INSECTS AU GRATIN - AN INVESTIGATION INTO THE EXPERIENCES OF DEVELOPING A 3D PRINTER THAT USES INSECT PROTEIN BASED FLOUR AS A BUILDING MEDIUM FOR THE PRODUCTION OF SUSTAINABLE FOOD

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ABSTRACT
Insects Au Gratin focuses on the future of food and explores the nutritive and environmental aspects of entomophagy (eating insects), combined with 3D food printing technologies.
The project has been investigating the possibility of using 3D dimensionally extruded insect paste filament as a method of creating foodstuffs, although the notion of printing food is not a new development, the innovation of using insect paste as a build medium is highly novel, this coupled with farming insects could create a sustainable source of food for an increasing global population. Why insects? Although entomophagy is alien to the western society, people in non-western territories eat insects as part of a regular diet. Insects are very efficient at converting vegetation into edible protein, full of vitamins and minerals: four crickets provide as much calcium as a glass of milk, and dung beetles, by weight, contain more iron than beef. Farming insects generates one-tenth of the methane produced by farming traditional meat sources per kg and it uses comparatively little water.
The focus of the paper is based upon the development work for two public engagement events as part of Pestival held at the Wellcome Collection in London and the World Food Festival in Rotterdam. The events aimed to explore and debate the potential of entomophagy as a sustainable food source as well as combining with new food production technologies and how those could affect human perception of food and technology.

Keywords: Future food, 3D printing technologies, entomophagy, insect paste, open source

1 INTRODUCTION

The project activity represents an unique partnership among the subjects of food technology, entomology, engineering, programming and product design. The objective is to exploit the aesthetics of food and the media attention by using new 3D food printing technologies as well as using the potential of insects as alternative source of protein and to incorporate these raw materials into feed or directly into food products. Issues related to food aesthetics, novel technologies, nutrition and raw material functionality are being investigated. The project aims to stimulate research into new food technologies through design thinking and engineering, raising the profile of new protein sources and developing innovative food products using new technologies. The activities associated with the project include:

- Accessing a consistent supply of insects. Suitable sources include mealworms, crickets and silkworm pupae and the potential to incorporate local species are being investigated.
- Micro scale insect farming and experiments with feeding the insects in order to develop a naturally 'flavoured' insect protein have been explored.
- Insects are harvested, dried and milled into a functional food raw material suitable for 3D printing.
- The raw material is being analysed for its nutritional composition.
- The raw material has been successfully combined with other food products, which can be extruded into various shapes demonstrating the potential for 3D food products encompassing insect protein.

These experiments were exhibited at Edible - Science Gallery Dublin, Ireland (Figure1); MART, Italy, St. Etienne Biennial, France; Who's the Pest? by Pestival at Wellcome Collection, United Kingdom (Figure 2); and Future Food House, World Food Festival, The Netherlands (Figure 3). The project has encouraged the development of students work amongst the areas of food technology and engineering product design generating transferable skills and cross pollination of ideas.



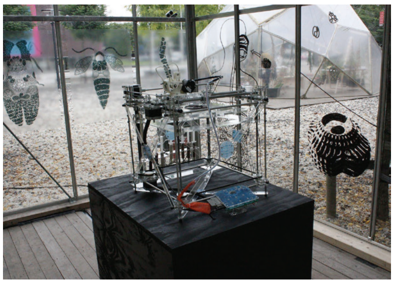


Figure 1. Insects Au Gratin at Edible, Science Gallery; Figure 2. Insects Au Gratin installation at Wellcome Collection; Figure 3: Insects Au Gratin exhibition for Future Food House, World Food Festival

2 BACKGROUND

The *Insects Au Gratin* was conceived in 2011 as part of *Edible* [1] exhibition at Science Gallery in Dublin. The project starting point was based upon two major premises:
1. In 2008 the Food and Agriculture Organization of the United Nations (FAO) made an appeal to the world population to eat less meat. FAO estimated that direct emissions from meat production accounted for about 18% of the world's total greenhouse gas emissions and strongly supported research aimed at reducing methane emissions from livestock farming [2]. According to Gimenez 'in addition to the global economic crisis and high prices for food, the effects of fluctuating weather patterns as a result of climate change, extremely low grain reserves, high oil prices, the increase in biofuel production, and the *meatification* of the global diet have contributed to the increase in the number of hungry in recent years' [3].
2. The University of Wageningen [4] research on entomophagy investigates the potential of insects as a novel protein source. The research showed the farming of insect meat has a better feed conversion efficiency, being more sustainable than the production of conventional meat. The intent is not a replacement of traditional meat based foodstuffs but as a supplement to a balanced diet.

