Research Paper

Is the adoption of insect meat in the Western World economically and environmentally viable?

Bachelor Thesis

Geneva Business School

Bachelor in Business Administration Major in Digital Marketing

Submitted by:

Steven von Hofsten

Supervised by:

Dr. Adil Qureshi

Geneva, Switzerland

Date: 06/06/2021

Word count: 8237

List of Abbreviations

GDP	Gross domestic product
PCBs	Polychlorinated biphenyls
OCPs	Organochlorine pesticides
PBDEs	Polybrominated diphenyl ethers
PFRs	Flame retardants and plasticizers
GHG	Greenhouse gas
OPP	Optimal price point
PMC	Point of marginal cheapness
PME	Point of marginal expensiveness

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Acknowledgements

I wish to express my sincere thanks to Adil Qureshi, my supervisor, for providing me with all the necessary assistance and the additional articles that inspired my research process.

I am also grateful for my partner Carla Schwarz for her motivational support during these trying times.

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Abstract

This study investigated the psychographics of a sample group of European citizens with relation to their willingness to consume insect meats. This topic was of interest as current literature argues that the mass adoption of insect meat consumption could have positive effects on the environment of our planet. It was also important to explore the potential avenue for commercial applications of insect meat. The results of this study indicate that European consumers are still adamant in consuming insect meats due to the presentation of the insect meat and the lack of knowledge surrounding entomophagy. The consumers are however ready to consider insect meat consumption for the betterment of their environment and personal health.

1. Introduction

Although this concept may seem novel, the act of insect consumption or entomophagy, as it is technically known, has been adopted by various cultures around the world for thousands of years. The Greeks were notably one of the first Europeans to consume insects as part of their diet, with literature dating back to Aristotle's time indicating that cicadas were consumed as a delicacy before becoming commonplace (Bodenheimer, 1951). Placing geographical limitations aside, the human species consumed insects even before the Greeks. Greek historians were aware of this, referring to the North Africans of Ethiopia as *Acridophagi* which directly translates to locust-eaters.

With humans having eaten insects in the past, the purpose of this thesis is to explore the viability of introducing insect meat consumption to the Western world in the present timeline. Meat consumption continues to be on the rise, with this increased consumption stemming from the recently analysed trend that states per capita GDP (per capita gross domestic product, a country's economic output per person) is a crucial factor in meat consumption and as countries become wealthier, meat consumption increases (Tilman et al, 2011). This topic is of a high importance as current patterns of consumption occurring around the world are not sustainable due to the finite resources that are available on our planet (Mar, 2011).

Finite resources and scarcity is not the only cause of urgency to debate the topic: production of conventional meats such as chicken and beef contribute heavily to greenhouse gas emissions through the intensive agriculture used to feed said livestock (Keyzer et al, 2005). This will inevitably lead to higher global temperatures which may exacerbate the problem even further. Currently available literature highlights the positive impact that widespread insect meat consumption could have on climate change and food insecurity.

Furthermore there are a limited number of companies that currently incorporate insect based substances and substitutes within products in the European market. To bring this idea into the market will require economic incentives as it is likely that private companies will have to undertake the implementation of the required infrastructure to mass produce insect meat. Analysis of the market's potential profitability and avenues of distribution included within this thesis will elucidate the present circumstances.

Falling in line with the economic aspects are the regulatory barriers that are currently hindering the mass adoption of insect meat in the West. These regulations make the market look unprofitable to potential investors. As insects comprise a different family in the arthropoda species, one may assume that legislation could easily be adapted from those set for the readily eaten crustacean family. This is not so as this lack of standardization for insect farming, processing and packaging for both human and animal consumption presents a unique challenge. Creating standardization that can be adopted by all European countries is time and resource consuming.

Arguments against the adoption of insect meat are valid and are necessary to ensure the safety of the general public. Insects are generally known to harbour potentially dangerous pathogens, fungi and diseases. Additionally, with the widespread adoption of pesticides and other chemicals, certain insects can also accumulate hazardous toxins (Smith et al, 2013). As such, insects are treated as pests.

This fact alone is the basis for the biggest argument against insect meat adoption. Culturally and socially, insect consumption is frowned upon by Western society. The psychological aspect behind it poses the greatest challenge. Insect meat would have to be presented in a way that is socially acceptable and in a way that does not trigger neophobia (fear of trying something new).

2. Literature Review

EU Meat Consumption and Environmental Change

Meat is an important aspect of our daily diet. The consumption of meat continues to increase and is projected to increase by 70% globally by the year 2050 (Smetana et al., 2015). Although this is a positive forecast for the meat producers economically speaking, it was reported in the literature that the environmental pressure placed by the meat industry is significant. During a 2010 study, researchers extensively measured the global warming potential (GWP) of various ruminants (farm animals). They found that the GWP of raising beef cattle was the highest, producing the most carbon dioxide (CO_2) amongst all other ruminants in the study (pigs and chickens) (Vries et al., 2010). This was attributed to the fact that the meat industry for beef consumes the most amount of energy which is still fossil fuel based, hence contributing to climate change.

In a 2017 article titled "CO_2 and Greenhouse Gas Emissions", researchers noted that livestock and the manure produced from livestock activities accounted for 5.8% of total global greenhouse gas (GHG) emissions (Ritchie et al., 2017). This included CO_2 and methane, another GHG released directly by cattle. Methane is especially prevalent when it comes to cattle farming. Proponents of ecological cattle farming, ie. grass fed cattle, opted to change the diets of the cattle in hopes of reducing said methane production and producing higher quality ethical meat. But researchers at Harvard University calculated that grass feeding cattle in the United States would produce an overall increase of 43% in methane levels if all cattle were grass fed instead of grain fed as the majority currently are (Hayek et al., 2018). This is bad as GHGs such as methane increase climate change through their molecular composition: they trap infrared radiation emitted from the planet into the atmosphere when it should have radiated out into space, thus heating up the planet. This warming has the potential to disrupt entire ecosystems and affect the food sectors, including the meat sector.

