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Edible Insects as New Food Frontier in the Hospitality Industry

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Entomophagy has led to the recognition of insects as playing a major role in improving global environmental health, food, and nutritional security. The processing methods have shown to greatly affect its acceptance and consumption. This review selectively summarizes the current trends related to consumption of edible insects among householders, the food and beverage industry consumers, and its prospects as a key attractant in tourism destinations. Its unconventional processing techniques have hindered its growth especially in the food business industry, thus influencing the food value chain in entomophagy. The paper reviews perceptions on insects' consumption by identifying already developed processing methods, emphasizing on the health benefits of entomophagy and its economic importance. A structured literature search is conducted to identify published studies on edible-insects product processing, food design, its acceptance, and consumption in the food industry. The literature search is focused on its acceptance as whole consumption or after product development and whether it can be accepted in the food industry in its new form. It was observed that Europe has the highest publications on acceptance, public perception, processing technology, and research trends. Africa tends to prefer whole consumption, as the Americans is still have not taken a stand. Results reveal that processing of the insects and incorporating other ingredients have greatly increased acceptance of edible insects. Therefore, we conclude that new food designs that incorporate insects as special ingredient should be promoted in main stream hotels to attract food and culture tourism.

Keywords: edible insects, food design, hospitality industry, processed products, entomophagy

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INTRODUCTION

Proponents of food security have severally cautioned the world of the impending world food shortage if adequate measures are not put in place in time. We can therefore say with confidence that this estimated world population of nine billion people by 2050 (FAO, 2009) will cause unique challenges to adequately feed. It will require unique approaches to provide the needed diet diversity for good health. The double increase in population will require double the current food production to cope with the observed growing food demand (Belluco et al., 2013). Consumers are increasingly looking for new foods and are willing to travel far and wide to taste new dishes. It is observed in Africa that almost all cultural events in communities have traditional dishes as a main attraction. The African chefs in such cultural events in Kenya make all efforts to include at least one traditional dish made of edible insects to replete the list of available traditional dished in the community. Insects, as alternative food resource, have received and is continuing to receive attention as they

are institutionally being accepted as indigenous to a tribe, culture, or a specialty in many regions (Murefu et al., 2019; Patel et al., 2019). For example, if you mention flying termites, you will be referred to western Kenya, lake flies will take you to the lake shore Luo of Lake Victoria, and sting burgs and mopane worms are indigenous to the southern Africa tribes.

INCREASED ACCEPTABILITY

Insects as food are not fully familiar with conventional western eating habit (Murefu et al., 2019). Even though edible insects are largely found in Africa, currently Europe and the United States are said to have the fastest growing formal edible insect industry. According to Patel et al. (2019), insect-based food items are in a transitional stage. New techniques involving developing visually attractive food products by combining and using isolated protein and processing technology can promise edible insect markets. This is simply because some insects are appreciated for their organoleptic characteristics, others for their look and smell, while others for their high food value and are consumed in high class restaurants for different reasons.

NEGATIVE ATTITUDE TOWARD ENTOMOPHAGY

Increased attention to the use of insects as human food and animal feed have raised great concerns on its safety. We cannot ignore the risks that come with this novel idea. The European Food Safety Authority (EFSA) has tried to address this concerns in the area of microbiological, chemical, and environmental risks that arise from the production and consumption of insects as food and feed. This was mainly raised due to the fear of Bovine Spongiform Encephalopathy (BSE) or better known as the mad cow disease. According to EFSA Scientific Committee (2015), the prevalence and concentration of contaminants in insects and insect derived foods are majorly influenced by insect production method, insect species, insect stage of harvest, and substrate used in the rearing process. Additionally the handling and storage of farmed insects could also be a risk factor. Heavy metals have also been shown to accumulate in some species of insects, but there is little published data to draw further conclusion and this will continue being a barrier for promoting edible insects. Going by van Huis (2016), some of the reasons why the western cultures have not fully embraced entomophagy is due to the insect size, dispersed distribution, and the seasonality unavailability. Apart from those mentioned, existing cultural differences were also used by western cultures to denigrate traditional people's beliefs leading to an association of disgust with insect consumption (Looy et al., 2014).

