disorder where people compulsively eat non-food items, in a talk show episode entitled "People with Bizarre Eating Habits" (2009) sends the wrong message. Weirdness has its uses: the USA's biggest producer of insect food, "Hotlix," depends entirely on the novelty factor to sell their cricket- or scorpion-lollipops (Menzel & D'Aluisio, 1998). To normalize everyday entomophagy, however, it needs fewer appearances on "Bizarre Eats" and more on standard cooking shows: Less Maury Povich, more Martha Stewart.

Entomophagy advocates have also neglected interpersonal channels (Rogers, 2003). Most use observability as an extension of trialability: if people see others eating insects in the media, they will know that eating insects is doable. However, when it comes to food, people are less influenced by what they see on television than by what their friends and family are eating (Frattini et al., 2013; Pitt & Shockley, 2014). For people to believe eating insects is acceptable rather than just plausible, they need to see their peers engaging in entomophagy in everyday environments. Insect dishes must become items one is comfortable bringing to a potluck, bake sale, or child's birthday party. These peers must also be "homophilous" to the observers (Rogers, 2003): an upper-class British celebrity chef cannot convince working-class Americans to change their diets any more than the other way around (Strong, 2006; Warin, 2011) Seeing insects in a grocery store or a friend's pantry would have a more significant impact than in a restaurant or on YouTube, since their presence alongside familiar foods in a familiar environment implies edibleness and normalization without novelty.

3. Why entomophagy failed

Before continuing, I must reiterate that a "failed innovation" does not mean one that nobody has adopted, but one which does not reach or approach total adoption by the target population, even if certain clusters do adopt it (Rogers, 2003). Rogers describes five categories of adopters whose percentage of the population is based on a Bell curve: innovators (2.5%), early adopters (13.5%), early majority (34%), late majority (34%), and laggards (16%). Innovators tend to be daring, venturesome, and cosmopolite: the members of the New York City "Explorer's Club" that attended a "bug banquet" in 1992 represent typical innovators (Ramos-Elorduy, 1998), along with the chef [although it is worth noting that some of the other kitchen staff ran away terrified when learning what they were

supposed to cook] ("The Chef's View…, 1992"). Early adopters are more localite, respectable, and show high opinion leadership. These are the people who will stand in line for a new product, often for the social status benefit of being among the first to have something new. Early adopters would in this case be trendsetting consumers with high social positions in their community who are seen buying and consuming insects by their peers in person, not in dedicated television appearances. The early majority need to deliberate before innovating and are typically not leaders, while the late majority is skeptical and requires peer pressure or clear economic necessity to adopt an innovation. Both these populations represent the average consumer, such as the modern day smartphone user. Laggards are more traditional, localite or isolated, less educated, less connected to leadership, and often in precarious economic positions that favor caution.

A 2013 survey found that 90% of Zimbabweans had participated in entomophagy, with the non-eaters including those with religious proscriptions against eating insects. Entomophagy in Zimbabwe is a successful innovation (Dube, Dlamini, Mafunga, Mukai & Dhlamini, 2013). Surveys for entomophagy in the Western world are limited (Gahukar, 2011), but it is very telling all such studies have focused on "readiness" or "willingness" to adopt insects, not on whether or not users actually use them. The most recent survey was in Flanders, Belgium, and found that 12.8% of males and 6.3% of females are likely to adopt insects as a meat substitute (Verbeke, 2015), representing a fraction of the early adopter population and only expressing "willingness" rather than actual usage. Entomophagy practice in the West has likely not yet reached the 2.5% threshold for innovators, despite over a century of constantly increasing advocacy. Entomophagy in the West is thus a failed innovation, with no indication that it will succeed with the current diffusion tactics.