Meat consumption in Europe has been on a rise since the early 2000's. In the most recent years of 2016 to 2018, the per capita consumption of meat within the EU increased from 68.5kg and peaked at 69.9kg (table A1). Yet, within the last 2 years alone, meat consumption has dropped from a per capita consumption of 69.9kg to 68.0kg. The European commission attributes this drop to the sudden COVID19 pandemic. They also forecast the demand for meat to fall within the next decade (EU Agricultural Outlook, 2020). It seems that European citizens are changing their consumption habits. This could be due to increased knowledge on climate change and changes in their environmental habits.

Insect Meat and Emissions

This forecast bodes well for the future of our planet's environment as the introduction of insect consumption would reduce the environmental strain caused by the production demands of ruminants without relinquishing the vital nutrition that they provide. The reduction in environmental pressure would also include an overall reduction in greenhouse gas (GHG) emissions as discussed by Oonincx et al. (2010). Their study focused on five primary insects: mealworms, crickets, locusts, beetles and cockroaches (the last two insects were chosen for potential animal protein applications such as feeding ruminants directly and creating food pellets for fish).

The researchers observed that the GHG produced by insects of a specific overall weight, reared in the laboratory, was roughly 1% that of herbivorous farm animals of similar weight in the study (beef cattle and pigs). The authors took it a step further and identified that the all insect candidates had higher average daily gain (ADG) values than their farm animal counterparts (Oonincx et al, 2010). ADG is the average weight an animal gains daily during its feeding period. Their reduced GHG emissions coupled with their higher ADG means that insects are also more efficient at converting animal feed to protein. The research method used by the researchers appears to be robust, having spanned three days and three to six repeated gas tests per species of insect. However, questions arise when considering the diet that the insects were fed during the study, primarily the chicken mash. The move towards mass insect production should not be fueled by increased farming of domestic fowls as animal feed as that will defeat the primary purpose of insect mass production.

Incidentally, the benefits surrounding the shift to insect meat consumption on a global scale are thoroughly studied. It is proclaimed in the literature that insect based substitutes, along with soy substitutes, revealed to have the least impact on climate change when compared to the production of an equal 1 kilogram of weight of chicken due to the effectiveness of current systems of production (Smetana et al., 2015). In isolated tests, it was reported that to produce 1 kilogram of protein with crickets, one would only require 1.5 litres of water, in comparison to 1 kilogram of beef that would require 3400 litres of water (Clarkson et al., 2019). The costs saved from this alone would make it economically viable. Additionally, most countries are expected to run into water shortages in the future as climate change continues to run rampant. An entire shift to insect meat consumption would result in savings of thousands of litres of water per person.

Psychological Barriers

These results highlight the positive impact that insect production could have on environmental pressure. Shifting Western consumer meat culture towards a more entomophagy (ie. the act of eating insects) focused consumption will be difficult. As the author Wim Verbeke noted, consumption of insects in countries where it is traditionally customary to do so, such as Botswana, has been in decline (Verbeke, 2015) primarily due to the Westernization of their diets. This is expected as low income countries where insect consumption is common move towards more staple diets. To expect that Western countries will take up insect consumption quickly is an optimistic point of view considering there is a strong neophobia (ie. fear of testing new foods) and, most importantly, a huge “yuck factor” surrounding the consumption of insects (Megido et al., 2016). This “yuck factor” is the instinctive response humans have towards things they find disgusting, such as insects or drinking reclaimed wastewater.

In the study Megido et al. (2016) hypothesized that younger consumers would be the most receptive to insect consumption and the results of their study proved it to be true:

> Nevertheless, in this study, only 39.0% of participants had heard about ento-mophagy and only 33% of respondents had eaten insects previously while 81% of them reported this previous experience was positive.(p.5)

The study was carried out at the Paul Lambin Institute in Belgium. Participants volunteered to consume four different burgers: a pure beef burger, a beef and mealworm burger, a beef and lentils burger and a mealworm and lentils burger. Additionally they were tasked to answer surveys before and after consumption of each burger, testing for the respondents knowledge of the nutritional benefits of insect meat, their reactions to each type of burger, whether they could tell which burgers included insect meat and whether their perception on entomophagy had changed.

Although the study provides a positive outlook about the future of insect consumption, it is critical to point out the limitations and possible biases of the study. The sample size of respondents was a significant limitation to the study as only 51% of the 159 potential participants participated. Furthermore all participants were students in different fields (medical biology, dietetics and chemistry). Admittedly, these fields of study may contribute to an increased likelihood of a positive bias towards entomophagy due to the knowledge the students may have picked up on in their respective disciplines.

Despite the potential pitfalls of the previously mentioned study, Western socio-culture has solidly embedded the bias against insects as most Westerners view them as pests and not as edible alternatives (Hartmann et al., 2015). According to both Megido and Hartmann, steps must be taken prior to the introduction of this meat substitute to reduce this neophobia, such as increasing familiarity with the textures and flavours of these meats. Increased education on the benefits of insect consumption are also likely to persuade early adopters with a higher risk appetite. This however is premature as a general conclusion based on the advantages and disadvantages of insect meat consumption must first be reached.

Consumer Knowledge

A more comprehensive study of the barriers towards this introduction was carried out in Hungary. In a survey conducted in 2016, gender was revealed as a statistically important metric in the readiness to consume insects as a meat substitute (Gere et al., 2016). The male gender is reportedly more willing and ready to consume insect meat according to the authors. Discussions brought forth by the authors highlights that consumers were aware of the health benefits and the climate benefits associated with the consumption of insect meat analogues (Gere et al., 2016, p. 5) suggesting that Hungarian consumers are somewhat educated on the matter. These results are very similar to those recorded 2 years prior during a 2014 study on the acceptability of entomophagy with respondents from the Netherlands and Australia. While the respondents did not necessarily feel that insects were personally beneficial to themselves, they did acknowledge the environmental and health benefits (Lensvelt et al., 2014).

