Home bioreactor –Local food from plant cell cultures

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1 author:

Niko Räty
Aalto University

HOME BIOREACTOR

LOCAL FOOD FROM PLANT CELL CULTURES

Niko Räty 2017

Author Niko Räty
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Master of Arts thesis abstract

ABSTRACT

This thesis investigates acceptance of plant cell-based cellular agriculture as food application that enables anyone to grow plant cells as a food in home environment. Cellular agriculture can transform food production by offering new sustainable alternative for food production that save agricultural space and resources. Cellular agriculture makes food production seasonless, cruelty free and it allows growing of rare species without harming the natural existence.

Problem of this novel way of producing is that many of the production methods require highly trained professional. Lab environment may seem strange and this way of production is in early stages and attitudes differ toward this kind of development. In spite of that, now the technology is ready to offer these solutions to anyone.

This thesis follows the design process of the home bioreactor that enables plant-based cellular agriculture. Constructive design research conceptualize the new product category in the future kitchen and investigates tangible aspects of the concept. Qualitative study shows reactions toward the topic. Social media outlets have worked as interactive channel between research group and enthusiast. This study used internet based Co-creation platform Owela in the beginning of the project to get the grasp of the attitudes toward the topic.

This thesis presents the final concept and prototype of the home bioreactor. It shows how it would be positioned to the future markets and characterized the first consumer group of the product. It also reveals interesting difference of reception of the plant versus mammal based cellular agriculture.

This work reveals how design can be tool which can provide important information and how even the designed prototype of the invention can offer important glimpse to the future.

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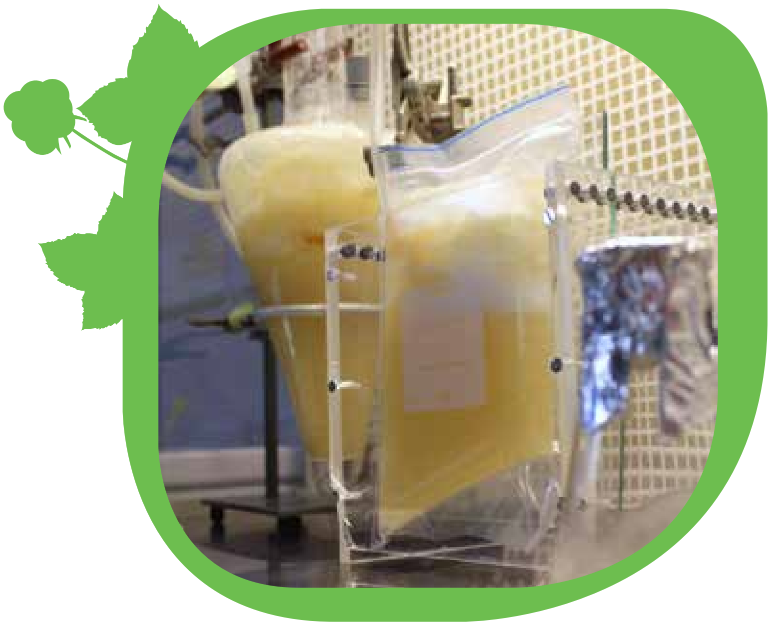
1. INTRODUCTION

Plant cell cultures as a source of food production has started to get recognition (Davies & Deroles, 2014). Increasing demand for natural compounds to food applications and need of new sustainable agricultural practices (New Harvest, 2017) has sifted the focus to the investigate potentials of the plant cell cultures (Longo & Sanromán, 2006).

In 2015, scientists Ahtinen, Nordlund, Pitkänen, Rischer of Technical Research Centre of Finland Ltd (VTT), started to wonder about the taste of the cultured cell lines. They realized the possibility to use the cultured plant cells as a source of food. At VTT, the cell lines which had previously been cultured for pharmaceuticals, cosmetics and chemical compounds for a variety of industries were now perceived under a different light (***Picture 1.***).

Picture 1. *Birch cell suspension culture*

Picture 2. *Contaminated, dead birch cell suspension culture*



Picture 3. *A prototype of a cartridge-based single use bioreactor build by scientists*

This curiosity led the scientist to seek funding for the project, which resulted in the development of the home bioreactor, later named as a CellPod. The aim of the home bioreactor was to enable future consumers to grow edible plant cell cultures. In order to bring cell culturing (cell farming) into the hands of an average consumer, the bioreactor used in the laboratory needed a simplified version that would not require expertise of its user. The plant cell cultures demand aseptic working to grow successfully ("Introduction to Cell Culture," n.d.). To avoid contamination which cause loss of the culture (***Picture 2***.) and to simplify the process, the scientists created the cartridge-based single use bioreactor which functioned as a fundamental basis for the product development project, Design Case, done in this thesis (***Picture 3***.).The research group also desired to discover a commercial application for plant cell lines as a type of food. This process needed a product designer to develop the concept, which is the focus of this work.

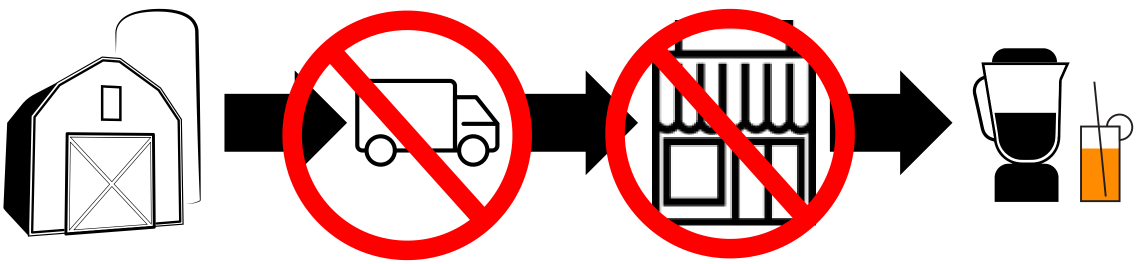


Figure 1. *In the future consumer-driven food production can obsolete many energy intensive steps in the food chain*

1.1 SETTING THE SCENE

Reviewing today's phenomenon around food, it can be argued that urban citizens in the developed world are emotionally affected by the matter of being detached from food manufacturing (Roberts, 2009). The consumers are increasingly worried about sustainability of the agricultural practices, non-transparent processing of the food and the resulting impacts on health.

Conscious consumers are looking for ethical, sustainable, healthy foods and transparent processing in food production. For that need the new concepts of healthy and ethical food are emerging (see benchmarking). In vitro meat, milk and eggs replace industrial animal farming ("New Harvest," n.d.). Mycoproteins, for example Quorn, provide alternative sources of protein ("Marlow Foods," n.d.). The "Wicked Problems" (Rittel & Webber, 1973) (Lazarus, 2008) of the current food chain motivate urban consumers to get closer and involved in the food production. Food can be seen as a form of activism and consumers' roles are shifting towards *prosumersm* (Toffler, 1980).

This project aims to answer these demands by bringing cellular agriculture to homes of the everyday consumer. For example, plant cells from arctic bramble can be grown as a cell culture, outside the plant (Biotekniikan neuvottelukunta, Lalli, & Reuter, 2016, p.38). The cultured plant cells can offer an alternative source of nutritious locally produced foods that can serve as one of the food production methods used in the future (Figure ***Figure 1.***).

1.1.1 GOALS OF THE PROJECT

This thesis is a design case that focuses on prototyping and customer segmentation of the home appliance that enables consumers to grow the plant cell cultures at the home environment.

The goal of this thesis is also to review how ready consumers are towards home cell culturing of food. The aim is to understand and produce information about reception from the customer point of view and understand phenomena of the cellular agriculture. The project aims to produce material that can lead the project towards the future development phases.

1.2 THE FRAMEWORK

This thesis investigates cellular agriculture as a new way to empower consumers towards local food production. This study reviews new food trends that have similar aspects on their approach excluding livestock based food production like aquaponics. Insect eating is only briefly mentioned in the trend analysis. The trend analysis, customer segmentation, and product design is the core of this study (***Figure 2***.).

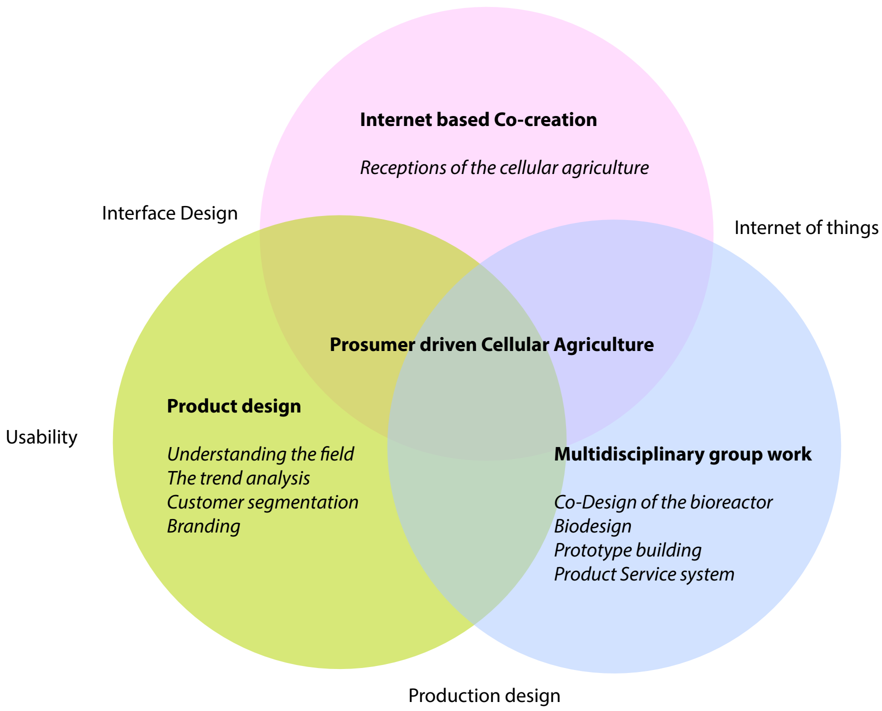


Figure 2. *Framework of this thesis*

1.3 RESEARCH QUESTIONS

This thesis is aiming to find answers to these research questions:

- *How design can change reception of the novel food innovation?*
- *How ready consumers are for cellular agriculture?*

2. METHODS

This study aims to provide qualitative data on views of plant cell based cellular agriculture and provide information how the public views the potential of this field of scientific development.

This thesis investigates the customer acceptance of the cellular Agriculture based on plant cell cultivation in home environment. Research was done using the Constructive design research method together with qualitative research with the focus group at the online co-creation platform Owela, where self-oriented people formed a focus group to discuss ready given topics under moderation. Interactive moderation was aimed to deepen the discussions and make the participants feel that the answers matter (Füller, Mühlbacher, Matzler, & Jawecki, 2009). At the end of the project, the end survey was conducted on a global scale, unlike the online forum Owela that was restricted to Finland, to see if the findings correspond to the discoveries made from Owela discussions.

This study also gained qualitative data from a variety of social media sites and face to face meetings in different events in which constructed prototypes had been displayed. Social media outlets in this thesis has been seen as the design probing tool (Mattelmäki, 2008).

The prototypes were constructed and discussed inside the research team where the design decisions were evaluated together. The main point of this thesis was to make a prototype to understand physical aspects of the innovation, to gain haptic feedback and discover errors in the real environment. However, it did not investigate industrial production methods for this product.

To understand the field of Cellular Agriculture, the field was benchmarked and the concept created in this thesis was positioned into the markets through the results of the benchmark process. The product service map was created to understand the alternative business models. This service map also helped the research group to understand the potential of the invention. In spite of the service map, this study does not focus on creating a ready business model around the topic. Instead, it provides a vision of the service system map that could be built around this concept.

The gained data are compared to the acceptance study of the novel and functional foods and qualitative research of animal-based cellular agriculture to expose understand subjective difference about topick.

2.1 METHODOLOGY

This thesis project follows designers radar (Koskinen, Mattelmäki, & Battarbee, 2003) by going from individual designer centre work towards user centered design. Although in depth usability studies have not included in this work because of its early status. *"It is, today, widely appreciated that Research-through-Design allows for designers to produce knowledge based on the skills and capacities of the design field itself" (Bang, Krogh, Ludvigsen, & Markussen, 2012, p.2).* Methods used in this thesis listed below.

OVERVIEW

Constructive design research

Prototype building.

Qualitative research

Co-creation with the enthusiasts

Hermetical analysis (Routio, n.d.).

Co-Design with the research group

Quantitative research

Clustering analysis method (Routio, n.d.).

2.2 . EXPECTED RESULTS

This project aims to actualise growing plant cells in home environment. The project is expected to normalize the idea of plant based cellular agriculture at the consumer level and visualize the idea of growing plant cells at home environment with the end goal of having a prototype that can display the home bioreactor. This project also aims to segment the novel food product idea to the future food markets and find the right audience that can be potential early adopters. By segmenting the right audience the project aims to find the link between future end users and research group. Understanding the future customer segment and their needs and position in the future food markets have also been seen as essential for pursuing this project to the next level. The project will be a reactive process that exploits rapid prototyping and social media to test the customer acceptance level of the plant based cellular agriculture.

2.3 CHALLENGES

Many different phases of the project relied on design theories to tackle design issues revealed in the project. The tight time schedule affected the decision making during the project which was one of the challenges.

On one hand, attitudes towards the topic may vary depending on the context and therefore more context based research is required to gain deeper understanding of the acceptance level of this invention at different locations and under different circumstances. On the other hand, the volume of participants in this project is not large enough to generalize information about the characteristics of the key findings.