OVERCOMING PERCEPTIONS TO INCREASE DINERS DEMAND

The lingering perceptions of insects are hampering global market expansion and are limiting insects as a mainstream dinning option (Dobermann et al., 2017). In other parts of the world, the efforts to promote entomophagy include studies aimed at customizing insects for the western tastes. The western tastes and preferences dominate diners in Africa as can be observed in most conventional restaurants in Kenya. This dominant eating culture, if well-exploited, can be deployed to improve perceptions on the dining tables to attract more food tourists. Kenya is among the East African countries that attract many tourists from the European nations. Overcoming the negativities of edible insect food items, particularly those local dishes containing edible insects would see increased consumers from the western nations. As such, even the supermarkets would realize improved sale of few insect-based flours in the retail markets. The same approach can be used in typical Africa food outlets customizing locally available dishes to fit into our markets in the hospitality industry. In order to increase palatability, insects have been processed into powder or meal and even mixed with other ingredients to camouflage visual associations and the dislike factor, a factor yet to be fully explored in designing foods for the lucrative tourism industry.

ENTOMOPHAGY AND THE WORLD FOOD INDUSTRY

According to Kim et al. (2019) and Han et al. (2017), the edible insect market is expected to exceed USD 522 million by 2023 and entomophagy especially for human has made a major progress and successful research endeavors. Studies show that ∼2,000 insect species are consumed in at least 113 countries worldwide (Yen, 2015). Most of these insects are appreciated for their organoleptic characteristics and consumed in high-class restaurant (Defoliart, 1999), while others are considered a delicate gourmet dish in Mexico, Laos, Cambodia and Europe (Ramos-Elorduy, 2010). Korean edible insect market especially for human consumption has grown since 2012 with government support and successful research outputs (Kim et al., 2019). However, the slow reduction of negative perceptions of insects in certain areas is hampering the desired fast market expansion, and is limiting insects as a mainstream dinning option. Even though non-locals tend to be skeptical to novel foods due to neophobic tendencies (Dobermann et al., 2017), several visitors often ask for edible insects or new foods to taste during food festivals, a behavior commonly observed during cultural displays in Kenya. Some studies in European countries such as the Netherlands have shown that the people who have eaten insects before are significantly more positive and receptive toward entomophagy than people who have not, and are also willing to eat them again and again if given the opportunity (Lensvelt and Steenbekkers, 2014).

PROCESSING INSECTS AND USE

Insects are increasingly being viewed as food for the future. In the Netherlands, the efforts to promote entomophagy is aimed at customizing insects for the Western tastes, thus, the sale of edible insects at retail markets (Schösler et al., 2012). Insects are being processed into powder or meal to minimize negative visual

TABLE 1 | Food processing properties of edible insects.

Types of insects	Scientific name	Observed quality	References
Emperor Moth (Larvae)	*Cirina forda*	Protein solubility Oil absorption capacity Foaming stability	Omotoso, 2006
Larvae Grasshopper Cricket	*Gryllodes sigillatus* *Schistocerca gregaria* *Achita domestica*/gryllus *Bimaculatus*	Protein solubility Water holding capacity Oil holding capacity Foaming capacity Emulsion capacity	Zielińska et al., 2018
Emperor moth (larvae)	*Cirina forda*	Protein solubility Oil absorption capacity Water absorption capacity Foaming capacity Emulsion capacity	Osasona and Olaofe, 2010
Rhinoceros beetle (larvae)	*oryctes owariensis*	Oil absorption	Assielou et al., 2015
Silk Moth (larve)	*Bombyxmori L.*	Water absorption capacity Foaming capacity Foaming stability Emulsion capacity Emulsion stability	Omotoso, 2015
Mealworm (Larvae)	*Tenebrio molitor*	Water binding capacity Foaming capacity	Bußler et al., 2016 Yi et al., 2013
Black soldier fly (Larvae)	*Hermetia illucens*	Fat binding Capacity Protein solubility	
Superworms (Larvae)	Zophobas morio	Foaming stability	
Lesser mealworm (Larvae) Cockroach	Alphitobius diaperinus *Blapica dubia*	Gel formation	

TABLE 2 | Functional properties of *C. forda* larva.