Mass Production Challenges

Historically speaking, there is still a lack of research surrounding the specifics of the mass production of insects, however, according to Peter Alexander, energy consumption of mass insect farming is on par with the energy consumption used in conventional livestock production (Alexander et al., 2017). These findings should be treated with a degree of skepticism as Arnold van Huis reported, in the same year, that energy consumption would be nominally greater than that spent on conventional livestock farming as insects are poikilothermic (ie. internal temperature of the animal fluctuates instead of maintaining a steady temperature)(Huis et al., 2017). This conclusion is further acknowledged in a later report by Sergiy Smetana. The author concluded that the biggest non-beneficial environmental impact of insect farming on a mass scale is current energy consumption (Smetana et al., 2019). The authors did state however that their modelling was based around conventional energy production means. Their results may be more that the introduction of renewable energy sources would reduce the energy consumption costs significantly.

Carrying out such a research to find out the exact impacts of insect mass production is a difficult task. For example, the research carried out by Alexander et al. simply took an exploratory approach at various scenarios and compared them to one another. Data used in the research included 6 year old aggregate data from 2011. One can see that it takes time for official data to be recorded and published en masse. The report by Huis et al.(2017) also looked at historical data. This is to point out that even within the last decade there has yet to be a thorough study on the commercial rearing of insects and their subsequent costs of production.

Insect Nutritional Aspects

To summarize, the type of insects being consumed will also play a vital role in the adoption of this alternative meat. Not all insects are built the same: some either take too long to grow to maturity whilst others do not provide the necessary nutrients to consider them as a meat alternative. In a report led by Claudia Clarkson, locusts were concluded to have the necessary composition required to provide sustenance to humans (Clarkson et al., 2019) with acceptable levels of protein, fat and fatty acids. Omega 3 fatty acid, commonly found in fish, is a key lipid found abundantly in insects consuming grass. As often is the case, current systems producing insects for human consumption use waste products of other farming endeavours as the feed to nourish and grow these insects. As expressed by Sirgey Smetana, insects fed and nurtured with low quality biomass (ie. waste products) are suitable for use as livestock feed but are unacceptable as a food alternative (Smetana et al., 2016). With a nutritionally diverse composition, insects are healthier alternatives to conventional meats but what we feed said insects affects their nutritional values when they end up on our plates.

Insect Contamination Risks

Although insects are naturally found with healthy nutrients (Belluco et al.,2013) it is likely that these insects may acquire diseases, pathogens, chemicals or metals that are harmful for human consumption. Food safety is paramount in Western society, especially within the European Union. Chemical and metallic toxicity is a primary concern in our present as increased industrialisation of our societies introduces new chemicals into new and existing applications, increasing the chances of spillage into the surrounding environments. In a study carried out by a Belgian toxicology team, a select group of insects and insect products that are already available on the Belgian market were found to have had lower or similar levels of commonly found chemicals and metals as those present in conventional meats (Poma et al., 2017). The study tested PCBs (oils used in electrical appliances), OCPs (pesticides), PBDEs (flame retardants), dioxins (toxic compounds) and metals.

It is noted in the article that the researchers used materials and state of the art equipment from reputable institutions such as Cambridge Isotope Laboratories and Dr. Ehrenstorfer Laboratories. At face value one would believe the use of up to date equipment would provide accurate results. However, one cannot help but scrutinize the scope of the study as the results conveniently align with the preferred outcome of this thesis. Although the study is comprehensive in terms of the number of chemicals tested, upon further investigation it was discovered that the toxicology team used a gravimetric method of lipid analysis as laid out by Xu et al. (2015). Whilst this method may not be incorrect, this method of analysis only provides the total amount of lipids present but not the actual anatomy of what types and amounts of lipids are present within the sample. A more accurate method of analysis could have been used such as gas chromatography, as described by Patel et al. (2019). One may argue that specific lipid composition is outside the scope of the study. A valid counter argument would be that identifying lipid composition is necessary in the sample candidate selection process as samples that do not provide enough lipid variety to meet requirements for human consumption would not be considered for mass production.

Pesticides are another concern against mass production of insect meat. Due to their widespread use, they are often on multiple plants that humans consume either through direct use or indirectly. This is a pragmatic concern as the type of feed provided to the insects are likely to be plant based in nature and any residual pesticides may find itself into the systems of these insects. The extent to which this occurs was studied by a team of Belgian researchers in a 2016 study.

Their results showed that mealworms, when fed contaminated plant matter, build up pesticide residue (Houbraken et al., 2016). After testing for multiple pesticides, the researchers concluded that pesticides with a higher octanol/water partition coefficient ($log\ (K_{ow})$) were more easily absorbed and harder to expel. $log\ (K_{ow})$ defines how hydrophilic a chemical is: chemicals with higher $log\ (K_{ow})$ values are less water soluble than chemicals with lower $log\ (K_{ow})$. Contrarily, pesticides with lower $log\ (K_{ow})$ values were not ingested as readily and they were excreted faster. Simply put this means that certain pesticides present in food waste are easily absorbed by insects but leave the body of the insect as easily. Additionally there are other pesticides that are harder to absorb by insects but once absorbed, these pesticides are very difficult to remove thus they may pass on to humans once consumed.

The use of $log\ (K_{ow})$ in the study as a measure of pesticide uptake and its subsequent results should be investigated further. The build up of pesticides can be affected by other natural internal functions of the mealworms such as their metabolism, hence results could have unknowingly been compromised. Nevertheless, this specific research is important as insects that are currently raised for human consumption may often be fed plant leftover scraps which may contain higher levels of pesticides. Farmers will have to be selective of the feed that they provide to their insects.

In summary, this review places a spotlight on the potential benefits of insect meat consumption whilst noting the conflicts in available literature on the subject topic. Understandably this field of knowledge is still limited, with the authority narrowed to a select group of authors such as Smetana, who having carried out several studies may harbour a positive bias towards the subject. Undoubtedly the biggest challenge in introducing this meat alternative lies in the consumers and the psychological barriers they face.

3. Materials and Method

The research took a survey approach, specifically a descriptive research approach. The goal of the survey was to analyse the sentiment of European citizens in general, on the topic of entomophagy. Previous studies have done so but only focusing on the people of their respective countries and not a generalised sentiment analysis (ie. analysis of the respondent's feelings towards aspects of entomophagy). Additionally, the economic analysis within this research was used to get a general idea of what respondents would currently be willing to pay for insect meat.