3. LITERATURE REVIEW AND TERMINOLOGY

3.1 GOALS OF THE LITERATURE REVIEW

Design grammar is not as developed as engineering or grammar in architecture. Designers create own grammar and often design processes are limitedly documented which makes synthesising of the grammatical rules difficult. Therefore, design grammar is often seen as form of art instead of science. (Königseder, Stanković, & Shea, 2016 p.2)

To clarify grammar used in this thesis, this literature review opens up the basic terms of design and terms used in the field of biotechnology simultaneously reviewing previously done research related to this thesis topic.

3.2 DESIGN TERMINOLOGY

3.1.1 CO-DESIGN AND CO-CREATION

Co-Design and Co-Creation refers to including future end users to the development process of the future product or service (Sanders & Stappers, 2008 p. 7). Aim of placing the user into the centre of the design process is to increase empathy and understanding of the needs of the end user (Koskinen, Mattelmäki, & Battarbee, 2003). In user center design "designers become interpreters of people's needs and dreams and not just the creators of artifacts" (Sanders, 2005 p. 5). Co-creation can be fully virtual (Füller, Mühlbacher, Matzler, & Jawecki, 2009) or physical or mixture of both (Mattelmäki, 2008).

The terms Co-creation and Co-design are often mixed together and the meaning of these terms may differ depending on the context (Mattelmäki & Visser, 2011). This thesis divides Co-creation and Co-design according to Mattelmäki and Visser, (2011) who propose that Co-creation refers to any act of collective creativity and where Co-Design includes users and stakeholders into the design process. In other words, in this thesis Co-design refers to the design work done together with a research team and Co-creation feedback and off and online discussions. Furthermore, co-creation platform and social media outlets in this thesis has been used as a design probing tool to gain future end user information about the topic (Mattelmäki, 2008) using principles of virtual Co-Creation to maximise involvement of the Co-creators (Füller, Mühlbacher, Matzler, & Jawecki, 2009).

3.1.2 BRAINSTORMING

Brainstorming is a group working tool for generating a number of new ideas (***Picture 4***). Aim of brainstorming is to write down all of the ideas that the group has in the positive mood to create atmosphere that generates even more new ideas (Moritz, 2005, p. 210).

In some cases, it has been argued that brainstorming in the group is not the most effective way to create new ideas, because social interaction creates an illusion of a high amount of ideas (Rietzschel, Nijstad, & Stroebe, 2006).

3.1.3 BENCHMARKING

Study of competitors, stakeholders, products or services to find success factors or market gaps for specific projects can be called Benchmarking (Cooper & Kleinschmidt, 1995, p. 374).

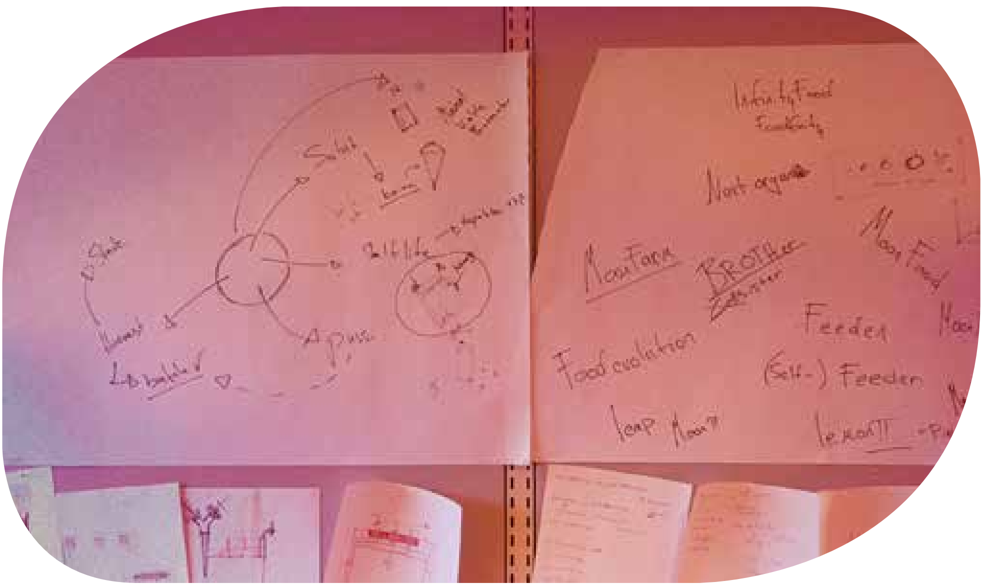
Benchmarking can be also mining of product repetition to understand hidden drivers of specific user group (Morinaga, Yamanishi, Tateishi, & Fukushima, 2002). Dickson, Schneier, Lawrence, & Hytry, (1995) crystallize the idea of benchmarking by saying: "it is best to study success and imitate success rather than to study and imitate failure" (p. 408).

3.1.4 DESIGN DRIVERS

Design drivers lead a design process by helping to focus on the right design targets. Design drivers help the designer to evaluate the significance of a problem and guides the decision making process especially in problematic situations. Design drivers can be for example, a written list of attributes that guide the design process. Too tight or too loose drivers can have a negative impact on the outcome of the design process and therefore it can be relevant to re-evaluate drivers during the process (Hyysalo & others, 2009, p. 87).

3.1.5 CONCEPT DESIGN

Concept design displays the key idea of the project and possible includes the rules of the project. Concept designs gives immediate understanding about character of the concept without requiring any expertise from the viewer (Stolterman & Wiberg, 2010). Concept designs present often the future design. Evaluation of the design concepts in the early stages of the product development process affects quality and the cost of a product to be developed (Zhai, Khoo, & Zhong, 2009, p. 7078). Concept driven design research produce knowledge that cannot fully be present in the text (Stolterman & Wiberg, 2010, p. 104)



Picture 4. *Outcome of the brainstorm*

3.1.6 PROTOTYPE

Prototype can be a tangible object or digital application or script for a planned service or combination of these. Role of the prototype is to see design errors and test the design before final production of the service or product (Hyysalo & others, 2009, p.180). The prototypes have important role specially when something is truly novel (Passera, Kärkkäinen, & Maila, 2012). It is important to know what to include and what to exclude from a prototype and understand what questions the prototype answers (Hyysalo & others, 2009, p.184).

3.1.7 DESIGN FOR DEBATE

"Design that asks questions could be just as important as design that solves problems" (Raby & Dunne, n.d.). Design for Debate sees design as a practice to provoke conversation. This approach argues that design is never neutral and can therefore be a good way to discuss social, cultural and ethical implications. Design for debate creates artifacts and scenarios around the topics perceiving human essence as individuals. (Antonelli, Juncosa Vecchierini, & Lipps, 2008)

3.1.8 RAPID PROTOTYPING

The term Rapid Prototyping comes from computer software industry where rapid software development has been adopted by manufacture industry (Chua, Teh, & Gay, 1999).

In the design field, rapidly built prototypes allow quick tangible look into the functionality of the idea; how product or services will work in real life. Rapidly built prototypes enable the designer to be less engaged with the original idea, which makes product development group more open for feedback. Prototypes requiring less resources are therefore more effective at generating information about the product idea (Olsen, 2015) (***Picture 5.***).

Digital fabrication workshops AKA, Fab Labs, makerspaces, and hackerspaces, where people can use equipment such as laser cutters and 3D-printers to create their own artefacts, have spread widely (Kohtala, 2016). This phenomenon has made prototyping easier and more accessible, which enables higher quality even for fast prototypes. Development of the digital fabrication tools have also raised interest in rapid manufacturing (Hopkinson and Dickens, 2001).

3.1.9 PRODUCT SERVICE SYSTEM

Product service system (PSS) is a system of products and services that are jointly able to answer a client's specific needs (Manzini & Vezzoli, 2003, p. 851). PSS can be used, for example, to lower the environmental impacts of products by merging them with services into services (Mont, 2002). For example, a system map can be used to display functionality of a PSS and to visualize example flows of materials, energy, information and money ("System map | Service Design Tools," 2017).

3.1.10 PERSONAS

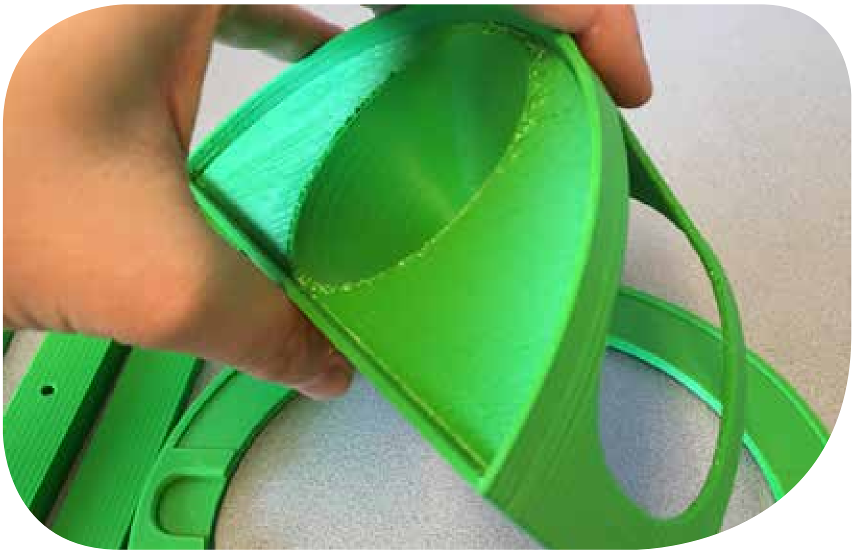
In order to imagine future consumer groups. The design process can use fictional character "personas" as basis of the user. With the help of fictional characters a designer can imagine scenarios how example, the developed product would answer the needs of the consumer groups. During the design process characteristics of the persona achieves more details (Hyysalo & others, 2009, p. 88). The realistic personas helps the product design teams to focus in to real needs of the target end users (Miaskiewicz & Kozar, 2011, p. 426).

3.1.11 PROSUMERS

Consumers that are active users of a product and who also develop the product itself or use the product to make other products, can be said to be a prosumer (Toffler, 1980). This is the professional (PRO) group of consumers that really know what they want. The term prosumer combines words producer and consumer. The term has been defined by Alvin Toffler, who used this term in his book The Third Wave in 1980.

3.1.12 INTERNET OF THINGS

Internet of things (IoT) are based on smart objects that can be controlled from a distance. Smart objects are the building blocks of the internet of things. Smart object that collect user data and provide data and combine data from various sources creates a network that can provide services that closed systems could not provide are the characteristic of the internet of things (Kopetz, 2011, p. 307). "The future is not going to be people talking to people; it's not going to be people accessing information. It's going to be about using machines to talk to other machines on behalf of people" (Tan & Wang, 2010).



Picture 5. *3D-Printed parts give haptic feedback in the design process*

3.3 BIOTECH TERMINOLOGY

3.3.1 CELL CULTURE

Cell culture refers to a technique where animal or plant *-derived* cells are cultivated in a gel or liquid based growth media (***Picture 6***). Cell cultures are used for research purposes in the medical and the biological fields, production of pharmaceuticals, stem cell treatments and tissue technology solutions. (Biotekniikan neuvottelukunta, Lalli, & Reuter, 2016, p.38).

3.3.2 CALLUS

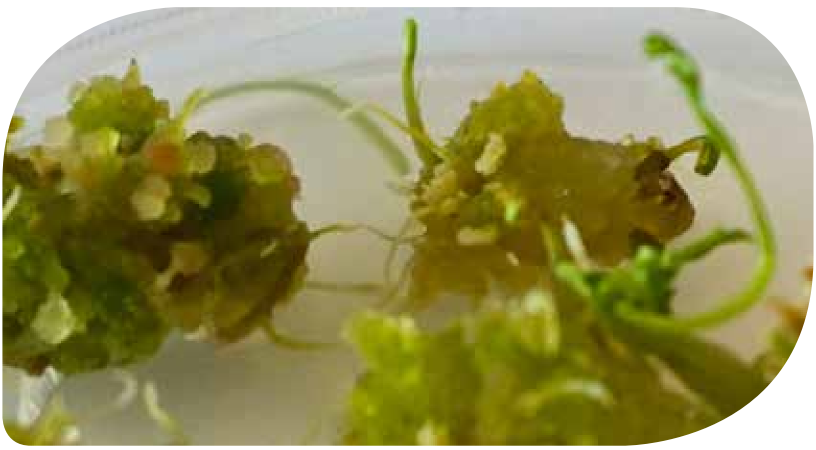
Callus is a term used for dedifferentiated tissue that appears at cut surfaces of a wounded plant. Single cells can be detached from a callus, which enables culturing plant cells separately from the plant. ("Tieteen termipankki," 2017) (Terv & Kanervo, 2008) Callus can be informally described as a scar tissue of the plant.

Picture 6. *Plant Cell Cultures on a petri dish*

3.3.3 PLANT-BASED SINGLE CELL CULTURE

Single cells are isolated from the callus tissue. For example, a wounded leaf that has been kept in the growth medium starts to form callus tissue to its wounded part. The isolated cells can be cultured in a liquid or a solid medium. (Srinbas, n.d.). On a solid medium, for example in a petri dish, the cells start to produce callus tissue as fragile piles. In a liquid medium, the cells divide and grow in small aggregates or files producing more biomass. The plant cell cultures can be maintained eternally by sub-culturing cells into a new growth medium regularly (Kheyrodin, 2015).

Plant cell cultures are easily scalable and offer multiple possibilities for production of pharmaceuticals, cosmetics or even food. (Rao & Ravishankar, 2002) (Huang & McDonald, 2012) (Reuter, Bailey, Joensuu, & Ritala, 2014).