2.1 Edible insects future food

More recently, in May 2013, FAO has published a report that concludes into encouraging people to consume edible insects as a driver to promote behavioural changes towards more sustainable ways of ingesting protein. Insects have a high nutritional value are rich in protein and good fats and high in calcium, iron and zinc; they emit less greenhouse gases compared with traditional livestock [5]; insect rearing does not require a vast amount of land use; since they are cold blooded crickets, for example, need 12 times less feed than cattle, four times less feed than sheep, and half as much feed as pigs and broiler chickens for the same amount of protein; insect harvesting/rearing is considerably low-tech in comparison to meat, naturally organic due to lack of antibiotics and pesticides used in their welfare[6].

2.2 The yuck factor

It is estimated that insects form part of the diet for about 2 billion people around the world, with more than 1200 edible species used as human food. Entomophagy is strongly influenced by culture and in most Western societies eating insects is associated with a 'yuck' factor. 'Edible insects have always been a part of human diets, but in some societies there is a degree of distaste for their consumption' [7]. The *westernisation* of eastern food cultures will promote even more uncertainty for future food sustainability. *Insects Au Gratin* aims to tackle that 'distaste' by exploring the aesthetics of food offered by 3D food printing technologies, looking at new ways of designing and or cooking insects. Moreover the average person already consumes about a 0.45kg of insects per year, mostly inadvertently mixed into other foods during conventional production processes.

2.3 The impact of aesthetics of food in food acceptance

The impact of aesthetics on choice is robust and well documented for physical product choices. At least two different studies showed that consumer response to the sensory properties of food (particularly appearance, flavour, aroma, taste and texture) is an important factor in determining the success of new products [8]. According to the *Art on a plate* authors on the impact of a food product physical appearance "It was concluded that expectations of liking for a food generated by appearance influenced final evaluation of the product during consumption." [9].

Food is a sensory as well as a social experience and taste is more than a gustatory perception, it is also a metaphor for social constructs of appreciation. Therefore, the aesthetics of food products containing insects are an innate aspect to tackle concerning entomophagy acceptance in Western cultures.

3 THE PROCESS OVERVIEW

The *Insects Au Gratin* project looks at the various aspects of the whole insect food production process. From harvesting insects, to grind various species of insects into a powder, to mix that powder with another food product that functions as a carrier, to 3D food printing to their consumption (Figure 4).