Previous research made in the literature review suggested that European respondents would be accepting of entomophagy. Logically, results similar to those already published in the literature could be expected. Having researched the subject to a reasonable degree, multiple possible hypotheses became apparent. However, only three hypotheses have been considered for this research:

The younger European citizens are more ready and able to consume insect meat than the older demographic.

The younger demographic are more educated on the subject and are likely to know what entomophagy is.

European citizens are likely to purchase packaged food products with insect based substances.

The answers to these three hypotheses would provide a good direction for future companies to take should they wish to attempt to enter this market. Additionally, it will provide a base for other researchers to further explore the economic and financial aspects of insect meat introduction to the Western world.

Research Setting
A questionnaire is the best form of data collection for this specific topic. It is free and very simple to implement. Being solely online, it allows for a greater reach thus having the ability to build a respectable sample size within a short period of time. Similar studies cited in the literature review used surveys in conjunction with their own models and methodology.This is to say that researchers believed that this form of data collection proved to be beneficial for this field of research.

The survey itself was carried out online during the COVID19 pandemic. It is important to acknowledge this as the majority of people within the European region were still under full or partial lockdowns. This meant that citizens were likely to be at home with enough time to answer the questionnaire at their own pace. Additionally, this was the reason why face to face surveys were out of the question as having the author go out in public to ask citizens to participate presented a risk to themselves and the author. Results were recorded for 5 days, from the 15th of March 2020 to the 20th of March 2020. Any responses after this period of time were not included within the analysis.

Research Strategy
Based on information and knowledge gained through the literature review, the survey has been divided into three distinct sections: demographics, education and economics. The demographics section posed questions about the customer demographics. Questions asked include age range, gender and region. The first two were used to make correlations whilst region was used to filter out survey answers as only the European citizens were considered in this study. This filter question was necessary as the mode of distribution was very generalised and was likely to receive respondents from non-European regions, especially due to the multiculturalism of the author (responses were recorded by respondents in the African and North American regions). Distribution was carried out online on social media platforms and privately distributed amongst family contacts through messenger platforms such as WhatsApp and Facebook Messenger. These contacts were then asked to share the survey with their own friends and family.

The next section of the survey assessed the respondent's knowledge on entomophagy. The questions assessed whether the respondents are actively interested in consuming insect meats, whether they have eaten insects before, whether they know what entomophagy is and where they learned about it. The education section also evaluated how likely and unlikely respondents are to consume insects in their natural form (ie. with their abdomen, head, carapace and all other associated body parts) and in a more familiar form (ie. insect meat sausages, insect meat ground meat, etc.). This education section of the questionnaire concluded with environmental related questions, specifically whether respondents believe eating insect meat would be better for the environment and whether respondents would consider consuming insect meat if it were better for the environment.

The final section of the questionnaire touches upon the economic and financial aspects surrounding a shift to insect meat consumption. In this section, respondents were first asked whether they would purchase packaged food products that do include insects. They were then asked if they would purchase restaurant made meals that include insects as part of their recipes. The preceding questions were based on the Van Westendorp pricing model (Kunter, 2016) which is often used by marketers to identify psychological pricing levels in order to determine possible demand and price elasticity of a product or service. In this case, the questions are searching for the respondents purchase intent for a hypothetical packaged insect meat of a weight of 500g. This weight was specifically used so that respondents may try to relate the available price options to that they pay for regularly at their local supermarket. Prices used were €1.00, €2.00, €3.00, €4.00, €5.00 and €6.00.

The Van Westendorp pricing model would ultimately provide the research a method of price sensitivity analysis. Using the results from the survey, several significant price points were identified. These were the optimal price point (OPP), the point of marginal cheapness (PMC) and the point of marginal expensiveness (PME). The OPP is the optimal price that consumers would pay for a specific product. The PMC is the price point at which sales volume would be hindered due to consumers questioning the quality of the product. Finally, the PME is the price point at which consumers begin to feel that the product is not worth the high cost. These values are important to identify as it would provide a basis for future pricing decisions of companies in search of entering the insect meat market. These results were analysed through graphical analysis on Google Sheets.

In general, the questions asked are all closed questions in nature as open questions would leave too much room for misinterpretation from both the author and the respondents. Furthermore, open-ended questions could also have left the author without any substantial data as respondents were likely to answer broadly, causing it to be difficult for the author to correctly code the data obtained (Reja et al., 2003). The Likert scales used in the entomophagy education section are also closed questions specifically used to measure the extent to which respondents agree or disagree with the questions.

The approach taken to testing the hypotheses solely relied on the use of chi-square tests of independence. The hypotheses were tested with the results of the survey but due to the nature of the survey, many of the questions provided dichotomous answers. Thus, the hypotheses are testing categorical variables (such as age range). These facts left only the chi-square test of independence as the only suitable method of analysis to find any statistically significant results, primarily if there is any relationship between the two variables.

For the first hypothesis, the respondents' age range was tested against their willingness to consume insect meat, which was tested using the question “Would you consider adding insects into your daily diet in the future?”. To answer this hypothesis, the chi-square test of independence was carried out twice: first on the younger demographic and then on the older demographic. The hypothesis refers to the “younger” respondents, hence in this paper the younger respondents were identified as 24 years of age and younger. The “older demographic” in the hypothesis refers to any respondents of 25 years and older. These two age ranges were each subjected to the chi-square test and their results were compared.

For the second hypothesis, another chi-square test of independence was carried out by putting the age range of the younger respondents against their responses to the question “Do you know what entomophagy is?”. Finally, for the third hypothesis, a chi-square test of independence was carried out testing the entire population against their responses to the question “Would you buy packaged food products that contain insects if given the option? (cricket flour for cooking, mealworm chocolate chip cookies, cricket chips, etc.)”. Fundamentally the goal was to find correlations between the two variables in order to determine the validity of the hypotheses.

Data Collection

An overall convenience sampling approach was used due to the advantages associated with the method: the data was collected quickly, it was free and the sampling was simple. The data collected is primarily descriptive in nature. All data used within this research is primary with no secondary data being used.