Picture 7. *Original plant can be grown from the plant cell cultures*

3.3.4 TOTIPOTENT PLANT CELLS

Totipotency means that a whole plant can be grown from the plant cell cultures (***Picture** 7*). In other words, the plant cells are totipotent, meaning that they carry the potential to differentiate into a complete plant. Totipotent plant cells contains the whole genetic information from their origin and can therefore produce many of the biomolecules found in the parent plant (Rao & Ravishankar, 2002 p. 104).

Nohynek, 2015 describes use of totipotency in production of chemical compounds as it follows: "the genotypically expressed desired chemical compounds present in natural plants can be generated in their cell cultures".

Picture 8. *An industrial bioreactor*

3.3.5 BIOREACTOR

Bioreactor is an installation or a machine that obtains required conditions for some biological process (***Picture 8.***). For example, a compost can be a bioreactor as it maintains microorganisms that decompose food waste (Biotekniikan neuvottelukunta, Lalli, & Reuter, 2016, p.19). In its simplest form, a petri dish can work as a bioreactor when plant cells are grown inside the dish.

3.3.6 BIOREACTORS FOR PLANT CELL CULTURING

Bioreactors can be divided into three types: mechanically agitated bioreactors, pneumatically agitated bioreactors and wave bioreactors (Kumar, 2015). Mechanically agitated bioreactors stir cell cultures mechanically to give a cell culture the required air, whereas pneumatically agitated bioreactors use pressurised air. Wave bioreactors, as the name suggests, uses wave movement to make cell suspensions move and provide the necessary air for the cells.

Each type of bioreactors has its pros and cons. The bioreactor type should be selected based on the desired outcome (Huang & McDonald, 2012) (***Figure 3.)***.

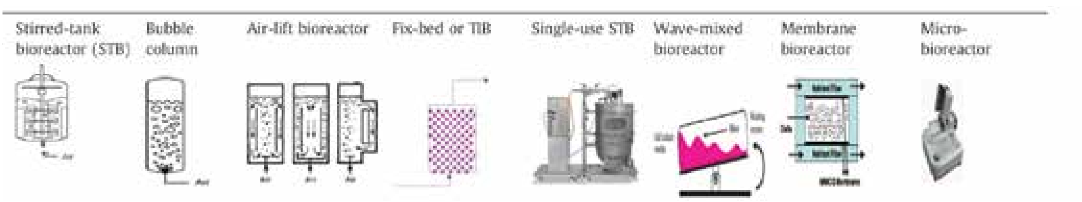


Figure 3. *Bioreactor systems for foreign protein production by plant cell cultures*
(Huang & McDonald, 2012)

3.3.7 IN VITRO

In vitro refers to the experiment done outside of its context, for example, a normal reaction inside of a living organism simulated within a test tube ("Tieteen termipankki," 2017) The word originates from the 19th century and means literally "in glass" in Latin ("in vitro - definition of in vitro in English | Oxford Dictionaries," n.d.)

3.3.8 MYCOPROTEIN

Mycoprotein is a relatively new protein source that has been developed to replace animal-based proteins to reduce environmental footprint of meat production. *Fusarium venenatum* A3/5 (ATCC PTA-2684) is a microorganism related to mushrooms which is grown in a continuous flow culture to produce mycoprotein, (Wiebe, 2004). This mycoprotein has been commercially named as Quorn by Marlow Foods (Williamson et al., 2006, p. 41). Quorn as a dietary supplement has a carbon footprint that is 75% and 90% smaller than for chicken

3.3.9 CLONING OF PLANTS

Cloning of a plant is rather simple (***Picture 9.)***. Many plant keepers may not know that when the scions are cut from the original plant the scion has the same DNA meaning that the original DNA is now doubled which is also known as cloning. (Biotekniikan neuvottelukunta, Lalli, & Reuter, 2016, p.31).

3.3.10 SYNTHETIC BIOLOGY

Synthetic biology modifies and builds living organisms and processes. The word synthetic biology originates from the 1970s when a Polish molecular biologist, Waclaw Szybalsk, envisioned ways technology based on enzymes that can modify DNA will revolutionize biological research. However, the actual leap towards the synthetic biology happened only in recent years when DNA sequencing technologies, genome modification tools and bioinformatics have developed to be powerful enough (Biotekniikan neuvottelukunta, Lalli, & Reuter, 2016, p.39). "Synthetic Biology is an emerging field of research where researchers construct new biological systems and redesign existing biological systems" (Alm et al., n.d.).¨

Picture 9. *Cloning is the same process as taking a scion from a the plant*

3.3.11 BIODESIGN

Design has developed and opened new fields for designers and it has developed to accommodate new market needs and possibilities (Moritz, 2005, p. 34). One of these fields is Biodesign, which relocates designers to new positions, for example, where designers will be able to replace energy intensive materials with fungi, bacteria or other living organisms (Miller, 2017). At syntheticaesthetics.org this has been phrased as follows: “By applying engineering principles to the complexity of living systems, scientists and engineers are making biology a new material for design” (2014). Biodesign can be considered as the next wave of industry; synthetic biology market alone is expected to reach $13.4 billion by 2019 (Bhisey, 2016).

Biodesign can also be seen as the new design discipline in which synthetic biologists design products, for example, by manipulating DNA sequences to make synthetic meats, cosmetic ingredients, and other products (Miller, 2017).

3.3.12 CELLULAR AGRICULTURE

Cellular agriculture is a relatively new and refined version of agriculture where food and other ingredients are produced on a cellular level, sparing whole plants and animals (***Figure 4***). These new technologies allow production of the same ingredients on cellular levels, which reduce negative impacts of agricultural practices (***Picture 10.***). Cellular agriculture of mammalian cells,for instance, can remove animal welfare problems when meat is produced in cell cultures or milk produced using yeast. (New Harvest, 2017).

In plant based cellular agriculture, many of the healthy compounds of a plant can be produced in cell cultures without the need of disturbing the natural existence of the plant. Instead, it is possible to cultivate the compounds that a plant has developed to survive in its natural environment, for example, “the purple to dark-red coloured anthocyanin protecting bilberry skins against UV–light and harmful microbes have a potentially similar effect on human skin” (Nohynek, 2015).

Previously, these techniques have been used in production of pharmaceuticals among others, (Ritala & Häkkinen, 2015) but biotechnology has over the years shown potential also in food production. The use of these techniques for producing food is relatively new and therefore public acceptance is crucial (Hart Research Associates, 2007).

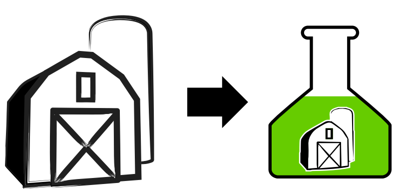


Figure 4. *Cellular agriculture is reshaping our understanding of agriculture. In future farms can fit in to bottles and test tubes*

3.4 FOOD TERMINOLOGY

3.4.1 FUNCTIONAL FOOD

In 1984, functional food was noted first by Japanese scientists who investigated the relationships between nutrition, sensory satisfaction fortification and modulation of physiological systems (Siró, Kápolna, & Lugasi, 2008).

Most of the countries have not defined the term functional food. Functionality varies from person to person and therefore defining functional food can be challenging even for nutrition professionals (Niva, 2007, p. 385). Despite different defining attempts, there is as of yet no universally accepted definition for functional foods (Rossi et al., 2014, p. 6).

In this thesis, functional food refers to the following definition made by The European Commission: "A food can be regarded as 'functional' if it is satisfactorily demonstrated to affect beneficially one or more target functions in the body, beyond adequate nutritional effects in a way that is relevant to either an improved state of health and well-being and/or reduction of risk of disease" (Diplock et al., 1999, p. 26).

3.4.2 SUPERFOOD

Superfood as a term is more blurred than functional food and also lacks a universal definition. The term Superfood has mostly been mentioned in articles that list health benefits of some foods (The European Food Information Council, 2012).

However, this thesis refers to the definition by the Oxford English dictionary that describes a superfood as "a nutrient-rich food considered to be especially beneficial for health and well-being" ("superfood - definition of superfood in English | Oxford Dictionaries," n.d.).

Picture 10. *"Food production takes up almost half of the planet's land surface" (Owen, 2005)*

3.4.3 . ORGANIC FOOD

Organic food farming is often referred to as chemical free farming that aims to reduce the environmental impact of farming. This claim does not fully correspond with the original idea of organic farming, which was observed as a holistic farming system that aims primarily to improve soil health and, through this, to lead to improved animal, human, and societal health. (Seufert, Ramankutty, & Mayerhofer, 2016, p.10)

Increasing organic food production and demand, together with increased international trading, has helped to reduce differences between organic food regulations. (Seufert, Ramankutty, & Mayerhofer, 2016, p.14).

Examples of organic food regulations by the European Commission:

- *Crops are rotated so that on-site resources are used efficiently*
- *Chemical pesticides, synthetic fertilisers, antibiotics and other substances are severely restricted*
- *Genetically modified organisms (GMOs) are banned*
- *On-site resources are put to good use, such as manure for fertiliser or feed produced on the farm*
- *Disease-resistant plant and animal species adapted to the local environment are used*
- *Livestock are raised in a free-range, open-air environment and are fed on organic fodder*
- *Animal husbandry practices are tailored to the various livestock species (European Commission, 2016).*

Regulators of organic production forbid use of genetical modification methods on species. However, the new species for organic production can be developed, for example, using radiation. The species that are developed by using radiation are, for instance, red grapefruit and Finnish Ryhti-oat, just to mention a few (Reuter, 2017). There is an ongoing debate about what GMO regulations should really cover. In order to shift the focus back to sustainability objectives, organic regulators should emphasize the best environmental practices of organic farms (Seufert, Ramankutty, & Mayerhofer, 2016, p.10).

It had been argued that focus of the organic regulations is narrow, which can be explained by the interest of the consumers who believe that organic foods are healthier and more nutritious due to a perception that less harmful substances are used in their production. (Seufert, Ramankutty, & Mayerhofer, 2016, p.10) In conclusion, it can be argued that organic products have taken the place of the functional food markets and they are starting to dominate the field.

5.9 percent of the European agricultural area is covered by organic production in 2014.(European Commission, 2016) In Finland corresponding figure is nearly ten percent (Evira, 2016) (***Picture 10***.).

3.4.4 LOCAL FOOD

Local food in general means food that has been locally produced. However, the meaning of local may differ from person to person. For some people, local food refers to foods that have been produced, for example, in the same living area. On the other hand, for some it may refer to food produced in the same country or even continent. The Finnish Central Union of Agricultural Producers and Forest Owners has defined local food as food that has been produced as close as possible to the consumer and the production chain is transparent and easily traceable (MTK, n.d.).

Local food movements are strongest in large cities, where consumers have been detached from food production. (Newman, Powell, & Wittman, 2015). Among food safety, local food has many socioeconomic benefits and it can increase self sufficiency and resilience of urban cities (Ghosh, 2014)(Colding & Barthel, 2013). Constantly expanding cities has taken spaces from agricultural lands, which together with local food movements has led to usage of urban spaces for agricultural, also known as a urban farming (Colding & Barthel, 2013) (***Picture 11.***) . New eco villages and residential areas that enable agricultural practices are now called "agriburban" areas. The key selling point of the agriburban neighbourhoods is the ability for agricultural practices, which indicates that people still have the desire to produce food while still being a part of modern food chains (Newman & Nixon, 2014).

Picture 11. *Use of urban spaces to agricultural practices increaces self sufficiency and resilience of the urban cities*

3.5 CONCLUSION OF THE LITERATURE REVIEW

This literature review briefly explained the terms used in the project related to the topic of plant biotechnology and terminology used in the design field. As this work has been done in a multidisciplinary group, it has been important to understand basic botanical solutions used in the project. Project complexity also required the use of many methods of design. Basing decisions on the different forms of design theory gave the project good tools to tackle different phases and challenges in the project.

This literature review covered the topics of Design, Food and Biotechnology, which are all related to this thesis.

3.5.1 DESIGN

The design section investigated studies done in the user-centred design and opened terminology used in this thesis. Designers currently use end-users as a source of inspiration. The better a designer can understand the end-user, the better design solutions can be made. The new technologies give new tools also for designers to investigate end-users. Social media also offers an interesting platform for new kind of data mining and interaction. These platforms can help designers to define usergroups and see instant reactions.

3.5.2 FOOD

The food section studied the terms used in the food sector from a human health and environmental point of view. It is well known that production, consumption and delivery of food affect the overall environmental footprint. Organic is neither a synonym for sustainability or health, nor superfood necessarily that functional either.

3.5.3 BIOTECHNOLOGY

New ways of using biotechnology and the new discoveries in the field opens the new exciting world of bioeconomy (Kruus & Hakala, 2017). This field has opened a new era of production which means also interesting opportunities for designers as well. One of the challenges in working in the new field is to get to know the basic terminology and methods used in the field. The emerging field of biodesign was the most inspiring part of this study. It shows that there is a large interest to combine biotechnology and design thinking together. Biodesign can function as a link between new technologies and users by making the topic more understandable for the people that are not in the field of biotechnology.

4. CASE STUDY

4.1 PROJECT BACKGROUND / PLANT CELL CULTURES AS FOOD

Plant cells have been recognised as an alternative to replace whole plants as sources of valuable industrial biochemicals (Oksman-Caldentey et al. 2004). Totipotency of the undifferentiated plant cells enables synthesis of the chemical compounds found in the native plant. In other words, cell cultures can replace whole plants in the production of the biochemical compounds and are in that sense more efficient compared to the whole plants. With this approach it is not necessary to grow the leafs, roots, or other parts of the plant to produce the desired compounds.

The plant cell cultures could offer environmentally friendly alternative to produce food (***Picture 12.***). Plant cells crow in sterile bioreactors which makes cultures free of any contaminations. In other words, plant cells do not require pesticides or fertilizers that pollute environment in normal agricultural practises. Growing plant cell as a food applications would also bring seasonless farming possibilities any location where the normal laboratory could be build. For example Phyton Biotech operate bioreactors at industrial scale to produce pharmaceuticals, all year around (Phyton, n.d.).