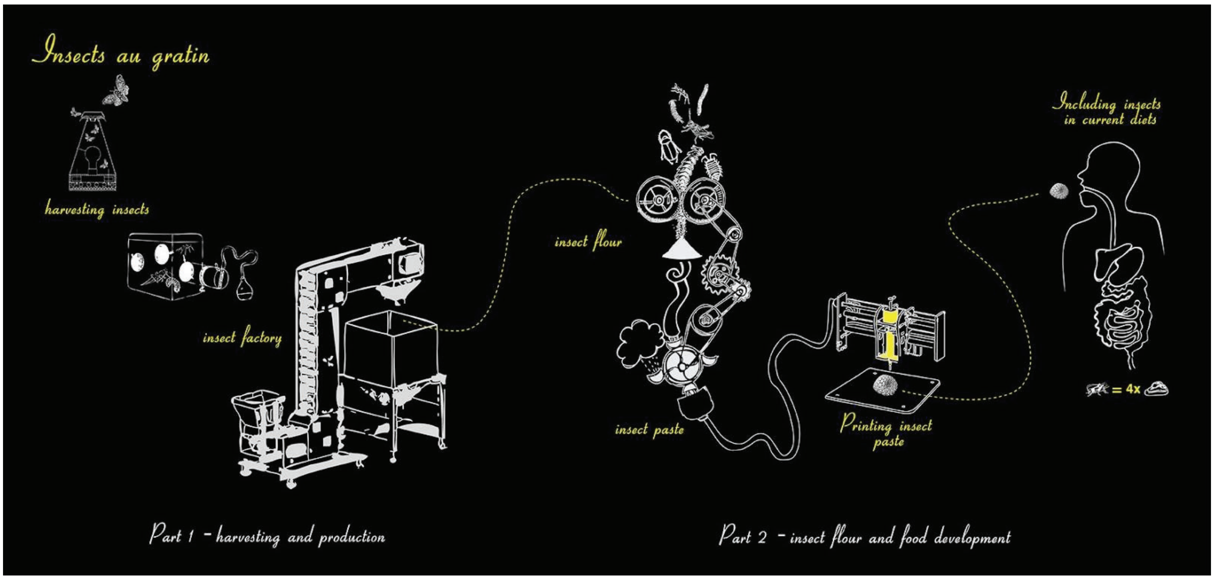


Figure 4. Insects Au Gratin illustration of process

3.1 Insect flour

Edible dried insects are ground into powder. The resulting insect flour is mixed for the prototyping process with other food products such as icing butter, chocolate, cream cheese and spices such as ginger, cinnamon, dried chillies to form the right consistency to go through the nozzle.

3.2 Food design using polygon CAD sofware

The initial proposed designs used common professional NURBS/polygon based CAD software that were exported to a STL file format to be printed (Figure7). The shapes were inspired by insects' natural forms and movements, such as their delicate wing patterns, microscopic images of insect eggs or the bees 'waggle dance' in an attempt to extract the inner beauty of such elements (Figure 5 and 6). The aesthetic decisions were also aligned to public display in order to catch audience attention and spark the debate around entomophagy, food acceptance. Their complexity and intricate design detaches it from recognisable food shapes and resembles jewellery as a way of communicating future problems with food prices. Food products might become a luxury if predictions about food scarcity and consequent rise in prices became reality.

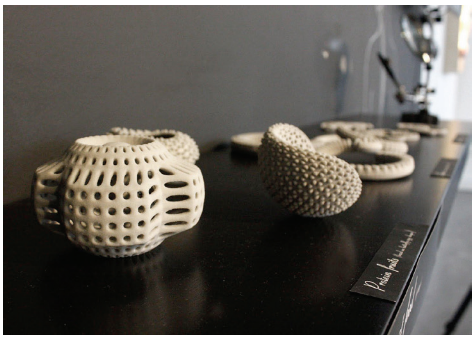
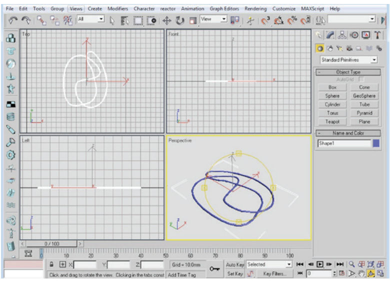


Figure 5. Aesthetics inspired by insects natural forms and patterns; Figure 6. Texture relates to caterpillar's shapes

3.3 Iterative development

After being exported to a printable format the files need to be sliced into printable layers, re coded based on the delivery performance of the printer head and re arranged to be able to be printed using a paste base or food product. A series of open source stereolithography (stl) slicing and conversion software were used to achieve the file coding, this was then modified iteratively to print a reasonable food prototype (Figure 8). It takes an average of 4 minutes to print a file that contains 10-12ml of insect flour mixed with spices (Figure 9) and a binder (icing sugar fondant). The timescales for development on this project were restricted to various requests to attend events with the printer prompted reassessment of the project status. Existing technology was 'hacked' for the project means rather than a representation of a 'slick' virtual model, this allowed empirical advances and learning about the relationship between paste viscosity, print coding, binder material, ambient / material temperature and importantly the relationship with the final taste of the printed product.



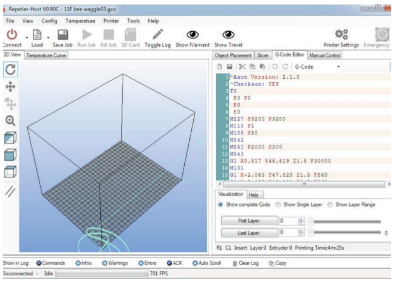


Figure 7. Polygon based CAD software is used to create the initial printable file; Figure 8. Conversion of file to gcode; Figure 9. 3D food printed insect paste using icing sugar as a binder

3.4 Why 3D printing?

3D food printing technologies: facilitates the process of modifying insects initial appearance which is seen as a factor that deters people from eating them, enables the development of new cooking methods and experiences, through a click. By digitising food design it increases the potential for the development of a new aesthetic related to food and combine what can be a potential sustainable process with a sustainable food product.