The survey is a cross-sectional styled survey as the data being collected is a set of variables across a sample of the population. These variables include general demographics (age, region, gender). Using education as one of these variables was considered but ultimately unchosen as education level was deemed unnecessary for the scope of this study. Aside from demographic data, the elusive psychographic data of the respondents was also collected. This psychographic data came in the form of opinions, beliefs and what the respondents felt in response to specific questions. This data was necessary for the testing of the hypotheses. The nature of the questions did not merit individual ethics approval.

Not all respondents of the survey were included in the study as there does exist an ideal respondent profile for this research: those who answered that they are in the European region and those that answered the survey within a reasonable amount of time. The respondents that are outside of Europe were not included within the sample and European respondents that answered the survey far above or far below the average response time were also excluded due to being outliers.

The survey was conducted using Microsoft Forms hence the data input by the respondents was first recorded there. This platform was chosen over the regularly used Google Forms because Microsoft Forms allows one to see the average time it takes to complete the survey. This will be a helpful metric to single out answers that are completed too fast without any real thought. Once the survey reached the end date, the data was then exported to an .xml file and then imported into the software JASP (JASP Team, 2020). JASP is a free, open source statistics program developed by the University of Amsterdam. The data was then analysed within the software in order to address the research question. Additionally some data was exported to the web program Google Sheets, where similar analyses were carried out. The analysis carried out on Google Sheets included the price sensitivity analysis using the Van Westendorp method and multiple chi-square tests of independence in order to prove/ disprove hypothesis 1 through 3.

4. Findings

The questionnaire was answered by a total of 38 respondents (table A2). The average amount of time taken to complete the survey was 11:39 minutes. Of the 38 respondents, only 89.47% (34) of the respondents were based in Europe. Of the remaining respondents, 5.26% (2) were based in Africa, 2.63% (1) based in North America and 2.63% (1) in Australia. For the rest of the analysis, these 4 outlier responses were not included within the data as we are only interested in the responses from the European citizens. With the exclusion of the respondents outside of Europe, it was established that 38.23% (13) respondents are within the age range of 24 and under whilst 61.77% (21) (table A3) were of age 25 or above. This distinction is important as these statistics will later be used to test the first hypothesis. In terms of gender, the sample consisted of 41.18% (14) females and 58.82% (20) males (table A4).

When asked “Do you know what entomophagy is?” 29.41% (10) of respondents answered yes whilst 70.59% (24) responded no (table A5). Of the 10 respondents that answered yes, 60% (6) said that they found out about it from their friends and/or family, 30% (3) found out about it from social media and 10% (1) found out about entomophagy from their students (table A6). Options included television, newspapers and radio. These statistics highlight that word of mouth is currently the most used method of messaging that has resulted in the spread of the idea of entomophagy.

Interestingly, although only 10 respondents knew what entomophagy was, when respondents were asked “Have you ever eaten an insect before?”, 35.29% (12) respondents answered yes, with the other 64.71% (22) answering no (table A7). Two respondents have consumed insects before but do not know necessarily what entomophagy is. Building upon the previous question, respondents that had consumed insects before were asked about their experience: 50% (6) of respondents had a positive experience, 25% (3) found it to be decent and 25% (3) found it to be disgusting (table A8). Surprisingly amongst respondents that have consumed insects, there seems to be a positive view of insect consumption.

Even though that trend may seem positive for the future of entomophagy in Europe, when respondents were asked “Would you consider adding insects into your daily diet in the future?”, 58.82% (20) of respondents answered no and 41.18% (14) answered yes (table A9). The sample is not reluctant to consume insects daily in the future. Despite this, a follow up question asking “Would you consider eating insect meats if they are healthier than conventional meats?” found that 58.24% (20) of the respondents answered yes, 35.29% (12) answered no and 5.88% (2) chose not to respond (table A10). Aggregately, respondents would be more willing to consume insect meats if there was an inherent health benefit over their ruminant counterparts.

When asked “How likely are you to eat insects in their original shape and form? (entire carapace, legs, head, abdomen, etc.)”, 73.53% (25) respondents answered very unlikely, 8.82% (3) answered somewhat unlikely. 5.88% (2) answered neither likely nor unlikely, 8.82% (3) answered somewhat likely and 2.94% (1) answered very likely (table A11). Conversely, when asked “How likely are you to eat insects if they were presented in a familiar form? (chicken nugget shaped, beef steak shaped, sausage shaped, burger patty shaped, ground beef style, etc.)”, 35.29% (12) respondents answered very likely, 23.53% (8) answered somewhat likely, 14.71% (5) answered neither likely nor unlikely, 5.88% (2) answered somewhat unlikely and 20.59% (7) answered very unlikely (table A12). Ostensibly changing the form in which the insects are presented caused an almost entirely negative sentiment to change to a more positive response towards insect meat.

The respondents were then asked about their sentiment towards insect meat in relation to the possible climate change and environmental implications. They were first asked “Do you think that consuming insect meat would be less harmful for our environment than consuming conventional meats? (eg. chicken, pork, beef, etc.)”. 55.88% (19) of respondents answered no, 38.24 (13) answered yes and 5.88% (2) did not answer (table A13). Whilst the proportion of answers is similar, respondents currently lean towards consumption of conventional meats. Respondents were then asked “Would you consider eating insects if it meant that less damage would be done to our environment? (greenhouse gas emissions, waste, etc.)” and 76.47% (26) answered yes, leaving 23.53% (8) respondents answering no (table A14). This is a striking contrast to the composition of answers of the previous question. Three quarters of respondents are ready to consider insect meat consumption if it meant that less damage would be done to the environment.

To truly gauge the commitment of the respondents towards insect meat, respondents were then asked questions that would psychologically commit their money. The first question was “Would you buy packaged food products that contain insects if given the option? (cricket flour for cooking, mealworm chocolate chip cookies, cricket chips, etc.)” wherein 76.47% (26) respondents answered no and 23.53% (8) respondents answered yes (table A15). Oddly the number of no answers matches the number of yes answers from the previous question. Even though respondents would consider consuming insect meat for the betterment of their environment, they are not ready to commit to purchasing it if it were available right now.

The second question that was asked was “Would you purchase restaurant cooked meals that included insect ingredients if given the option?”. 55.88% (19) of the respondents answered yes and 44.12% (15) of respondents answered no (table A16). Intriguingly, most respondents may not wish to purchase insect food products but more than half would be willing to consume a meal with insect contents at a restaurant.