Now the potential of this method has started to be seen as the future alternative way of producing food ingredients (Davies & Deroles, 2014) (***Figure 5.***). Larger demand for natural products in the food industry has led to development of biotechnological processes that investigate the potential of the plant cells to produce natural additives for that demand (Longo & Sanromán, 2006). For example, Diana Plant Sciences that operate in the field of food supplements, has already launched its first plant cell culture product a freeze-dried cocoa cell culture cells under the Generally Recognized As Safe (GRAS) status (Diana Plant Sciences, n.d.). Furthermore, single use bioreactors with illumination possibilities

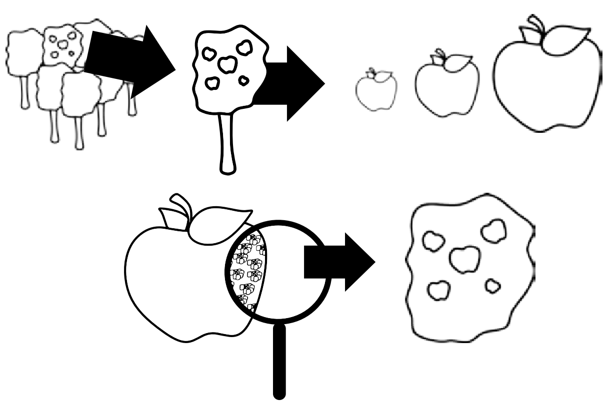


Figure 5. *Plant cell cultures can replace whole plants in the production and can be seen as a new form of agriculture, AKA Cellular Agriculture*




Picture 12. The plant cell cultures as food

have started to appear in the portfolio of the world's largest bioreactor manufactures, like Sartorius, which indicates that plant cell cultures will be used increasingly outside of pharmaceutical industry in the future. At VTT, cell culture -based production of cloudberry cells has been used in products of cosmetics, nutraceuticals, and pharmaceuticals at a 300 L scale (Nohynek et al., 2014).

Single use bioreactors are widely used in the pharmaceutical industry, but the potential use of them in consumer-driven food production has not been established yet. However, the solutions for pharma industry have different standards and are at a very different price point in comparison to that is required for food applications.

4.2 STAKEHOLDERS

This thesis has been done inside of the VTT Department of Solutions for Natural Resource and Environment (SONE) in the Plant and Biotechnology team. From that team a multidisciplinary research group had been formed for this project. The core group consists of professionals from biotechnology and one designer (the author of this thesis) described below. In addition, technical staff of the Plant and Biotechnology team have been an essential part of the development work of the pre-packed cartridge bioreactor and the cell lines used in this concept.

Lauri Reuter, PhD, Project manager

Lauri is an enthusiastic young researcher with ambition to make a difference. He defended his doctoral dissertation on utilization of plant cells for industrial scale protein production in December 2016.

Niko Räty, Designer

Niko is a young designer, whose portfolio covers everything from branding food products to design of eyewear and from furniture to sustainable development. Niko has designed the heart and soul of the CellPod concept and explored the introduction of plant cells as a new kind of a food to wider audience.

Heiko Rischer, PhD, Plant cell culture expert

Heiko has more than 20 years' scientific experience in the plant cell cultures and plant-derived chemicals. Lately he has developed plant cell cultures towards scalable industrial applications and explored the idea of plant cells as food and food ingredients.

Juha-Pekka Pitkänen, PhD, Bioreactor expert

JP is the Gyro Gearloose of bioreactors. He is an experienced scientist with enthusiasm for design and construction of equipment for bioprocess cultivations, sampling and analytics. This has resulted in three patents or patent applications and in one company.

4.2.1 PROJECT BRIEF

*This project aims to design and produce prototype of a bioreactor that can be operated with the same ease and reliability as any other kitchen appliance – CellPod. The starting point for the design will be the existing concept of single use bioreactors where the actual device is lined with a disposable bag containing the aseptic culture (**Picture 3.**). At the moment cell culture based food production is bound to laboratory environment and dependent on highly trained personnel. Re-designing the bioreactor concept is the way to bring decentralized production of single cell food to reality.*

User centered design process investigates triggers that affect mindset towards CellPod concept. Outcome of co-design process underlines the first customer segment and reveal results that can be used to find markets to this novel product idea. Co-creation used to establish relevance of product design decisions and helps in decision making during the product development process. Functional product is not enough in these days demanding product field and therefore whole product service system (PSS) has to be designed. Good product service systems can tackle issues around the end product in any time in its lifespan (Manzini & Vezzoli, 2003). Aim of the functional product service systems guarantees that end customer is happy before and after purchase of the product. Services around the single purchase product like the CellPod maschine can create cumulative incomes. Example by creating delivery system for seed cultures and taking care of the waste of the disposable bags can be extra feature for environmental focused customer segment. Help of good product service systems opens opportunities also in B2B level where synergies can create service packages that benefit end customer and other stakeholders in this chain. Therefore creating product service system among product is one of the fundamental goals.

In order to succeed, CellPod also need to create a solid business case. Goal is to work on a winning business model from early on and develop a desirable product based on consumer interviews and meticulous design.

Ideally CellPod can be used to grow a variety of single cell foods ranging from berry cells to algae and fungi. In the framework of this project, however, the aim is to generate proof of concept for arctic bramble. In addition, stocking of the seed cultures is of importance so that the prosumer can easily, aseptically and reliably start the cultivation every time. Similarly, the nutrients need to be designed so that they are easy to use and add.

The CellPod will be an important step towards sustainable urban food production. More importantly, dissemination of the research project and promotion of the prototype will create interest towards biotechnology in food production and induce discussion on alternative sources of nutrients.

Plant cells as food fall under the Novel Food regulation as previously confirmed by the Finnish Food Safety Authority EVIRA. Regulatory aspects will therefore not be handled in this project.

4.3 POSITIONING INTO MARKETS

Urban consumers are increasingly seeking connection to their food sources, which is shown in rising trend of the local food movements (Newman, Powell, & Wittman, 2015, p. 102). Concern consumers are aware of the environmental footprint of the products they buy and the sustainability aspects of the product comes centre of purchase decision. Urban consumers have increasing need to become active part of the food chain and the possibility to produce own foodstuffs are now preserved as exciting (Newman & Nixon, 2014). Can be argued that the possibilities for home production is limited to gardening of own salad in now popular Kitchen Gardens and in some extend what urban garden spaces are allowing.

The main drivers might differ in other parts of the world (***Figure 6.***). For example, in some countries food may not contain at all what the package says or the food may even be toxic. Pollution may be transferred from the farms to the foodstuffs of consumer (Roberts, 2009).

The countries where obesity is a serious problem new appliance that produce healthy foods in home environment might increase interest among health related consumer group. Also consumers with the special diets might have special interest for new way of producing foods.

Nespresso, has been able to transform the coffee brewing trend, by simplifying the coffeemakers to use single-use capsules that makes easier to make different types of coffee drinks. Ease of use and versatile selection of different coffees makes consumers more willing to pay more for coffeemakers and capsules.

Same way, SodaStream have rethinked of selling carbonated drinks by offering the consumer appliance that enables consumers to carbonate the drinks by themselves at home. Steady income conforms from sales of the appliance and carbon dioxide bottles. Also healthy meal replacement for example, Nutrilet owned by Norwegian Orkla, have become market leader in Nordic countries (***Figure** 7*).

Home biorector (CellPod) concept aims to imitate business models of the Nespresso and SodaStream, but focusing in food sector. The main aim is to bring Cellular Agriculture to the hands of environmentally conscious urban consumers. Tailoring possibilities of the cell cultures makes CellPod concept more versatile in long run. One possibility can be for example, to offering the company's exclusive rights for specific cell lines, with special properties.

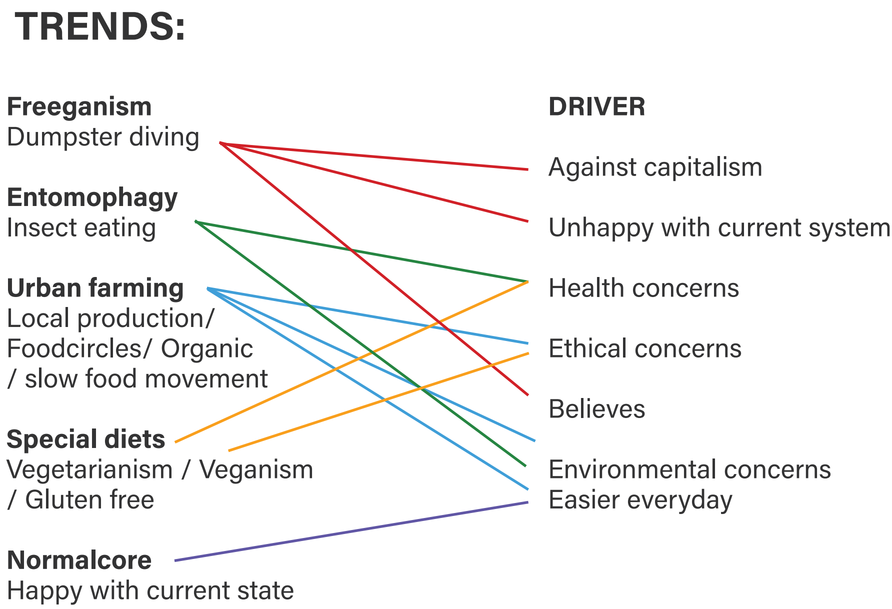


Figure 6. Trend driver map.

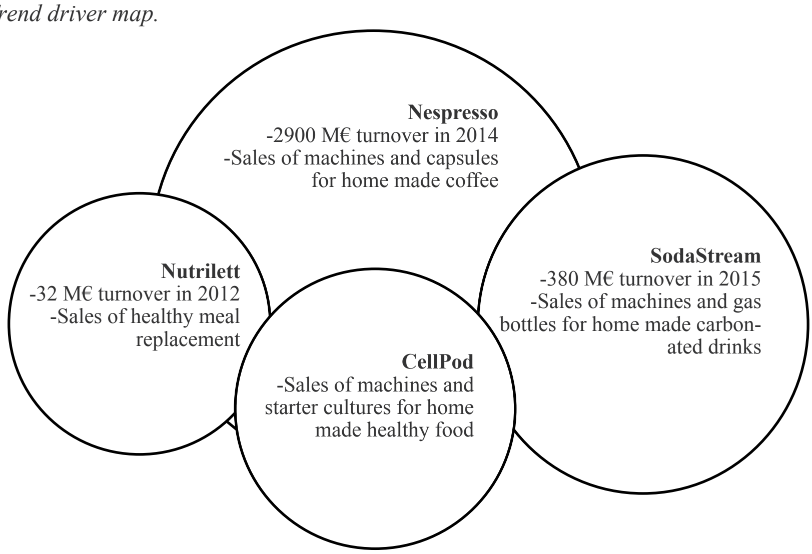


Figure 7. The position of the CellPod concept in comparison to existing products on the market with comparable business model

4.4 BENCHMARKING FOR THE FUTURE KITCHEN APPLIANCE

Aim of this benchmarking was to understand on going trends in field of new kitchen appliances. This was light look up to set to focus and design drivers into the CellPod project.

Smart kitchen appears to be one of the ongoing trend. Kitchen appliances are getting more smarter and it is more likely to see people communicating with the appliances. Smart devices shapes our future and react to the trend of globalisation and urbanisation. New kind of hybrids of devices have been seen. Small spaces makes new mobile solutions more appealing and gives more freedom to create kitchens in spaces what have been earlier unthinkable.

Internet of things

Mobility / Nomadic lifestyles

Urbanisation / High density cities

Small living spaces

Aging population / health awareness

4.4.1 BENCHMARKING FOR FOOD INNOVATION

This section reveals results of the benchmarking process. Aim of the benchmarking is to see and understand markets around new food innovations related to CellPod concept. Benchmarking was specially focused on cellular level food innovations and urban food production in home environment. This benchmarking excludes animal based food production innovations like aquaponics in urban environment but its include insect farming and animal cell based food innovations like In Vitro meat. See benchmarked companies below.