When reviewing the strategies used by entomophagy advocates and researchers, several patterns and problems emerge. Firstly, the overwhelming focus has been on increasing demand and acceptance of insects through education and trialability, with frequent (though occasionally misplaced) observability blitzes via mass media. These efforts ignore the fact that changes in values are often supply driven, and not the other way around. Second, follow up studies testing for passive rejection do not exist. Post-intervention interviews after insect-eating fairs or displays are predominantly positive, but whether these attitudes manifest in changes in diet months or years on is unknown. Such studies are also inherently biased, as the kind of people who visit an entomology museum or eat at the "Explorer's Club" are already respectively more likely to have positive views of insects or be less prone to neophobia [fear of trying new foods]. When a general population is tested, acceptance of entomophagy is found to be much lower, with the increased food neophobia the largest factor for this difference (Verbeke, 2015). Lastly, the environmentalist claim that insects are the inevitable replacement for meat is widely touted as the main, if not sole, justification for promoting entomophagy to the West. Such arguments do not match the way insects are prepared, and can also be used to promote other, greener lifestyles which themselves are struggling with diffusion (Paoletti, 2005; Tucker, 2014). In addition, arguments that assign "individual blame" for systemic issues—saying climate change is caused by one selfishly eating beef instead of beetles while living in a society that praises carnivory (Strong, 2006; Tucker, 2014)—rarely lead to widely adopted innovations (Rogers, 2003).

4. New directions for entomophagy promotion

In light of these issues, there are three ways entomophagy advocacy could better advance the practice in the Western world. 1) Develop insects as livestock feed rather than human food. 2) Change the ways entomophagy is marketed and justified to better fit the needs [or lack thereof] of Western consumers. 3) Focus on supply-side innovations.

4.1. Promoting entomophagy for sustainability

If reducing the environmental impact of food production remains the predominant goal of entomophagy promoters, realistic goals focusing on systemic blame are needed. The appeal of insects is their higher conversion efficiency relative to livestock, so perhaps the solution is to increase the latter using the former (DeFoliart, 1975; 1989). Rearing insects on organic side streams or on waste compounds humans cannot process, then feeding them to traditional livestock normally fed all-plant diets (van Huis, 2013; Nadeau et al., 2014), will not only reduce waste but also the ecological footprint of the livestock, which can convert insects to flesh much more easily (Ramos-Elorduy, 2008). Some reports even claim the meat from livestock fed insects tastes better (Ramos-Elorduy, 1998). One example is rearing blowfly maggots on chicken dung and feeding them back to the chickens, a nearly closed system producing healthy poultry for a fraction of the input costs and requiring less land than for standard chicken feed (Vane-Wright, 1991). For livestock that are conventionally fed human foods, such as soybean meal or wheat bran (Fellows, 2014; Lardé, 1989), replacing these items with insects would fight the rising costs of grains and other staples—the very concerns for the future of meat that motivated much initial entomophagy advocacy (Vane-Wright, 1991).

4.2. Promoting entomophagy for Western Cuisine

The notion that wealthier consumers will ever replace vertebrate meat with insects by choice seems unlikely (Tucker, 2014; Verbeke, 2015). No extant cultures, rich or poor, see insects as superior to vertebrate meat or voluntarily use them as a staple or primary protein source (Schabel, 2008), so fighting the global decline in entomophagy using individual blame strategies is going against the tide. More realistic is promoting insects as alternatives to nuts, to whom their texture, macronutrient content, and even flavor are already comparable. In fact, when one looks at entomophagy in the world today, insects are already used in much the same way as nuts are: as optional ingredients in otherwise complete dishes [covered in chocolate, mixed into baked goods, or sprinkled on salads], mildly processed and used as snacks [fried or roasted, as in Hotlix-brand "Larvets" or "Crick-ettes"], or ground thoroughly and used to add a unique flavor or nutritional profile to an item [as in Cochineal dyes, or cricket-meal baked goods] (DeFoliart, 1990; Martin, 2014; Menzel & D'Aluisio, 1998; O'Callaghan, 2013). One unexplored use of insects in the West is rendering insects for fat or oil (Schabel, 2008), which certainly qualifies as disguising their appearance.

Accepting that insects will never be staples, how could we introduce them into the First World diet? The tactics mentioned in entomophagy papers have changed little in the past few decades, even as information technology has shifted radically (Fellows, 2014). For example, instead of printing new cookbooks, recipes should be posted freely in online recipe depositories alongside everyday foods. This promotes the normalcy of entomophagy as opposed to novelty. Another problem is the prevalence of mealworms and crickets in the literature. Firstly, limiting recipes to the most commercially available insects can overlook those that taste best (Taylor & Carter, 1976). Second, a limited set of choices does disservice to the wide variety of insects available in these nations that natives may find more familiar and palatable (Ayieko et al.,

2010; Raubenheimer & Rothman, 2013). Americans might not like mealworms [which have strong, negative connotations as pests and as pet food], but may be much more apt to eat cicadas. Indeed, though nearly impossible to rear, cicadas may be the most readily consumed insects for Americans (DeFoliart, 1990). They are highly abundant during emergences, famously non-toxic, large enough that they can be prepared like shrimp, and local. Other native American insects known to be consumed by Native American humans are Mormon crickets, Mono Lake shore flies, and June bugs (DeFoliart, 1994; 1999). Tying entomophagy to the local-vore movement or establishing American insects as distinctively American cuisine will be much more effective than pointing out consumption of unrecognizable species by indigenous cultures on other continents [a distinctly non-homophilous group to Western gourmets] (Looy et al., 2014).