The final four hypothetical questions were answered by all respondents. The resulting data was used in the Van Westendorp model to identify possible price points that respondents would be willing to pay. This price sensitivity analysis was plotted on a graph (figure B1). The optimal price point (OPP) is the value identified by the intersection of the “Too Inexpensive” and the “Too Expensive” plot lines. The two lines intersect at the €3.00 mark. Two other price points were identified: the point of marginal cheapness (PMC) and the point of marginal expensiveness (PME). The PMC was found to be slightly below €2.00 at €1.90, an intersection of the “Too Inexpensive” and “Inexpensive” lines. The PME was found to be just above €5.00 at €5.20, an intersection of the “Too Expensive” and “Expensive” lines. The results show that respondents would be willing to pay the current price of conventional meats for insect meat.

The hypotheses stated within the methodology were tested using multiple chi-square tests of independence. During the testing of the first hypothesis, two p-Values were identified during two chi-square tests: 48.78% for the younger demographic sample and 94.33% for the older demographic. For the second hypothesis, the p-Value was identified as 56.86%. Lastly, the third hypothesis analysis identified the p-Value to be 63.71%.

5. Conclusions, Limitations, and Recommendations

Chi-square Results and Hypothesis Interpretation

The answers submitted by the respondents provided valuable insights into the feasibility of insect meat introduction to European markets. However, the data collected later proved to be unable to conclusively address the proposed hypotheses.

The first hypothesis stating “The younger European citizens are more ready and able to consume insect meat than the older demographic” was proven to be inconclusive. Both p-Values calculated are greater than the significance level set for this analysis, which was 5%. This result means that there is insufficient evidence to truly say that the younger demographic are more willing and able to consume insects than the older demographic. Hence, we cannot reject the null hypothesis that the younger demographic is less willing and able to consume insects than the older demographic. Additionally, we cannot compare the two p-Values to state which sample experienced a greater effect. This is because the total number of respondents in the younger demographic are less than the total number of respondents in the older demographic. To carry out this comparison, the research would require an equal sample size.

For the second and third hypotheses, similar results were obtained. In both analyses, the p-Values were greater than the significance levels set for each of the analyses. Once again, this outcome indicates that there is a significant lack of evidence in order to prove or disprove any relationship between the categorical variables and to accept the alternative hypothesis. A possible solution to this setback would be to survey a far greater sample size. For comparisons between groups, an equal sample size would also be required.

Analysis of Psychographic Results

The data found that word of mouth was the primary vehicle in teaching the respondents about what entomophagy is. A possible reason for this could include vacations taken by European citizens to countries such as Thailand where insects are readily available for consumption. Apart from word of mouth, social media was the secondary method. Ideally, social media could be an avenue that future companies can explore in order to increase consumer knowledge and acceptance of entomophagy. This is likely to be met with legal challenges as current EU regulations hinder multiple aspects of marketing insects for human consumption (Finke et al., 2015).

This would not necessarily be a complete uphill battle. Of the respondents that had consumed insects, 50% of the respondents reported a positive experience. This coupled with the fact that 58.24% of respondents reported that they would consume insects for their health benefits points at the potential flexibility of their minds. Highlighting the health benefits will be a necessary component of the marketing attempts made by companies to help consumers get over the "yuck" factor, as also noted in the article *"The Yuck Factor When Disgust Meets Discovery"* (Schmidt, 2008).

Another benefit that could be used in marketing and increasing awareness of insect meats would be the direct benefits to the environment. Currently 55.88% of respondents believed that consumption of insect meats would not be less harmful than consumption of conventional meats. It is likely that most respondents have lived their lives consuming regular amounts of conventional meats and are not completely aware of all the environmental impacts of farming ruminants. Although that may be the case, over 75% of respondents noted that they were ready to consider insect meat consumption if less damage would be caused to our environment. These conflicting statistics highlight the lack of awareness about the benefits of insect meat consumption and the willingness of consumers to adapt for the sake of their environment.

Health and environmental benefits alone will not be enough as suggested by the questions regarding the presentation of the insect meats. Insect meat products will have to come in familiar forms and be packaged in a form factor similar to those of packaged ruminant meats. Companies will have to adjust to this reality, which may be more costly as this would require substantial investments in technology.

With regards to pricing of said products, over 75% of respondents stated that they would not buy insect products right now if they were given the chance. Furthermore, during the price sensitivity analysis through hypothetical questions, it was identified that respondents would pay €3.00 for insect meat of a weight of 500g. This is about the same price of minced beef of a similar weight. The result insinuates that pricing is not a driving force behind the consideration of insect meat consumption.

The lack of knowledge surrounding entomophagy could once again be the culprit. Respondents are not over the psychological barriers that have engraved insects as pests in Western culture or may simply not know how to properly cook insect based meals. The latter argument may be valid as 55.88% of respondents noted that they would purchase insect based meals cooked at restaurants. This suggests that respondents are likely to trust professionals with the preparation of said foods in order to ensure that they do not fall ill due to any mis preparations during the cooking process.

Despite all of this, even with the “yuck” factor present, half of the sample showed an interest in consuming insect meat. These results are indeed promising especially since there are no expansive marketing campaigns. Additionally, age and cost do not seem to be a factor in the willingness to consume insect meat. We can conclude that there is potential for the adoption of insect meat in the Western world.

Limitations and Study Weaknesses

Whilst the entire survey data collection went according to plan, the limitations experienced during the entire process should be discussed. A missed variable that could have been useful in the economic analysis could have been the income level of the respondents. Although current results suggest that cost is not a factor in the willingness to consume insect meat, this variable could have been used to find a possible correlation between the income level and the willingness to consume insect meat. Moreover, questions regarding the ethics of insect meat consumption could also have provided an additional layer on the psychographic analysis of the respondents’ willingness to consume insect meat.