SPREAD

"SPREAD constructed the Kameoka Plant, the world's largest plant factory in terms of production that produces 21,000 heads of lettuce per day.." http://spread.co.jp/en/

Soylent

"We engineer foods that offer complete nutrition, value, and convenience." https://www.soylent.com/

Plantui

"Smart garden" https://plantui.com/fi/about-us/

Tregren

Indoor Garden http://tregren.com/fi/

Click and Grow

"The kitchen garden for modern life" http://www.clickandgrow.com/

Helsieni

"Helsieni grows oyster mushrooms on Helsinki's coffee waste and aims to be part of the city's sustainable food ecosystem." http://www.helsieni.fi/fi/etusivu/

EntoCube

"Finnish EntoCube provide and produce technologies for insect farmers.
We offer the technology to farm insects for insect producers and the insect protein ingredient for food industry." http://www.entocube.com/

Cellular Agricultture

Algae Lab

"Grow your own Spirulina superfood algae at home!" http://www.algaelab.org/

Perfect Day

"Using yeast and age-old fermentation techniques, we make the very same milk proteins that cows make." http://www.perfectdayfoods.com/

Geltor

"At Geltor, we make real gelatin, without the animal." http://geltor.com/

Clara Foods

"Unlike other replacements on the market, our Clara Whites work in even the most sensitive products such as angel food cakes, meringues, and macarons. Our baking and binding applications team uses a proprietary protein functionality matrix to deliver improved volume, foaming, texture, and tensile strength for all your product needs." http://www.clarafoods.com/#homepage

Afineur

Cultured Coffee "Afineur is a biotechnology company pioneering the use of controlled natural fermentations to make better, healthier and more sustainable food products." https://www.afineur.com/

Memphis Meats

Announcing the world's first chicken produced without the animal. http://www.memphismeats.com/

Supermeat

"Real meat cultured in a replicated environment." http://supermeat.com/stop.html

Pembient

Bioengineered Wildlife Products."We are leveraging advances in biotechnology to fabricate wildlife products, such as rhino horn and elephant ivory, at prices below the levels that induce poaching. Our goal is to replace the illegal wildlife trade, a $20B black market, the fourth largest after drug, arms, and human trafficking, with sustainable commerce. " http://signup.pembient.com/

Sothicbio

"We are an Irish biotech startup with a high tech twist to animal conservation: our in-house platform technology allows us to remove the threatened Horseshoe Crab species from the pharmaceutical quality control supply chain - and to disrupt industrial animal hell." http://sothicbio.science/

Modern Meadow

"Growing leather without an animal might seem futuristic but at we're making it reality. Biofabrication enables us to grow nature's materials using living cells instead of animals. We grow collagen, a protein you find in animal skin, from which we create a leather" http://www.modernmeadow.com/

4.5 POSITIONING MAP

This section focus on Positioning (Aaker & Shansby, 1982) of the cellpod concept in market and trends discovered in benchmarking process.

CellPod aligned in the cross section of four emerging trends: healthy nutrition, high-tech urban agriculture, prosumers and modular kitchen appliances (***Figure 8.***) number of companies are competing in all four areas. CellPod, however, is positioned in the middle connecting these trends into one concept.

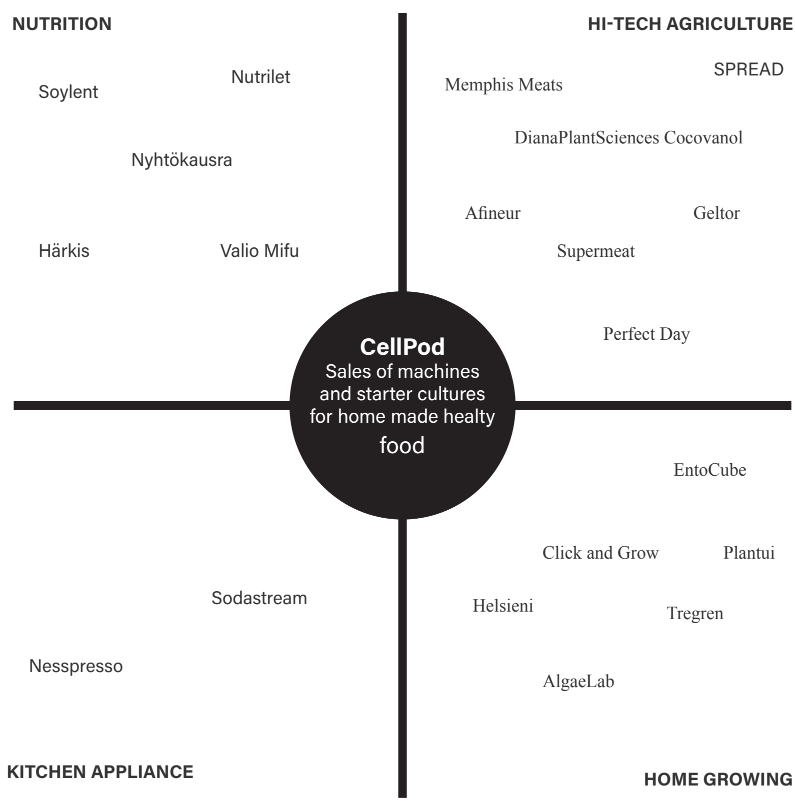


Figure 8. *Alignment of CellPod in the current trends and companies on the field*

4.5.1 ESTIMATION OF BUSINESS POTENTIAL

The CellPod is aimed to launch firstly in small scale and it will be aimed to the tech ware health and environment conscious consumers (***Figure 9***). However the real business potential of the CellPod device is in big cities, densely populated countries, like Japan, Korea, China or USA. In second wave when the home bioreactor concept has established its position it will have ten times more potential customers.

- ***Claims:***
- *No pesticides*
- *No fertilization*
- *No long distance food miles*
- *Season free production*
- *Always fresh ingredients*
- *Possibility produce food in urban environments*
- *Scalability*
- *Space efficiency*

Needs	**Approach**
Highly nutritious, local, fresh, exciting and clean Food more food awareness reduce food waste stemming from inefficient distribution chains from producer to consumer food with consistent quality independent of season	We have a solution to provide the customer with a tool to locally produce healthy food indoors Free, unexploited, national natural resources are upgraded into accessible goods The concept is based on a cartridge (to be repeatedly purchased) and a hardware (to be purchased once)
Benefits	**Competition**
The consumer becomes a prosumer i.e. is given an active partThe generated food is nutritious, local, fresh, clean and independently produced anytime The consumer rests with peace of mind due to the reduced environmental impact of the food production A spearhead activity in future food production is started with potential to solve global problems grand challenges New jobs are created in a whole new business	Our approach is unique in offering small, decentralised, local on-site production systems for the consumer Competition comes from established businesses in the home gardening and conventional food / food supplement sectors There will be competition for kitchen space with other home appliances

Figure 9. *NABC-analysis*

4.6 MULTIDISCIPLINARY PROCESS

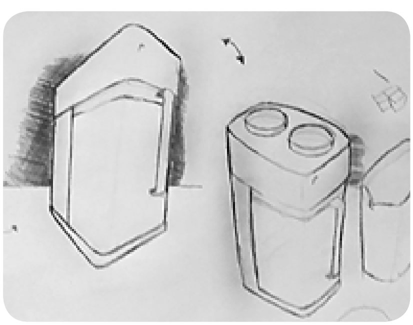
"The exciting thing about the emerging field of biodesign is that it is made up of both scientists and designers, and often the most significant projects are the ones that see the two disciplines partnering up. Artist and designers need the scientific know-how of biologists, while biologists benefit from the big-picture thinking and outside perspective of artists and designers" (Miller, 2017).

Inside the multidisciplinary research team designer role has been lead visual communication and give visual feedback to the process (***Picture 13.***). With help of visuals and illustrations working in the team had when designer can underline the visual feedback of the conversations and brainstorm sessions, which have also wonderfully phrased in the study by Rodgers, Green, & McGown, (2000), "sketches can provide insight into the designer's mode of thinking at any particular point in the design process" (p.464). When concept has strong visual identity it is easier to start comunicate idea to the other members of the group.

In this informal conversations with other plant scientist project got other relevant information about other possibilities that The CellPod project can look upto. More importantly even discussions about the design itself got straight feedback which helped through the design process.

The physical starting point for the product idea was the early prototype done by scientist without any design experience (***Picture 3***. on page 9.). This prototype just showed that idea works. Designers job was to redefine the early model which were made together with scientist. First designed prototype 1.0 were made with laboratory equipments and few designed and 3D - printed parts. The whole model were built and designed at the same time.

The role of the designer in this multidisciplinary group have been lead design process with the visual input. The designer task has been to produce visual material as well as work with prototypes to gether with scientist in the team. Designer is in a key role to defining the possible head user group of the concept and see end product from the end users point of view. Together with team all the solutions has been widely discussed and decisions has based on mutual understanding. This type of multidisciplinarity working have empowered all team members and it has strongly characterised this project. In some standard this project can be said to be one example how and what Biodesign can be.



Picture 13. *First sketches of the home bioreactor*

4.7 DESIGNER IN THE LAB / PRE STATE

At the beginning of the thesis project, the principles of growing edible plant cell cultures and aseptic working in laboratory environment were introduced in practical manner. Showing concrete examples how plant cells were cultured clarified the process (***Picture 14***). Learning by doing was an effective way to emerge from design field into the field of biotechnology (***Picture 15)***. Understanding basic working methods revealed the boundaries of the cell culturing which were important drivers when the design process was initiated.

Picture 14. *Carrot sprouts growing from cell cultures*

Picture 15. *Carrot sprout from cell culture planted in the soil*

4.8 FIRST IDEAS ABOUT THE FUTURE CONCEPT

At the beginning of the project, we studied the past in order to understand what had been done in the field of cellular agriculture and kitchen appliances previously. The results of the benchmark process worked as a foundation of the design work (***Figure 8.***) Considering new trends in kitchen appliances gave the first ideas regarding to the future kitchen appliance. Benchmark of the companies that worked in the field of cellular agriculture helped understanding the brand and customer segment which we were developing simultaneously with the design process.

The First drawings of the concept visualized the idea of the appliance that were familiar looking compared to the existing appliances found in western kitchens (***Picture 16)***. Visualisation of the idea helped communicate the idea to the rest of the group. Changes were made based on comments of the group members (***Picture 17***.). The Members of the group mainly commented about the functionality of the concept (***Picture 18.***). One of the early ideas was to focus on the familiarity of the device to mitigate novelty of the innovation, but the problem in this approach was its lack of excitement. Resemblance made this concept feel that it can be easily outdated and, therefore, we decided to look in other objects in home environment. Soft round forms are believed to make appliances more friendly. This driver led to the fundamental idea that we chose to start to develop.

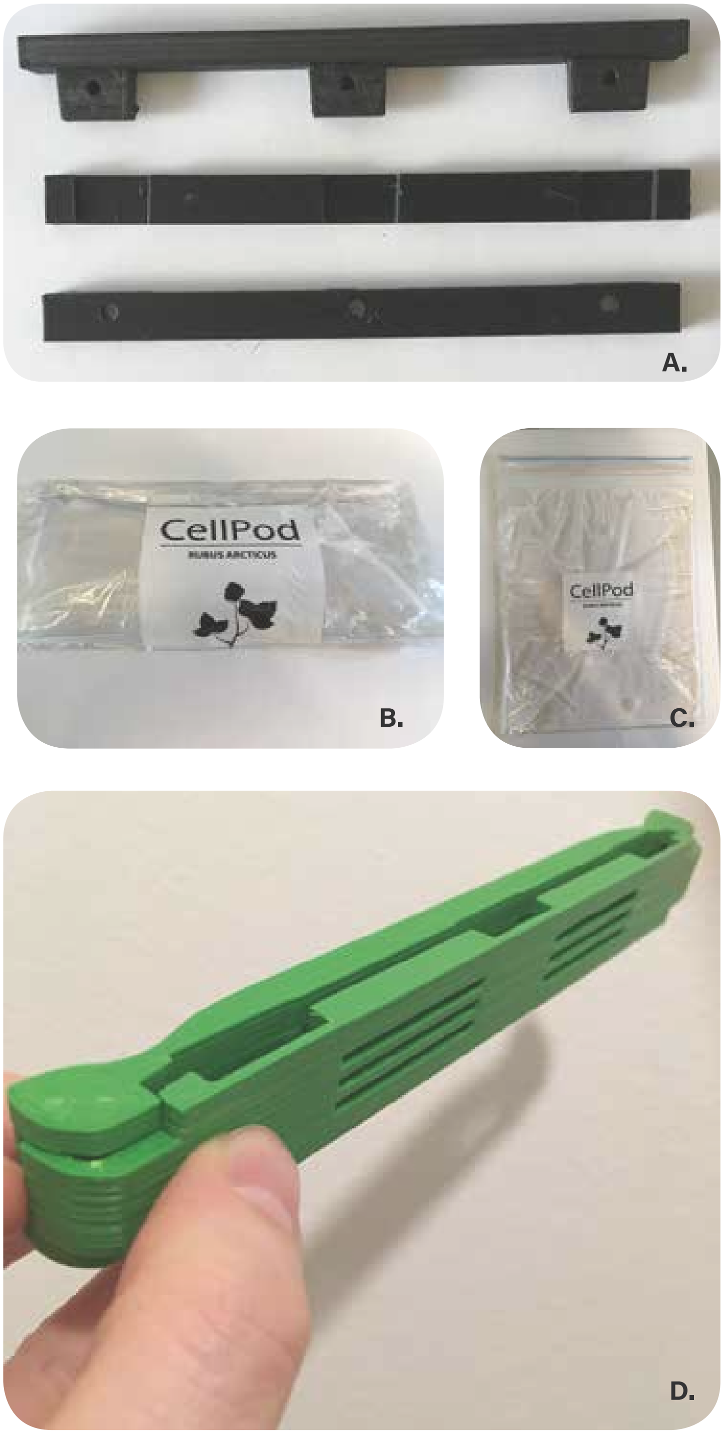
A.

B.

C.

Picture 16. *A.B.C. First 3D-drawings of the concept*

Picture 17. *B.C.* Changes were made based on comments of the group members



Picture 18. *A. B. C. D The design evolution of the CellBag seal*

Picture 19. *Prototype 1.0 in the home environment*

4.9 PROTOTYPE 1.0

3D-printing was selected as a manufacturing method for the prototyping. 3D-printing opened possibilities to design forms more freely and gave more finished outcome. Parts that were not reasonable to produce by printing were made out of the existing lab equipment. 3D-printed parts raised excitement inside The CellPod team and rapidly led to the construction of the first model. LED-lights from a deconstruct Ikea product and an aquarium pump made the first prototype functional which gave information about look and feel of the future product. Actual construction work was pro actively done in the team simultaneously discovering and discussing what works and what doesn't, for example the noisy aquarium pump underlined the importance of a quiet appliance. In the end, the building process of the prototype pinpointed problems that helped us in the further development process (***Picture 19***.).

4.9.1 FIRST REACTIONS

The General response was received curiosity and excitement. We were surprised by positive feedback and curiosity gained by the first prototype.