Parameters	Percentage (%)
Water absorption capacity	300.00 ± 0.15
Oil absorption capacity	358.00 ± 0.21
Emulsion capacity	36.67 ± 0.11
Emulsion stability	45.36 ± 0.21
Least gelation	6.00 ± 0.00

Mean ± SD of triplicates.

associated with bugs and to increase ease of use and palatability (Bußler et al., 2016). In addition, researchers are investigating the functional properties of insect proteins, including gelatinization capacity, foaming capacity, bulk density, emulsification capacity, and oil and water solubility which will help in the use of edible insects as food ingredients. Such studies will promote processing, formulating, and designing insect-based formulae for producing different kinds of recipes (**Tables 1**, **2**), as adopted from Kim et al. (2019) and Omotoso (2006).

The increased consumer knowledge about edible insects is increasing the willingness to pay for insect-based food items (Piha et al., 2018). However, cultural differences in acceptance of insects as food cannot be changed overnight (Defoliart, 1999). Despite the numerous advantages and benefits of insect consumption, rapid uptake of entomophagy in western societies has been observed to be slow (Sogari, 2015; van Huis, 2016), thereby reducing popularity to promote entomophagy for tourist attraction in the European fields. Attracting tourists from such regions will mostly depend on how well the food items will be processed and packaged for attraction. Continuous promotional efforts to increase exposure, coupled with development to enhance taste and appearance, have successfully reduced the negative perceptions in some western countries (van Huis, 2013; Looy et al., 2014). For example, consumers in Belgium increasingly accept insects as an excellent food source (Van Thielen et al., 2019). Such encouraging attitudes and perceptions would equally enhance tourism attractions. It is noted that the edible insect industry in the Netherlands is more advanced and is successful in marketing freeze-dried insect powder that is sold as a meat replacement (Raheem et al., 2019).

DEVELOPING CONVENIENT FOODS

In several countries, edible insects are sold in the streets as finger foods and attract many people to frequent the market places when in season. In Western Kenya, salted flying termites are hawked in the market places and people buy in small quantities dished out with table spoon measures. Food tourists, particularly foreign visitors, frequent such places to sample the seasonal attraction. The lake flies are made into small balls or patties and also sold in the streets when in season. Local families also normally visit such market places to buy a stock for their consumption in the case they are not able to collect for themselves from the wild. In Korea, canned silkworm pupae are sold in retail markets and processed as snacks. Grasshoppers

seasoned with soy sauce are eaten in rural areas (Pemberton, 1994). In Japan, a dish called *inago* involves fried grasshoppers seasoned with soy sauce are freely available as street foods. Bees or wasp larvae/adults are considered expensive delicacies, eaten raw, boiled with soy sauce, or served with rice (Defoliart, 1999). In Northern India, eri-silkworm (*Samia ricini*) pupae is a delicacy (Peigler, 1993). Sago grub (*Rhynchophorus ferrugineus*) is a popular edible insect in Papua New Guinea and a main part of an annual grub festival (Mercer, 1993). In Australia, entomophagy is still low among European but considered acceptable among the original Aborigines (Yen, 2010). From such well-established spread of entomophagy, edible–insect market has dramatically developed alongside bush foods. Edible insects are now available as certain restaurant menus (Irvine, 1989). From the above-mentioned examples, it is clear that finger foods are popular as a chosen design for edible insects in traditional insect eating communities. However, use of powdered edible insects incorporated in other food as carriers may be developed to suit the traditional Ala-carte in restaurants and dining tables and will offer greater room for creativity in pastries.