The type of questions asked should also be contested. Most of the questions asked provided dichotomous answers. These dichotomous questions were used due to their simplicity but their nature was detrimental to the overall research. Because of their binary nature, these dichotomous questions were unable to record any sensitivity (ie. unlike a likert scale of 1 to 5). Additionally, the categorical question of the age range was also harmful for this study. Without the exact age of the respondents, methods of analysis such as the T-test and regression analysis were left on the table. These could have provided better insights into the relationship between varying factors and the respondents willingness to consume insects.

It may also have been useful for the research to observe the connection between insect meat consumption sentiment and plant based meat substitute consumption sentiment. These types of faux meats are becoming increasingly popular due to being entirely plant based yet retaining the consistency, visuals and taste of real conventional meats. Furthermore, cultured meat in laboratories are also becoming more popular and both are viable alternatives to insect meat. This is where this research paper falls short. A comparison between insect meat, lab cultivated meat and faux meats could have created a more comprehensive view of the reasons for the adoption of insect meats or vice versa.

Other common limitations were present during the analysis phase such as the sample being quite small. This limitation impeded the relevancy of the statistical analyses carried out. A greater number of respondents would have provided a better outlook. The survey data collection period was short so had it been longer, more answers could have been collected.

Another limitation that could have been present may have been dishonesty. Respondents may have felt obligated to answer more progressively as society is now shifting towards a culture of shunning individuals who are not trying to help the environment. Lastly, respondents may have experienced survey taking fatigue which occurs if they perceive the survey to be too long. Having 20 questions, it is likely that a few respondents may have felt this, especially as the average time for completion was 11:39 minutes.

Recommendations for the Industry

Based on the conclusions of this study, the following summary of recommendations are highly likely to help the adoption of insect meat consumption in the Western world:

- Focus marketing efforts on highlighting the health and environmental benefits of insect meat consumption over conventional meats

- Invest in technology capable of changing the shapes, textures, flavours and appearance of insect meats to that of conventional meats to get over the “yuck” factor and other psychological barriers presently associated with consumers

- Lobby for insect farming frameworks for human consumption to reduce current legislative barriers

- Carry out small scale farming trials to examine the electricity, water, space and feed costs

Recommendations for Further Research

Below are recommendations derived from the results of this research for further research on this topic:

- Carry out infield surveys whereby participants consume meals with insect based ingredients to analyse any changes in their perception of insect based meals, before and after consumption

- Carry out smalls scale farming trials to replicate real life situations and examine the environmental and climate change impact of all the associated functions

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7. Appendix A

Table A1 EU Aggregate Meat Consumption and Forecast

TABLE 8.36 **Aggregate EU meat market balance (1 000 t c.w.e.)**

	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Gross Indigenous Production	43476	43367	44442	44369	44242	44006	43933	43910	43831	43745	43653	43558	43472	43384	43311
Imports of live animals	4	4	4	4	3	3	3	3	3	4	4	4	4	4	4
Exports of live animals	319	344	347	340	308	300	291	281	272	264	257	249	242	235	230
Net Production	43161	43027	44099	44033	43937	43709	43646	43633	43562	43484	43400	43313	43234	43153	43085
Imports (meat)	1 587	1 520	1 546	1 561	1 400	1 472	1 500	1 510	1 532	1 561	1 585	1 609	1 629	1 649	1 670
Exports (meat)	6 529	6 406	6 551	7 295	7 238	6 823	6 821	6 949	7 048	7 109	7 130	7 148	7 159	7 160	7 166
Consumption	38218	38140	39093	38298	38086	38302	38315	38204	38058	37949	37880	37781	37706	37650	37568
per capita consumption (kg r.w.e.)*	***68.5***	***68.2***	***69.9***	***68.4***	***68.0***	***68.4***	***68.3***	***68.2***	***68.0***	***67.9***	***67.8***	***67.7***	***67.7***	***67.7***	***67.6***
of which Beef and Veal meat	11	10	11	11	10	10	10	10	10	10	10	10	10	10	10
of which Sheep and Goat meat	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
of which Pig meat	34	34	34	33	33	33	33	33	33	32	32	32	32	32	32
of which Poultry meat	23	22	23	23	24	24	24	24	24	24	24	24	24	25	25

** r.w.e. = retail weight equivalent; Coefficients to transform carcass weight into retail weight are 0.7 for beef and veal, 0.78 for pigmeat and 0.88 for both poultry meat and sheep and goat meat*

Table A2 Respondent Region Frequency Table

Frequencies for Respondent Region

Respondent Region	Frequency	Percent	Valid Percent	Cumulative Percent
Africa	2	5.263	5.263	5.263
Europe	34	89.474	89.474	94.737
North America	1	2.632	2.632	97.368
Oceania	1	2.632	2.632	100.000
Missing	0	0.000		
Total	38	100.000		

Table A3 Age Rage Frequency Table

Frequencies for Age Rage

Age Rage	Frequency	Percent	Valid Percent	Cumulative Percent
18-24	12	35.294	35.294	35.294
25-34	7	20.588	20.588	55.882
35-44	4	11.765	11.765	67.647
45-54	4	11.765	11.765	79.412
55-64	3	8.824	8.824	88.235
65-74	3	8.824	8.824	97.059
Under 18	1	2.941	2.941	100.000
Missing	0	0.000		
Total	34	100.000		

Table A4 Gender Frequency Table

Frequencies for Gender

Gender	Frequency	Percent	Valid Percent	Cumulative Percent
Female	14	41.176	41.176	41.176
Male	20	58.824	58.824	100.000
Missing	0	0.000		
Total	34	100.000		

Table A5 Entomophagy Definition Frequency Table

Frequencies for Entomophagy Definition

Entomophagy Definition	Frequency	Percent	Valid Percent	Cumulative Percent
No	24	70.588	70.588	70.588
Yes	10	29.412	29.412	100.000
Missing	0	0.000		
Total	34	100.000		

Table A6 Knowledge Sources Frequency Table

Frequencies for Knowledge Sources

Knowledge Sources	Frequency	Percent	Valid Percent	Cumulative Percent
Friends and/or family	6	17.647	60.000	60.000
Social media	3	8.824	30.000	90.000
students	1	2.941	10.000	100.000
Missing	24	70.588		
Total	34	100.000		