- How user should fill the tank?
- How much space all the technical parts would need?
- What is the real volume?
- How much it can produce cell mass?

4.10 PROTOTYPE 2.0

Prototype 2.0 were more focused on fitting the all the technical parts inside the prototype, where the first prototype exclude the air big, clumsy air pump. Now the priority of the second prototype was to make a more advanced model (***Picture 20- Picture 26.)***. The design driver was to include all the crucial parts inside to make prototype functional enough to display the core idea (***Picture 27.)***.

4.10.1 PROTOTYPING

Picture 20. *Volume*

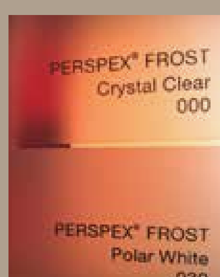
Picture 21. *Welded cell bag prototypes on the air flow test.*

Picture 22. *Study of usability*

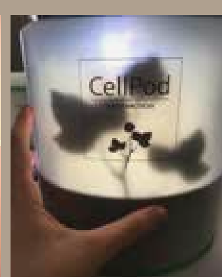
Picture 27. *A. B.Rendered image of the prototype 2.0*

Picture 23. *Study of luminosity and volume*

Picture 24. *Study of light*



Picture 25. *Study of luminosity*



Picture 26. *Study of luminosity*

4.10.2 BUSINESS MODEL

The product design process included discussions about the product service systems around the CellPod concept. Based on this conversations two alternative business models were created (***Figure 10***). The services were seen as a good medium to work on the ecological, environmental and social issues of the product, for example, the waste and maintenance management of the product.

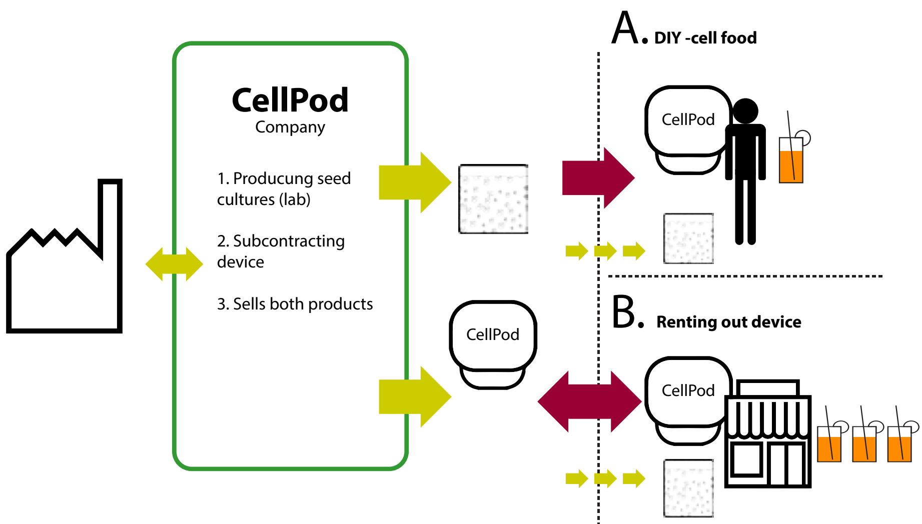


Figure 10. *The B2C model consists of sales of the device and the capsules to the end-users. B2B model may consist of selling or renting the devices for restaurants or grocery stores selling the final product further*

4.11 SOCIAL MEDIA

The social media was an important part of the development process. The preliminary idea behind the concept required to be clarified prior to opening any social media outlets. Inside of the research team a brainstorm method was used to find a new name for the device. The name of the device and the slogan desired to promote values of the original concept. The name hunting process forced to rethink the reasoning behind this concept and its aim, see list below:

Brainstorming, mind-mapping and circulation of the post-it notes worked as co-creation tools when the team was rethinking of the concept. The early state of the project made name selection difficult and therefore the original working title of the concept, CellPod, was selected as the official name of the device. To promote selected values, we created a slogan to support the original name.The new

- **Why?** *We believe that the world needs new more sustainable ways to produce food. Everybody should have access to fresh food*
- **How?** *We want to create an easy to use device that enables everybody to produce food.*
- **What?** *We aim to design a home bioreactor for the plant cell farming. (Sinek, 2011)*

slogan, Next Generation of Food, was created based on work done in name creation, and it collected the essence of the name suggestions done in the brainstorm process (***Picture 4 on page on page 19.***), which promoted the hypothesis of the first consumer group, see profile of the first consumer group.

Disclaimer

Just Googling the name was not enough to find out that almost the same name (Celpod) in almost the same domain was already registered. Therefore the name CellPod will not be used for this device in the future

Profile of the first consumer group

- *- Lifestyles of Health and Sustainability (LOHAS)*
- *- Early adopter*
- *- Urban consumer*
- *- Technology oriented*
- *- Prosumer*
- *- Conscious consumer*
- *- Consumer of the other alternative food tech brands*

This process clarified the core idea of the concept and offered a first view about the customer segment. The research team concluded that home bioreactor itself would not change the food chain; however, it would provide a new tool for an average consumer to produce food, and the object itself would promote the values of self-sustaining prosumerism. The project opened a website and a Facebook account based on the brand development work. A Press Release, Facebook page (***Picture 30.***), Website and an article written to Bioeconomy site (http://www.bioeconomy.fi/future-food-from-your-kitchen-table/) (***Appendix 1.***) kicked off the interactive part of the project. In this phase all of the social media outlets were used to promote The Owela co-creation project in which we wanted to recruit the people interested in the topic.

The clarified concept made interaction easy between the research group and the consumer. Transparent communication between the people who had shown interest in this project and the research team promoted trust that was important to involve people to the co-creation process and to obtain the feedback from the real consumer perspective. The research team performed a two-week co-creation project on Owela (***Picture 29.***), the online co-creation platform provided by VTT.

Picture 28. *The images of the plant cells as a food were provided to inspire participants*

4.12 OWELA

Owela is an online innovation space provided by VTT, which helps companies to develop products and services together with their users. Owela supports active user involvement in the design process from the early ideas to execution of the real project. Co-creation increases the quality of the products and services and leads to faster implementations to the market. Involvement of the users leads to better user acceptance and commitment (www.owela.fi).

Picture 29. *front page of the online co-creation platform Owela*

4.12.1 IN USE

The Owela platform was used early in the development phase of the project. In that point the early design concepts was discussed inside of the research group and first illustrations of the home bioreactor and images of the plant cell cultures as food was used to provoke conversation (***Picture 28***). In that point prototype 1.0 and partly 2.0 were already build and 1.0 displayed for inner event of VTT. Images of the prototype 1.0 or 2.0 were not displayed in Owela forum to provoke imagination of the participants. However illustrations of the concept and images of the plant cells as a food was provided to inspire participants.

The project was advertised in the first press release which received a wide coverage in Finnish and international media. Re-posts of the press release at science based platforms promoted the project to the technology oriented audiences which was beneficial for building the right audience to the project.

The Owela platform covered questions around the bioreactor concept. Questions was clustered to the four topics plant cell cultures as food, Finnish plant cells, CellPod home cell incubator, service and price, and the idea section for new ideas. In beginning there was also a brief background survey.

Picture 30. *Facebook page collected 504 followers during the project*

Answers were based on open conversation that anyone in the project could comment. Users of the platform had avatars which generated the conversation even more straightforward. Participants of the Owela project were enthusiastic about technical innovations which built a positive mood in the conversations in general. The Owela project was made only in Finnish; however, the project was also requested to be repeated in English. Overall, participants were increasingly enthusiastic about novel food development and viewed it more as an opportunity. Only few of the participants were critical towards the topic.

To take part in the co-creation project, participants were required to create a profile to the Owela platform which might have caused dropping out people who did not really care about the idea. Accessibility of the platform might have also posed an issue for some people even if they would have otherwise liked to take part. On the other hand, some of the Owela users were old users from other Owela projects that made taking part in to this project also relatively easy. Collected qualitative data from this particular project is not representative sample of the Finnish population. More likely this data shows a collection of people that got recruited via the Owela platform newsletter, VTT press release, and inner and outer announcements. The co-creation period was also communicated via the project Facebook page.

Conversations where replied promptly provoking conversations at the Owela platform. Aim of the active interaction hoped to make participants feel more committed to the project (Füller, Mühlbacher, Matzler, & Jawecki, 2009). Active participants got points anytime they took apart of conversation and the most active participants were promised to be awarded with movie tickets.

4.13 KEY FINDINGS

71 participants

22 more active participants

Majority of the participants viewed concept more positively

Participants were active and conversations flowed freely. Conversations characterised possible head user groups, optimistic prudent and sceptics users. In each group the most active ones were selected to present character of the group. Those characters reveals different drivers from different groups. Money ease of usage, special needs like diets (***Appendix 2.***).

People had possibility to create topics related to the concept and few topics got more interest by other participants. Public cell automat for public harvesting of the cell cultures and cellpod to growing foods for pets. This user self created ideas where also sign that cellular agriculture was an inspiring concept for the audience.

What was remarkable in this study was that no one who took a part to the conversation did not bring up moral or ethical topics like “playing a god argument” which can affect the level of acceptance of new technologies (Rollin, Kennedy, & Wills, 2011). This correspond to the acceptance study of the new food technologies, which revealed that in Finland, Sweden and in Netherlands people are less worried about new food technologies than rest of the Europe, particularly countries like Italy and Greece which were highly skeptical (Rollin, Kennedy, & Wills, 2011).

Provided images and concept visualisations might be one reason of more accepting reception of the concept. Background survey also reveals that most of the users comes form city area which has been seen to affect acceptance of new technology. However there was no enough answers coming from countryside to generalize this finding.

The attitudes differ between new animal and plant-based food technology. Plant-based technology are preserved more positively than animal based, which more likely races ethical questions (Rollin, Kennedy, & Wills, 2011). Also terminology used affects to the reception, for example Cellular Agriculture was received more positively than lab grown meat in Qualitative study done by New Harvest institute 2017.

Interestingly in the same study showed that higher educational background also affected positively to the reception of Cellular Agriculture (New Harvest, 2017). In this Owela study we did not ask about educational background, but instead living environment, form and size of living, which indicated that people in the urban environment was more optimistic about the concept. Also in the urban environment living forms were more heterogeneous which might have an effect to the attitudes toward new technologies. Also when participants learned more about the topic the attitudes seemed to change, this notion correspond to qualitative research of the perceptions of Cellular Agriculture done by New Harvest research institute.

Participants were increasingly curious also about the taste of the cell lines. Taste is important factor in acceptance, it has been discovered willingness to compromise on taste for health has been decreased and consumers have become more convinced that good taste and health are not necessarily to be traded-off against each other (Verbeke, 2006, p.130), but it is also health claim related how much consumers are willing to sacrifice (Bech-Larsen & Grunert, 2003) Currently, the cell lines used in the CellPod concept have neutral taste, which is a good thing if the cell lines are desired to use dietary supplements in future.

Picture 31. *The third prototype 0.3 Touch interface is digitally edited to the picture*

Picture 32. *The home biorector works as light source to the herbs and salads grown on the kitchen counter*

Picture 33. *Shadow stickers were designed to visualise origin of the plant cell culture that bubbling water and light brings shadows live*

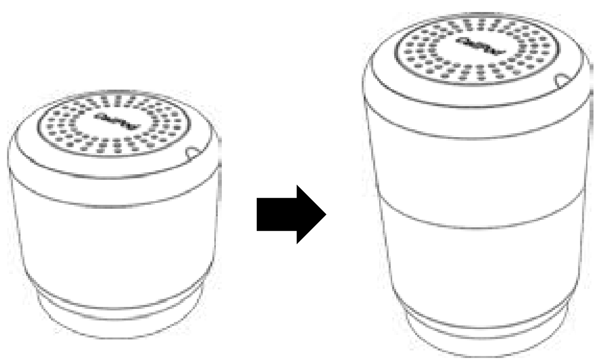
4.14 PROTOTYPE 3.0

The third prototype, included the technical parts and revealed the final design solutions (***Picture 31-37.*** and ***Figure 11. - 15.***). This prototype promoted the emphatic, look and feel, of the future kitchen appliance. The prototype was meant to display the concept and its design in physical form. The positive feeling of the product was emphasized through soft and friendly forms. The friendly appearance aimed to promote the positive picture of the near future kitchen appliances and inspire the future end-users of the upcoming possibilities. Overall, one of the design goals was to produce a concept that would work universally in different locations (***Picture 37 page 60.***). The following principles of the universal design guide functioned as the main drivers that helped in the decision making process:

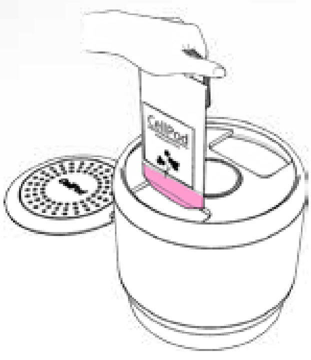
1: Equitable Use
2: Flexibility in Use
3: Simple and Intuitive Use
4: Perceptible Information
5: Tolerance for Error
6: Low Physical Effort
7: Size and Space for Approach and Use
(NDA, n.d.)

Modularity was seen as a way to create the scalable device and to be seen as a platform for future development of the concept (***Figure 11.***). Modular design was aimed to inspire the prosumer customer segment, who was taught to enjoy the modification possibilities of the device .