Focusing on certain species rather than insects *sensu lato* also improves compatability with past experiences, reducing the association of edible insects such as bee larvae or Mopane worms with inedible or negatively perceived insects such as cockroaches and flesh fly maggots. Specific clades can be more easily marketed with clever euphemisms, like "land shrimp" or "tree lobster" for the cicada, or using the more exotic scientific or indigenous names for organisms rather than the common, entomological terms (Holt, 1885; Looy et al., 2014). The words "entomophagy" and even "insects" also add a clinical artificiality that other, more successfully diffused diets never needed. The [until just now] nonexistence of words like decapophagy, omopisciphagy, and musaphagy has not hindered the normalization of eating crustaceans, raw fish, and bananas respectively, and may even have helped normalize these ideas.

Insects also need to be tied into the needs and wants of a West currently experiencing strong shifts in dietary patterns (Kearney, 2010; Looy et al., 2014). In light of concerns over obesity, genetically modified foods, and major outrages in food production such as mad cow disease scares and the British horsemeat scandal, the 21st century is seeing a rise in [allegedly] healthful eating trends such as smoothies, nutraceuticals, "superfoods," probiotics, organic foods, "detox," and various dietary restrictions such as the gluten-free fad (Sexton, 2014; Shaw, 2014). Even when scientifically unsupported, such innovations are succeeding where entomophagy has failed, in part because they successfully address the real [or perceived as real] needs of an increasingly health-conscious populace (Siegrist, 2008). These movements are advantageous to the cause of entomophagy, because insects are strongly seen as "natural" and can be easily marketed as such to those concerned with eating less processed products (Barska, 2014; Siegrist, 2008), and especially with the "Paleolithic diet" that seeks a return to foods eaten by pre-civilization humans (Ramos-Elorduy, 2009). Insect-fortified flours can be marketed to those seeking higher protein-to-carbohydrate ratios in their diet, such as bodybuilders or followers of the Atkins diet [a cricket based power bar already exists (O'Callaghan, 2013)]. Chitin may also become a marketing tool (Goodman, 1989; Ramos-Elorduy, 1998): Previous authors assumed consumed insect chitin has no nutritional value to humans (Gorham, 1979), but the discovery that some humans do possess working chitinases (pointedly, those from low socioeconomic backgrounds who still depend on insects for protein) suggests that the role of chitin in human nutrition needs to be re-evaluated (Paoletti, Norberto, Damini, & Musumeci, 2007). Insects are also non-GMO and some species are gluten-free, although whether selling more insects is worth contributing to pseudoscientific or orthorexia-enabling dietary trends is debatable (Stein, 2014).

4.3. Increasing insect supply

All of these innovations, be they for livestock or human consumption, cannot be implemented unless there is an inexpensive, readily available supply of insects. Worldwide, insects cost more to purchase than nearly any other meat (Ramos-Elorduy, 1998), meaning entomophagy is too expensive for the majority of potential uses to adopt. This passive rejection can only be overcome by supply-side innovations. Commercial-scale sources of insects would not only drive down costs [both economic and ecological], but also, according to DoI, would be "disruptive innovations": paradigm-changing technologies that create new markets and value networks while replacing or displacing old ones (Christensen & Raynor, 2003). Consider the automobile. Though today seen as a large improvement over the horse-drawn carriage, it was actually a failed innovation because the first cars were too expensive to establish a market. The *mass produced* automobile, however, was a disruptive innovation. The Model T not only had a strong relative advantage over horses, but also spawned various other technologies: new cars, new parts, new accessories, and other mass-produced items (Christensen & Raynor, 2003). Mass produced insects, DoI predicts, could have the same effect.