Table A7 Previous Insect Consumption Frequency Table

Frequencies for Previous Insect Consumption

Previous Insect Consumption	Frequency	Percent	Valid Percent	Cumulative Percent
No	22	64.706	64.706	64.706
Yes	12	35.294	35.294	100.000
Missing	0	0.000		
Total	34	100.000		

Table A8 Consumption Experience Frequency Table

Frequencies for Consumption Experience

Consumption Experience	Frequency	Percent	Valid Percent	Cumulative Percent
Decent	3	8.824	25.000	25.000
Disgusting	3	8.824	25.000	50.000
Positive	6	17.647	50.000	100.000
Missing	22	64.706		
Total	34	100.000		

Table A9 Future Consumption Sentiment Frequency Table

Frequencies for Future Consumption Sentiment

Future Consumption Sentiment	Frequency	Percent	Valid Percent	Cumulative Percent
No	20	58.824	58.824	58.824
Yes	14	41.176	41.176	100.000
Missing	0	0.000		
Total	34	100.000		

Table A10 Insect Meat Choice Frequency Table

Frequencies for Insect Meat Choice

Insect Meat Choice	Frequency	Percent	Valid Percent	Cumulative Percent
No	12	35.294	37.500	37.500
Yes	20	58.824	62.500	100.000
Missing	2	5.882		
Total	34	100.000		

Table A11 Original Form Consumption Likelihood Frequency Table

Frequencies for Original Form Consumption Likelihood

Original Form Consumption Likelihood	Frequency	Percent	Valid Percent	Cumulative Percent
Neither likely nor unlikely	2	5.882	5.882	5.882
Somewhat likely	3	8.824	8.824	14.706
Somewhat unlikely	3	8.824	8.824	23.529
Very likely	1	2.941	2.941	26.471
Very unlikely	25	73.529	73.529	100.000
Missing	0	0.000		
Total	34	100.000		

Table A12 Altered Form Consumption Likelihood Frequency Table

Frequencies for Altered Form Consumption Likelihood

Altered Form Consumption Likelihood	Frequency	Percent	Valid Percent	Cumulative Percent
Neither likely nor unlikely	5	14.706	14.706	14.706
Somewhat likely	8	23.529	23.529	38.235
Somewhat unlikely	2	5.882	5.882	44.118
Very likely	12	35.294	35.294	79.412
Very unlikely	7	20.588	20.588	100.000
Missing	0	0.000		
Total	34	100.000		

Table A13 Insect Meat Consumption Beliefs Frequency Table

Frequencies for Insect Meat Consumption Beliefs

Insect Meat Consumption Beliefs	Frequency	Percent	Valid Percent	Cumulative Percent
No	19	55.882	59.375	59.375
Yes	13	38.235	40.625	100.000
Missing	2	5.882		
Total	34	100.000		

Table A14 Insect Consumption Environmental Sentiment Frequency Table

Frequencies for Insect Consumption Environmental Sentiment

Insect Consumption Environmental Sentiment	Frequency	Percent	Valid Percent	Cumulative Percent
No	8	23.529	23.529	23.529
Yes	26	76.471	76.471	100.000
Missing	0	0.000		
Total	34	100.000		

Table A15 Insect Packaged Products Purchase Intent Frequency Table

Frequencies for Insect Packaged Products Purchase Intent

Insect Packaged Products Purchase Intent	Frequency	Percent	Valid Percent	Cumulative Percent
No	26	76.471	76.471	76.471
Yes	8	23.529	23.529	100.000
Missing	0	0.000		
Total	34	100.000		

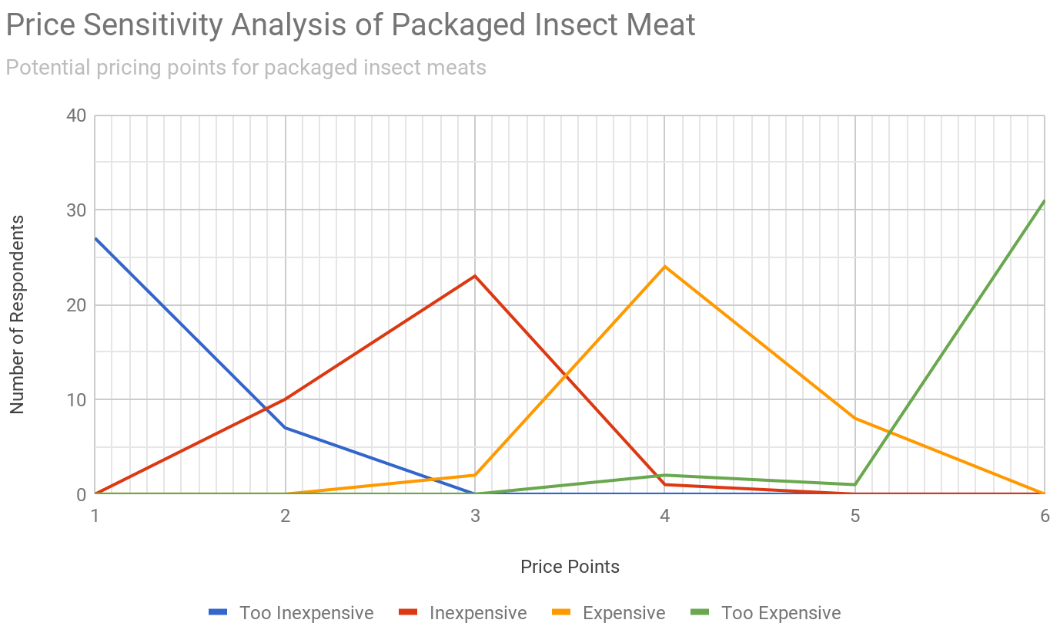
Table A16 Restaurant Purchase Intent Frequency Table

Frequencies for Restaurant Purchase Intent

Restaurant Purchase Intent	Frequency	Percent	Valid Percent	Cumulative Percent
No	15	44.118	44.118	44.118
Yes	19	55.882	55.882	100.000
Missing	0	0.000		
Total	34	100.000		

8. Appendix B

Figure B1 Price Sensitivity Analysis of Packaged Insect Meat



9. Appendix C

[Chi-Square independent analysis sheets]

[Van Westendorp price sensitivity analysis sheet]