PRODUCT PROCESSING AND FOOD DESIGN

Insect species look different and different developmental stages are used for food. For some, it is the larval stages that are harvested for consumption, while for the others, it is the adult stages that are consumed. Such diversity comes with challenges of how best to prepare the items to attract consumers. This makes the ability to process and designing edible insect an issue for consideration. A number of studies with American, Belgian, Indian, and Swiss samples suggest that people prefer insect foods with crispy textures and familiar tastes and that they are more willing to eat processed foods containing insect flour, such as cookies or crackers, than they are to eating whole insects (Ruby and Rozin, 2019). As observed earlier, processed insects tend to have higher acceptability than raw unprocessed insects (Caparros Megido et al., 2014; Gmuer et al., 2016). Processed insect foods may lead to increased number of Africa people considering insects as a commodity of value adding for entrepreneurship in the villages. For long, harvested insects go stale in homes due to inadequate processing knowledge, lack of storage capacity, and unwilling consumers to buy more than they can eat at a given time. Informed capacity to process and trade in edible insects would thus increase entomophagy into traditional diets for variety. Furthermore, a research done with Kenyan school children found that biscuits containing 10% cricket flour were well-liked than those containing 10% milk powder (Homann et al., 2017). During subsequent annual agricultural exhibitions in Kisumu (Kenya), it was observed that the biscuits were the main attraction for children. Gmuer et al. (2016) also used photographs of chips including insects in different ways and an array of affect-laden words in evaluation of acceptability. The study noted that positive emotional expectations played a significant role in promoting processed products of insects. Participants of this study also confirmed that sensory attributes of buns containing 10% cricket flour to be more acceptable (Pambo et al., 2018). To contribute to this preposition, preliminary studies being undertaken at a university in Kenya seeks to explore the role of elate termites and lake fly characteristics in preparation of cuisines and cocktails. As observed indeed, Giordano et al. (2018) and Hartmann and Siegrist (2018) confirm that food taste preferences reflect a spectrum of attitudes from neophobia to neophilia, just as desire to try novel food sources.

CONCLUSION

Initiatives to promote edible insects in the tourism industry can be improved by improving preparation, processing, and presentation to appeal to diners' tastes and preferences. Presenters should try and emphasize on edible insects' practical values, which can create consumer demand (Sun-Waterhouse et al., 2016). Tasting events or educational workshops can also provide opportunities to learn about edible insects (Han et al., 2017) for marketers and promotional tours in potential areas. The promotions have to start with the areas that are typically known to be consumers of all kinds of insects to provide opportunities to identify the insects with high potentials in the tourism industry. In respect to this, the development of haute cuisine using edible insects need to take center stage in the efforts to promote its consumption in the food service industry. Incorporating edible insects in already familiar foods will increase acceptability among insect-phobic cultures than providing whole insects directly as a food item. Formation of sustainable edible insect food value chains and appealing business models have a place in emerging food tourism industry.

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All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

REFERENCES

Assielou, B., Due, E. A., Koffi, M. D., Dabonne, S., and Kouame, P. L. (2015). Oryctes owariensis larvae as good alternative protein source: nutritional and functional properties. *Ann. Res. Rev. Biol.* 1–9. doi: 10.9734/ARRB/2015/19093

Belluco, S., Losasso, C., Maggioletti, M., Alonzi, C. C., Paoletti, M. G., and Ricci, A. (2013). Edible insects in a food safety and nutritional perspective: a critical review. *Compr. Rev. Food Sci. Food Saf.* 12, 296–313. doi: 10.1111/1541-4337.12014

Bußler, S., Rumpold, B. A., Jander, E., Rawel, H. M., and Schlüter, O. K. (2016). Recovery and techno-functionality of flours and proteins from two edible insect species: meal worm (*Tenebrio molitor*) and black soldier fly (*Hermetia illucens*) larvae. *Heliyon* 2:e00218. doi: 10.1016/j.heliyon.2016.e00218

Caparros Megido, R., Sablon, L., Geuens, M., Brostaux, Y., Alabi, T., Blecker, C., et al. (2014). Edible insects acceptance by Belgian consumers: promising attitude for entomophagy development. *J. Sens. Stud.* 29, 14–20. doi: 10.1111/joss.12077

Defoliart, G. R. (1999). Insects as food : why the Western attitude is important? *Annu. Rev. Entomol.* 44, 21–50. doi: 10.1146/annurev.ento.44.1.21

Dobermann, D., Swift, J. A., and Field, L. M. (2017). Opportunities and hurdles of edible insects for food and feed. *Nutr. Bull.* 42, 293–308. doi: 10.1111/nbu.12291

EFSA Scientific Committee. (2015). Risk profile related to production and consumption of insects as food and feed. *EFSA Journal*, 13, 4257.