Once mass insect rearing is accomplished, the next task is to convince retailers to carry insects. Some supermarkets in Europe have already begun to carry pre-made, insect-based meals and snacks, so whether this will influence the rather negative local perception of entomophagy (Verbeke, 2015) will soon be seen. Retailers possess disproportionate influence over what is considered edible (Sexton, 2014), which can be used to the advantage of entomophagy advocates. Unprocessed insect ingredients may be more useful than ready-made meals. The sight of bags of cricket meal, bottles of termite oil, or loaves of insect flour bread would instill in consumers the idea that these items are edible and can furthermore be worked into extant family recipes. Once a few intrepid early adaptors begin cooking with insects, others will see them doing so and may be inspired to try the new ingredients themselves, causing a "snowballing effect" (Pitt & Shockley, 2014). In this way one person can influence others more directly and more positively than any televised insect-eater could (Frattini et al., 2013). In addition, the public may find novel ways to use insect foods that entomophagy advocates had never even considered, leading to reinventions of demand as observed with the development of desktop 3D printing (Soares & Forkes, 2014). Scientists interested in developing entomophagy should focus on rearing and packaging insects rather than worry over how to convince others to eat them. Create a safe and steady supply, and demand will take care of itself.

5. Final thoughts: risks and consequences

Throughout *Diffusion of Innovations*, Rogers reminds readers that new technologies can have unforeseen consequences (Rogers, 2003). Once again, consider the lobster. Even at luxury prices, demand eventually rose to the point where supply was no longer sustainable and lobster stocks decreased. Today lobster fishing is regulated with an eye on conservation (Townsend, 2011). The risks and consequences of entomophagy have been noted throughout the literature, especially when supply depends on wild harvests (Schabel, 2008), and provide food for thought. In Hidalgo, Mexico, fourteen out of thirty insect species used as food are now threatened following commercialization of a once subsistence-only food (Johnson, 2010). In China, the *Polyrhachis* ant is now in danger of extinction due to its use in medicinal rice brandy (Menzel & D'Alusio, 1998). Mass rearing would mitigate the problem, but is not possible or cost-effective for all desired species, such as the

threatened Mopane Worm. Consider what would happen if cicadas, which are notoriously difficult to culture, became popular among Americans. As high as periodical cicada numbers are during their seasonal broods, humanity's capacity to hunt a species to extinction is more than enough to threaten their existence. Pending successful development of rearing methods for such species (Menzel & D'Alusio, 1998), regulation is essential to ensure sustainable harvesting practices (Johnson, 2010).

Other frequently mentioned risks of entomophagy include allergies in consumers and, in particular, workers in insect production, especially among those allergic to shellfish (Gorham, 1979; Phillips, 1995). Amateur collection of wild insects poses risks as people may collect toxic species or those exposed to insecticides (Costa-Neto, 2013; Gahukar, 2011; Yen, 2009b). If bee brood consumption becomes popular in the West, theft of honeybee combs could occur, exacerbating problems caused by colony collapse disorder. Processed insects would also have to be given the same attention to food safety as any other product, as botulism is a risk in improperly packaged insects (Gahukar, 2011; Schabel, 2008).

If entomophagy successfully diffuses, what would be the economic effects? DoI predicts that the wealthier, larger farmers capable of scaling-up and adopting new mass-rearing technologies will quickly overtake the smaller insectaries active today, driving the latter out of business. A similar scenario unfolded as tofu became mainstream (Menzel & D'Aluisio, 1998). Otherwise the impact is unpredictable. Demand for insects as human food may drive up the costs of insects as pet or livestock food. If mass insect rearing uses the same input as other livestock, such as chicken feed, it can drive up the costs of meat. The cost of transporting live or fresh insects will likely be high, meaning insects may always be relatively expensive, only now relegated as a luxury food. The economic and environmental impact of insect waste and its disposal must also be considered.

Lastly, what would be the effect on the developing world if everyone adopts entomophagy, albeit from environmentally sustainable sources? Consider a scenario where upper-class lifestyles are observably heavy on insects, with characters on British sitcoms casually munching on cricket chips or Hollywood romantic dramas taking place at a cicada harvesting party. Given the predominance of acculturation towards Western lifestyles among economically marginal populations, we may see other cultures emulate the new, fashionable trend of entomophagy and add insects to their diet … exactly what we wanted in the first place (DeFoliart, 1999).

Conflict of interest

The author has no financial or other ties to any food, insect, or other industries that would present a conflict of interest.

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