Figure 11. *Modular design was aimed to inspire the prosumer customer segment. With the scalable solution CellPod can grow for bigger needs and in the future other modules and parts can be added to expand the functionality of the CellPod device. This approach aims to make CellPod a center of home food production in the future.*



Picture 34. Home bioreactor next to arctic bramble cell culture



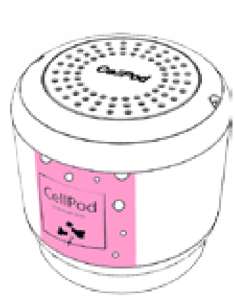


Figure 12. *CellPod. 3.0 is a smart kitchen appliance that cultures plant cells for food. The home plant cell incubator functions according to the capsule principle and can grow 500g fresh plant cells in a week.*

Figure 13. *The CellPod 3.0 includes two capsules that enable to culture two different plant cell lines at the same time.. User adds only water to start cultivation*

Figure 14. *Dual system enables two harvesting days allowing user to have fresh produce twice in a week*

Picture 35. *With the help of smart censor technologies, the home bioreactor could improve health by producing food based on monitored information coming from other health measuring devices*

Picture 36. *After one week produce is ready to use*

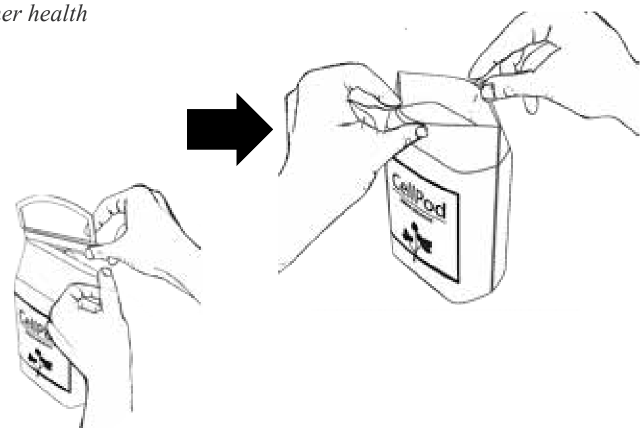
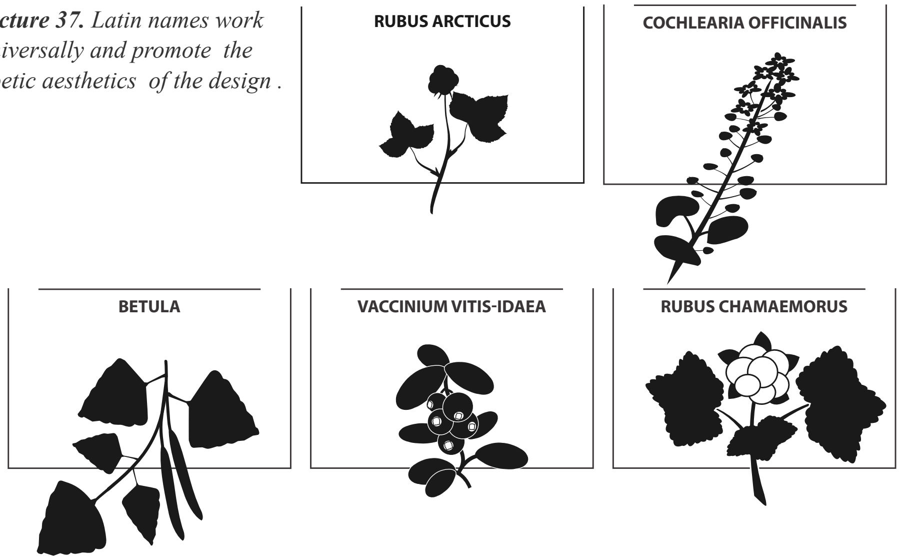


Figure 15. *Cell bags stands without sport to help opening and use of the cultivated cell cultures*

__Picture 37.__ Latin names work universally and promote the poetic aesthetics of the design .



4.15 11.1. PRESENTING AT SLUSH

The home bioreactor concept and the prototype gained positive reactions in Slush, an international startup fare in Helsinki. The new way of making food was said to be the first really new innovation in the field of food tech for a long time. In addition, the appliance received curiosity among visitors of the Slush and many questions were repeated, such as:

What to put inside of the device?

When I can buy it?

What are these plant cell cultures?

How does it taste?

This feedback gave us good information about the reception of the concept and its design. The visitors also wanted to taste the presented cell lines even though they were told that we were not allowed to offer tasting because the cell lines had not gone through the novel food legislation process. Instead of tasting we recommended the curious explorers to smell the cell lines to get the sensation about the cells as the future food ingredient.

4.16 SURVEY

The final survey was planned to gain feedback from the wider audience. The final survey was launched at the same time with the third prototype and the new website (***Picture 38.***). In this phase we collected all the relevant information to the web page to familiarize anyone interested with the topic. The new site had a more branded feeling compared to the early web page of the project, through which we wanted to underline that this was still a science project rather than a company. We strongly believed that transparent communication from inside out creates trust that appeals to the enthusiastic prosumer customer segment that we wanted to reach.

This survey was divided into the following five parts:

Background information

Plant cells as a food

Future of food (What is important?)

The future kitchen appliance

Appliances as a service

Picture 38. *The new site had a more branded feeling compared to the early web page of the project*

Each part of the survey was designed to reveal factors that might affect the interest level towards the new technical food innovations. The questions were kept short and not too much extra information about the questions was revealed to allow participants to answer questions based on how they felt about the topic. For example, the way participants experience living in the city, suburb, small town or countryside is a subjective matter and depends on the way participants experience their living environment. To obtain more information about inner drivers, user's own subjective experience is more relevant to this study. Participants also had an opportunity to leave some of the questions blank which is shown in the amount of the replies to some of the questions.

To lower the threshold of getting people to answer the survey, we did not require participants to leave any contact information and answering was done anonymously. This factor was important to gain more answers and to give participants anonymous freedom to be even blunt without the fear of losing one's face. The anonymity also enabled multiple entries to the survey from the same person, which has been taken into account during the analysis. The automatic analysis of the answers by Google can be found in appendix (***Appendix 3.***)

__Figure 16.__ This survey underlined that urban technology oriented adults are the potential customer for the CellPod concept. Figures show that people in the city are more open to the new technologies which correspond together with co-creation study done previously in Owela. This survey also validate the customer profile created earlier in this project (See __Figure 17.__ - __Figure 23.__ below).

__Figure 17.__ . Living environment

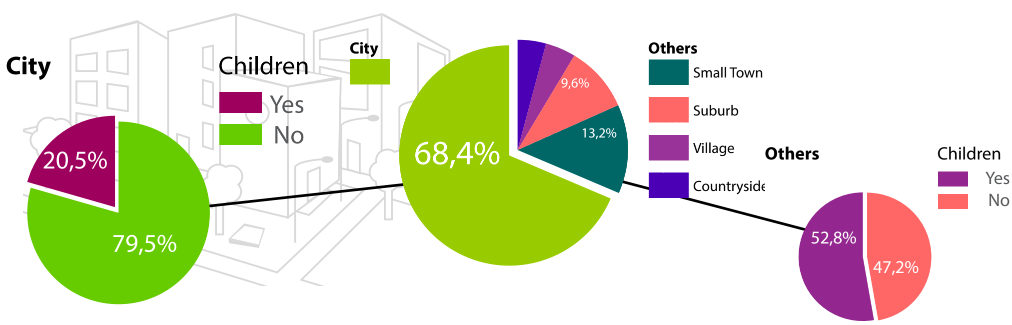


__Figure 18.__ Plant cells as food is

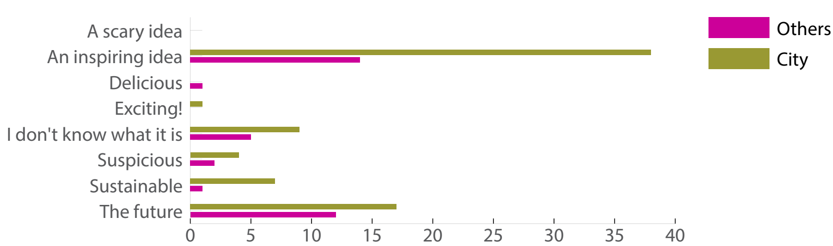


__Figure 19.__ Growing plant cells for food is interesting because

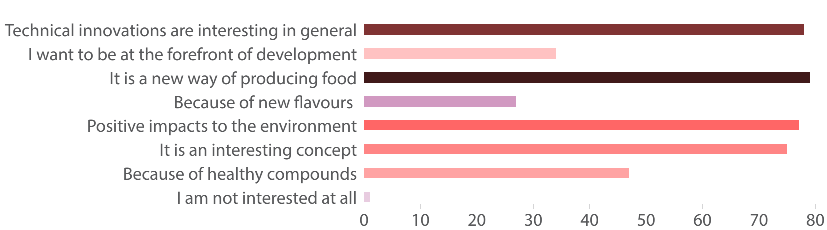


Figure 20. Price of the device

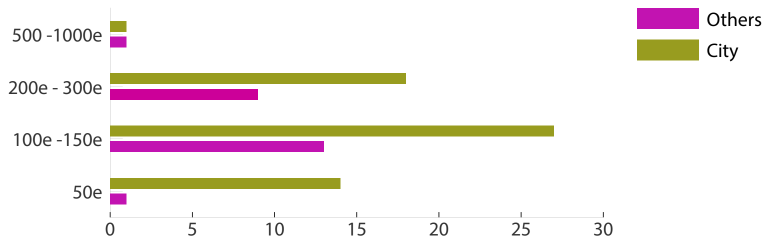


Figure 21. Price of the device detailed

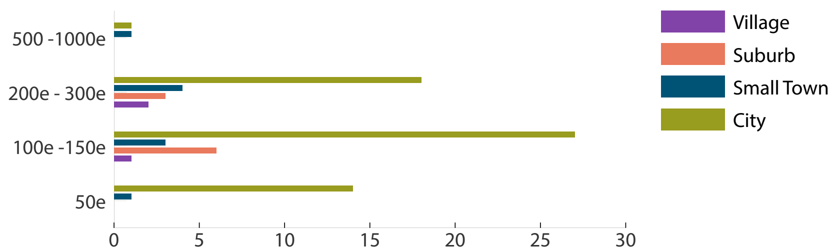


Figure 22. I am familiar with

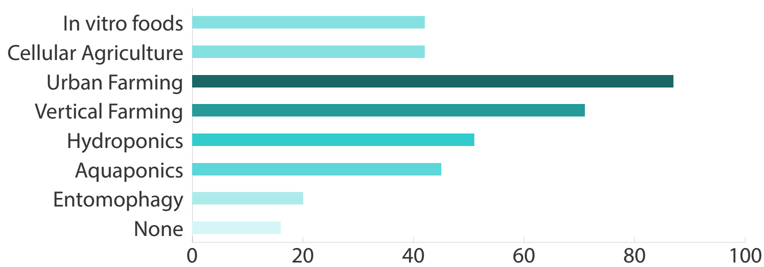
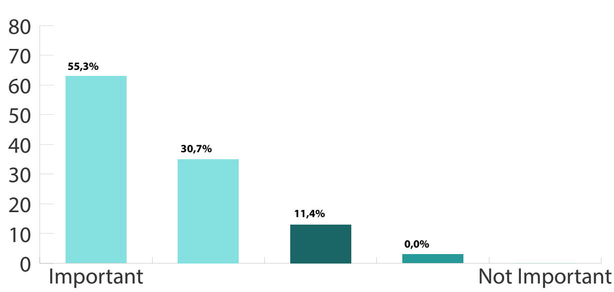


Figure 23. How important is it to you to know where the food comes from



5. CONCLUSIONS

5.1 ACHIEVING THE GOALS

The project achieved its goals and also gained much media attention. After the first media release by VTT, Home Bioreactor raised interest around the world. In addition, the project was noticed internally inside of VTT, picked as the one of the highlight projects of VTT, and also pitched in the Slush event. At this point the project had formed several contacts with companies from different industries. Further funding is still open and discussions continue.

5.2 ANSWERS TO THE RESEARCH QUESTIONS

This paper seeks to answer the research question how design can change reception of the novel food product innovation. In this case we need to first define what design means in this context. By design we mean reshaping the early prototype as well as the branding and the social media communication work. This work can stated to be a tough process that rethinks the cellular agriculture from the customer point of view. Defining and understanding a customer segment can be argued to be the core of this design research, the right targeting with the transparent communication between consumer and research team. The project was able to form a social platform that helped understand and define the future consumer group of the CellPod (consumer segment). By doing the surveys and qualitative development work we were able to find the audience that are enthusiastic about our project and who are somewhat part of the project.

The importance of the defined audience was discovered to affect the reception of the project. Because food is an unavoidable part of the human life, it is natural that it raise emotions. Food is more political now than ever and it reflects consumer beliefs (Ruokakulttuurin professori Johanna Mäkelä (Valto, n.d.). Food embodies our ways of seeing life and therefore it increases emotions among enthusiasts who have health, ecological or ethical concerns of living. Food choices of the consumer can be argued to be one of the small everyday things that the consumer can vote for her values. Sensitivity of the topic was one of the concerns that guided this project from its beginning. In contrast, the research group saw how other novel plant based food innovations like Bullet Oats, aka Nyhtökaura, and broad bean product Härkis had been positively received in the Finnish markets during their launch in 2016. The previously mentioned observations indicate that we are living in the times in which consumers are more open to the new food innovations, at least in the Finnish context. In the end it is a question of trust and how to create it.

One of the factors that affects this particular food innovation is location. According to the studies done in Europe, consumers in the Nordic context are more open to the novel food innovations, whereas the southern Europe tends to have more sceptic stances towards novel food innovations. Environment affects how we see technical innovations and how openly consumers accept them. In the Nordic climate people have strong traditions to trust innovations which have kept them alive in Nordic environment, in which the growth conditions of food have always been challenging.