4 CREATIVE COLLABORATION METHODS

In order to develop the project we have formed cross faculty and external partnerships as well as building upon open sourced working methods. The team's food scientist has developed a range of insect flour material that is combined with spices and a fondant to produce a material that can be printed. There was significant iteration in both the codification of the part files and the grade of milled protein, the results can be shaped into various designs that are aesthetically manipulated through the aforementioned software.

4.1 Building on the work of others, Open source donor prototypes and Codification

A vital aspect of the realisation of this project was capitalising on the time compression afforded by the use and modification of donor components from open source websites such as "thingiverse"[10], this allowed a focus on the critical aspects of coding for delivery, rapid iteration of design ideas and time to explore and test results relating to variations in the viscosity of the paste from changing elements of the drive coding in the second phase of the research.

Radical uses of 3D printing technology may enable us to overcome the traditional aesthetic issues of entomophagy by allowing the users to manipulate the food digitally as a future pastime and challenge people's perceptions of eating insects. The use of insect protein as a 'printable' material opens up a range of new applications and questions existing thinking about sustainability, raw materials, nutrition, food culture and culinary explorations.

5 PUBLIC ENGAGEMENT

A key indicator of interest in the eating of insects was evident at public engagement events such as the *Insects Au Gratin* workshop at the Wellcome Collection as part of Who's the Pest? by Pestival (Figure 10). Members of the public reserved a place for the workshop sessions run by the *Insects Au Gratin* team, they were taken through the key stages of the project and voiced their interest and opinions culminating with a virtual food creation session where modelling clay was used to create insect *hors d'oeuvres* based on their personal reflections about the concept. It was intended to create real time CAD models of a chosen design but time constraints dictated that this was not achievable. The paper plates that the models were served on were also used to garner insight and feedback about the project (Figure 11).

Figure 10. Insects Au Gratin workshop at Wellcome Collection; Figure 11. Example of paper plate with food model and feedback

6 OPPORTUNITIES

It has already been demonstrated that the activity has benefited from an inter-disciplinary approach and is capable of attracting positive media publicity and funding. Proof-of-concept work was presented at the Future Food House, in Rotterdam, Sep-Oct 2013. The exhibit included a 3D food printing demonstration for creating edible items from insect flour. The project attracted significant attention in the national and international media and was cited in a review article in the prestigious science journal Nature, on the website of Wired and New Scientist magazine. The project featured in Who's the Pest? BBC Radio 4 and made BBC World News in April 2013. As an expansion of this project it is felt that it would needed to revisit the original concept and consider notions of the quantified self, possible uses for food aid and the Internet of things.

7 EDUCATIONAL BENEFITS

The project has benefited the student experience: two undergraduate projects in Food Science developed high nutritional cereal bars and bread that contained insect flour. Design and Engineering students have been assembling 3D printers as a project based learning activity with the aim to enhance the technology by experimenting with varied delivery systems. This would generate transferable skills that can be of use in their major undergraduate / postgraduate projects by allowing the students to observe and follow the project progress.

Currently there are plans to include a range of student disciplines to the project under direction from the authors, the inclusion of students into the project would be an extra curricular project as it is perceived that a whole cohort contributing to the project would outweigh the benefit.

As an element of the design students education it is felt that the project is a good example of empowerment through product design for behaviour change [11] this can be employed as part of the educational provision where design students can evidence their learning through a broad range of narratives, including product re-design, new product development and arguably invention.

8 CONCLUSION

The success of this activity will rely heavily on strengthening links with external organisations, developing new networks and seeking new partners. As with all form of radical uses of technology transfer the aim is to generate a momentum so the process moves from novelty through niche and becomes the norm. The authors are currently investigating various avenues for the research project to become a reality, part of which is to look into the possibility of setting up insect farming facilities, distribution channels and development of a domestic printer that can deliver the product defined by the user.

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