FAO (2009). How to feed the world in 2050 (Online).

Giordano, S., Clodoveo, M. L., De Gennaro, B., and Corbo, F. (2018). Factors determining neophobia and neophilia with regard to new technologies applied to the food sector: a systematic review. *Int. J. Gastron Food Sci.* 11, 1–19. doi: 10.1016/j.ijgfs.2017.10.001

Gmuer, A., Guth, J. N., Hartmann, C., and Siegrist, M. (2016). Effects of the degree of processing of insect ingredients in snacks on expected emotional experiences and willingness to eat. *Food Qual. Prefer.* 54, 117–127. doi: 10.1016/j.foodqual.2016.07.003

Han, R., Shin, J. T., Kim, J., Choi, Y. S., and Kim, Y. W. (2017). An overview of the South Korean edible insect food industry: challenges and future pricing/promotion strategies. *Entomol. Res.* 47, 141–151. doi: 10.1111/1748-5967.12230

Hartmann, C., and Siegrist, M. (2018). Development and validation of the food disgust scale. *Food Qual. Prefer.* 63, 38–50. doi: 10.1016/j.foodqual.2017.07.013

Homann, A. M., Ayieko, M. A., Konyole, S. O., and Roos, N. (2017). Acceptability of biscuits containing 10% cricket (*Acheta domesticus*) compared to milk biscuits among 5–10-year-old Kenyan schoolchildren. *J. Insects Food Feed* 3, 95–103. doi: 10.3920/JIFF2016.0054

Irvine, G. (1989). Putting insects on the Australian menu. *Food Aust.* 41, 565–566.

Kim, T.-K., Yong, H. I., Kim, Y.-B., Kim, H.-W., and Choi, Y.-S. (2019). Edible insects as a protein source: a review of public perception, processing technology, and research trends. *Food Sci. Anim. Resour.* 39, 521–540. doi: 10.5851/kosfa.2019.e53

Lensvelt, E. J. S., and Steenbekkers, L. P. A. (2014). Exploring consumer acceptance of entomophagy : a survey and experiment in australia and the netherlands exploring consumer acceptance of entomophagy : a survey and experiment in Australia and the Netherlands. *Ecol. Food Nutr.* 53, 543–561. doi: 10.1080/03670244.2013.879865

Looy, H., Dunkel, F. V., and Wood, J. R. (2014). How then shall we eat? Insect-eating attitudes and sustainable foodways. *Agric. Human Values* 31, 131–141. doi: 10.1007/s10460-013-9450-x

Mercer, C. W. L. (1993). "Insects as food in Papua New Guinea," in *Proceedings of the Invert Farming Seminar Antwerp* (Antwerp: Institute of Tropical Medicine), 33–40.

Murefu, T. R., Macheka, L., Musundire, R., and Manditsera, F. A. (2019). Safety of wild harvested and reared edible insects: a review. *Food Control* 101, 209–224. doi: 10.1016/j.foodcont.2019.03.003

Omotoso, O. T. (2006). Nutritional quality, functional properties and anti-nutrient compositions of the larva of *Cirina forda* (Westwood) (Lepidoptera: Saturniidae). *J. Zhejiang Univ. Sci. B* 7, 51–55. doi: 10.1631/jzus.2006.B0051

Omotoso, O. T. (2015). An Evaluation of the Nutrients and Some Anti-nutrients in Silkworm, Bombyxmori L. (Bombycidae: Lepidoptera). *Jo. Jour. of Bio. Sci*. 8.

Osasona, A. I., and Olaofe, O. (2010). Nutritional and functional properties of Cirina forda larva from Ado-Ekiti, Nigeria. *Afr. J. Food Sci.* 4, 775–777.

Pambo, K. O., Okello, J. J., Mbeche, R. M., Kinyuru, J. N., and Alemu, M. H. (2018). The role of product information on consumer sensory evaluation, expectations, experiences and emotions of cricket-flour-containing buns. *Int. Food Res. J.* 106, 532–541. doi: 10.1016/j.foodres.2018.01.011

Patel, S., Ansar, H., Suleria, R., and Rauf, A. (2019). Accepted manuscript edible insects as innovative foods: nutritional and functional assessments. *Trends Food Sci. Technol.* 86, 352–359. doi: 10.1016/j.tifs.2019.02.033

Peigler, R. S. (1993). Wild silks of the world. *Am. Entomol.* 39, 151–162. doi: 10.1093/ae/39.3.151

Pemberton, R. W. (1994). *The Revival of Rice-Field Grasshoppers as Human Food in South Korea*. Chesterfield, MO: The Pan-Pacific Entomologist.

Piha, S., Pohjanheimo, T., Lähteenmäki-Uutela, A., Krečková, Z., and Otterbring, T. (2018). The effects of consumer knowledge on the willingness to buy insect food: an exploratory cross-regional study in Northern and Central Europe. *Food Qual. Prefer.* 70, 1–10. doi: 10.1016/j.foodqual.2016.12.006

Raheem, D., Carrascosa, C., Oluwole, O. B., Saraiva, A., Millán, R., and Raposo, A. (2019). Traditional consumption of and rearing edible insects in Africa, Asia and Europe. *Crit. Rev. Food Sci. Nutr.* 59, 2169–2188. doi: 10.1080/10408398.2018.1440191

Ramos-Elorduy, B. J. (2010). The importance of edible insects in the nutrition and economy of people of the rural areas of Mexico. *Ecol. Food Nutr.* 36, 347–366. doi: 10.1080/03670244.1997.9991524

Ruby, M. B., and Rozin, P. (2019). Disgust, sushi consumption, and other predictors of acceptance of insects as food by Americans and Indians. *Food Qual. Prefer.* 74, 155–162. doi: 10.1016/j.foodqual.2019.01.013

Schösler, H., Boer, J., de, and Boersema, J. J. (2012). Can we cut out the meat of the dish? Constructing consumer-oriented pathways toward meat substitution. *Appetite* 58, 39–47. doi: 10.1016/j.appet.2011.09.009

Sogari, G. (2015). Entomophagy and Italian consumers: an exploratory analysis. *Prog. Nutr.* 17, 311–316.

Sun-waterhouse, D., Waterhouse, G. I. N., You, L., Zhang, J., Liu, Y., Ma, L., et al. (2016). Transforming insect biomass into consumer wellness foods: a review. *Food Res. Int.* 89, 129–51. doi: 10.1016/j.foodres.2016.10.001

van Huis, A. (2013). Potential of insects as food and feed in assuring food security. *Annu. Rev. Entomol.* 58, 563–583. doi: 10.1146/annurev-ento-120811-153704

van Huis, A. (2016). The future of animal products in the human diet: health and environmental concerns' Boyd Orr lecture edible insects are the future? *Proc Nutr Soc.* 75, 294–305. doi: 10.1017/S0029665116000069

Van Thielen, L., Vermuyten, S., Storms, B., Rumpold, B., and Van Campenhout, L. (2019). Consumer acceptance of foods containing edible insects in Belgium two years after their introduction to the market. *J. Insects Food Feed* 5, 35–44. doi: 10.3920/JIFF2017.0075

Yen, A. L. (2010). "Edible insects and other invertebrates in Australia: future prospects. in forest insects as food: humans bite back," in *Proceedings of a Workshop on Asia-Pacific Resources and Their Potential for Development*, eds P. B. Durst, D. V. Johnson, R. L. Leslie, and K. Shono (Chiang Mai, CM), 65–84.

Yen, A. L. (2015). Insects as food and feed in the Asia Pacific region: current perspectives and future directions. *J. Insects Food Feed* 1, 33–55. doi: 10.3920/JIFF2014.0017

Yi, L., Lakemond, C. M., Sagis, L. M., Eisner-Schadler, V., van Huis, A., and van Boekel, M. A. (2013). Extraction and characterisation of protein fractions from five insect species. *Food Chem.* 141, 3341–3348. doi: 10.1016/j.foodchem.2013.05.115

Zielińska, E., Karaś, M., and Baraniak, B. (2018). Comparison of functional properties of edible insects and protein preparations there of. *LWT—Food Sci. Technol.* 91, 168–174. doi: 10.1016/j.lwt.2018.01.058

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