The surveys done in this thesis also correspond to the argument that even the living density of the environment can affect acceptance of the new innovation. Urban environment seems to speak for acceptance towards new technical food innovations and that had been acknowledged in the product design process. In addition, the form of living (kids: yes/no) seemed to affect the interest level. Overall, the interest level was high with participants in Owela. Respondents who claimed to have children were only little less enthusiastic about the topic. The opinions about the unfinished design were also important design drivers during the process.

Overall, design has a great impact on the scientific innovations. The design work that is based on scientific innovation coming from a trusted source, such as VTT, can can become a global game changer. Design makes innovation more reachable and understandable. It is easier to provoke conversations about concrete examples and show how some innovation could be used instead of showing only the data of the scientific results. which also speaks from the hypothesis that design can affect to the reception of the innovation.

This project gathered plenty of interest from media globally. Even though the Owela project was made only in Finnish, there were requests to make the same in English. The project gained just little negative feedback what we believe is because of right positioning. (And because we were not focused on animal based cellular agriculture.) The study by (Füller, Mühlbacher, Matzler, & Jawecki, 2009) also shows that it is not beneficial to try to convince all the consumer groups; instead it is more reasonable to understand head users and early adopters in this group. In our case we used social media also for understanding this matter better by investigating discussions from various social media platforms. This gave us a quick look and brief understanding about the audience that we would like to receive. Because Cellular Agriculture is a new topic, online discussions about it were harder to find. Companies that worked under the theme were a good source for the benchmark process, specially responses that they had gained. During the process we also got noticed by other brands and their fans working in the field of novel food.

5.3 REVIEW OF THE PROJECT

The project started in early in summer 2016. At that time the term of Cellular Agriculture was new even among the project group. After including the designer into the project, the plans started obtain visual input that drive project forward. A visual input gave a common vision about the concept to the research group and helped communicate the ideas, even to outside of the group.

The fast prototyping methods were used through the project. A rapid prototype clarified the 3d form and gave a haptic feedback to the group. With the prototypes we were able to test our concept in the real environment, which made discovery of the challenges and design errors possible. In this project we did not solve all the faced problems, further more we gained clarified picture what to do in the next steps of the development work. The discussions with the targeted customer segment gave us wide feedback which gave us the possibility to pro-actively develop the concept. We mapped and positioned Home Bioreactor into the novel food market and in the end of the project, CellPod were mentioned by Forbes inside of "Ten Food Trends That Will Shape 2017" (Lempert, 2016). In that listing our design driven science project was placed on the same line with other other brands of the cellular agriculture which shows that our positioning has been successful in that matter.

In general, Co-design were used successfully inside to the research team. In addition to co-creation -platform Owela project took advantage from a Facebook page as a platform to enable low barrier interaction between the science group and the average enthusiasts. Via Facebook the project gained comments internationally and elaborate the picture about our customer segment, and their wishes and needs. Overall, social media discovered to be useful especially for communicating about the overall happenings about the topic. This platform gained real time feedback that promoted a natural transparency which believed to create the trust among enthusiasts that is seen as the crucial part to make new food innovation go through to the audience.

The project showed a power of the multidisciplinary work and the power of design. Well designed and communicated the project gather enthusiast and their comments. The right target group revealed the customer willingness to buy the product, which promotes the fact that there is a market for our innovation. The project also were noticed inside VTT and already gained interest of investors and few companies working around the topic of food, food production and kitchen appliance manufacture. In future development phases will show where the CellPod will take its direction and how soon cellular agriculture becomes normal part of the food production and more importantly production that happens locally in average households globally.

5.4 DISCUSSION

Cellular Agriculture will reshape our understanding of agriculture. The term established by the New Harvest research institute organisation that gather companies and people working in the field to gather. New ways to produce meat milk eggs leather and plant-based ingredients is the natural next step for humans who created agriculture (Harari, 2015). Concept of natural is changing because humans have always modified their environment. Species that you see in the farm do not exist in the nature, therefore it is easy to see cellular agriculture just the next step for humans to grow food. Maybe in future normal farms that we see today start to look primitive. In future meaning of farm can be something completely different.

We have started to notice that our actions have negative impacts for the environment. Our aim has been to try to shape the environment as human friendly as possible. On the global scale negative effects not necessarily show in places where the damage originates and that maybe makes us more blind to believe that our everyday actions actually can matter. We operate on a human scale and it is understandable that we can not see the bigger picture, but luckily we are curious species who can learn from our action.

Ironically we are living healthier lives that has led us to a growing and generally older population. This led us to the new challenges in food production. We need to produce more food to the growing population using less resources. Cities and agricultural areas are growing together forming new agurbian areas at the time people feel more detached from food production. Now cellular agriculture re defines and shapes what this food production could mean in future and also in urban environment. The Home Bioreactor gives everyone possibility to grow food in an urban setting and more efficient way than any other urban garden has allowed us to do. Plant Cell cultivation is refined version of urban gardens that are not limited by the space of natural light.

These new technologies are now providing interesting new possibilities to tackle global issues that the human population is now facing. In that sense we are living now in the interesting beginning of a new era of green economy where “the biology is the new digital” (Lederman, 2016).

5.5 MY PERSONAL PERCEPTION

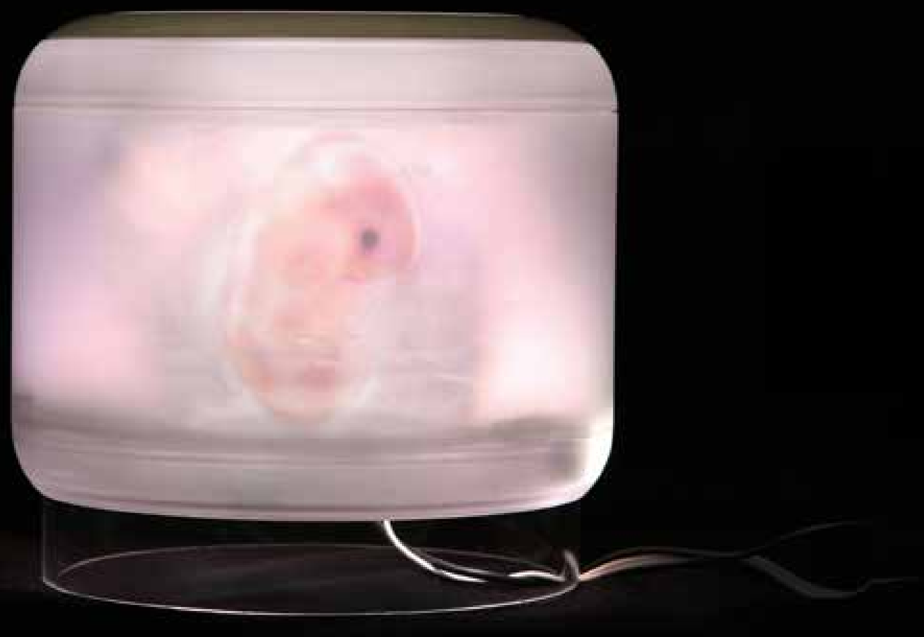
In the beginning of the project, I was completely unaware about plant cell cultures. When I was applying to the position in this project, I said when the topic was introduced that I was as excited about it as I am scared about the topic. When I got into the lab everything felt new and scary. However, once I had an opportunity to get to know the equipment functionality and was introduced to some working methods, the perception of that environment changed. The unknown became a known and I started to understand basic practices.

It was inspiring to begin to understand what cell culturing is and to realise that there is a name, cellular agriculture, for the practices that we were trying to conceptualise in the project and that there are other people who are also interested in this topic area. Later on, it was exciting to taste cell cultures and to hear people's reaction to this topic generally. During the project, I realised that it aims to reduce prejudice towards cellular agriculture among a wider audience as it had managed to do to me during the process. We will try to introduce the concept of cellular agriculture to the wider audience and make it more familiar and understandable. The device serves this purpose quite well.

When the final prototype was ready, I had it in my home for one-week on trial. During that week, I experienced what it would actually feel like to grow plant cells as food in ones own home. The device resembled something of an aquarium and made it more alive. The light emitted was pleasing and it looked like it belonged on the kitchen counter. As the cells grew inside, the culture started to resemble something of a virtual pet. It is not an aquarium, it is not an animal and it does not look like a traditional plant. Is the "home bioreactor" a new "computer"? Is the bioreactor something what a computer was decades ago? Something you will not find in every home in the past, but nowadays is prevalent and an indispensable part of everyday life for many people and their homes.

Even though the bioreactor was a prototype, it gave me a glimpse into an exciting future that this concept can lead to for consumers. It was easy to envision this kind of device as a centre of future home food production that would definitely empower some users, especially those who would like to be more self sufficient and health conscience. Personally, the idea of exchanging seed cultures or similar interactions with other bioreactor owners would be exiting. In the future, if we combine this technology together with smart sensors, it would enable us to code food and share them with other enthusiasts. Perhaps we need to change the way we perceive food before cellular agriculture can gain in popularity.

Before the week of home testing was over, I discovered that the cell bag had leaked and, as a result, the cell culture had been contaminated. In spite of the unsuccessful home cultivation, I was left eager to await where this kind of development will lead up to and I am definitely proud to have been a part of this development project. I strongly feel that we are at the starting line of an exciting new era of bioeconomy (***Picture 39.***).



Picture 39. *Design for debate*

DISCLAIMER

The information contained on www.thecellpod.com and www.facebook.com/TheCellPod websites were for study project purposes only and are no longer available. The CellPod name has only been used for non-commercial purposes and for the work described in this thesis. The CellPod name will be used only when referring the work done in this thesis. At the time of writing this thesis, the project in the process of selecting a new name for the home bioreactor. Until a new name is announced, the project will refer to the product and appliance category simply as Home Bioreactor.

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All images and figures taken or created by the author, except pictures listed below:

- ***Picture 3***. *Lauri Reuter*
- ***Picture 6***. *VTT*
- ***Picture 8***. *VTT*
- ***Picture 10***. *Apple maps: near Santa Maria do Oeste — Paraná*
- ***Picture 12***. *Heiko Rischer edit Niko Räty*
- ***Picture 19***. *Heiko Rischer edit Niko Räty*
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- ***Picture 29*** *Screen Shot http://owela.fi/?lang=en*
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- **Figures:**
- ***Figure 3***. *Huang & McDonald, 2012*
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- ***Figure 9***. *Jouni Ahtinen, recreated by Niko Räty*

APPENDIX

Appendix 1. Article, biotalous. fi

Appendix 2. Selected, clustered and characterised answers from Owela forum.

Appendix 3. Google Survey and automatically analysed data from the survey.

Appendix 1

FUTURE FOOD FROM YOUR KITCHEN TABLE

Forget the shrivelled basils! How about a cloudberry or arctic bramble-smoothie with fresh ingredients grown on your kitchen table in a gadget that resembles a design lamp? Time for superlocal food!

The gadget is CellPod and it grows plant cells. The CellPod-concept was developed in the VTT Technical Research Centre of Finland. CellPod reaches out boldly into the future and formulates visions for tomorrow's food, together with the consumer.

The next big leap: we'll only grow the best parts of plants

Humans have bred crops for thousands of years. The plants have become more productive and fruits larger and more suitable for human consumption. The green revolution, that started in the sixties, revolutionised agriculture with machinery and efficient fertilisers. CellPod introduces the next great leap – instead of an entire plant we'll only grow its best parts.

A design model of CellPod. (Picture: Niko Räty)

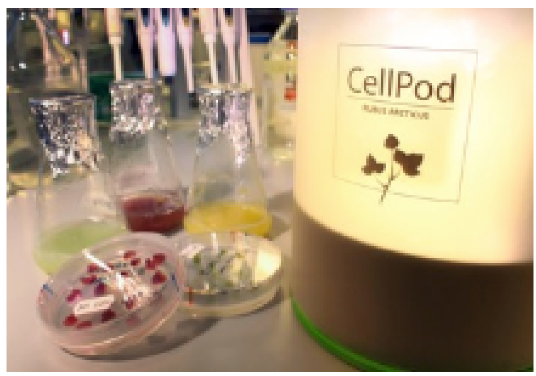
CellPod is based on the idea of plant cell plantations that consist of undifferentiated cells where the whole genetic potential of the plant is retained. These kinds of cells can produce the same nutritionally important compounds as the whole plant – such as antioxidants and vitamins.

Increasing urbanisation creates even greater pressure to produce at least some of our food in the urban environment. Producing food where it is consumed reduces the need for transportation and is more ecological. Today urban farming is developed especially in large metropolises. But the trend is clear here in Finland as well. For example a mushroom farm is built at Hernesaari, Helsinki, and sprout salads are grown in a semi-underground space in Vantaa. Fully automated greenhouses are built in industrial halls and basements around the world.

Urban consumers want to be more in touch with the origin of their food. CellPoc brings food production to home kitchens in a new and exciting way. The home cultivation of plant cells doesn't replace agriculture but it can provide a good addition to future diets.

CellPod is the first cell plant device for domestic use

Plant cells have been grown in bioreactors under laboratory conditions for decades. Now a number of inventions enable the development of much simpler growing devices. With CellPod anyone can grow plant cells at home. Buy a capsule of plant cells of your choice and put them in your device. Just add water and flick the switch.

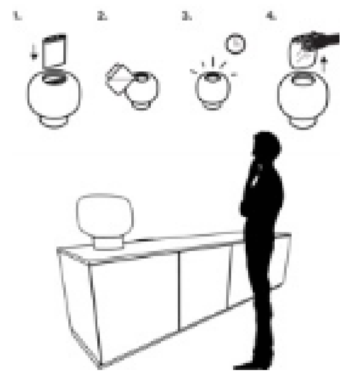


A CellPod prototype. (Photo: Lauri Reute

Cellpod creates ideal growing conditions for plant cells which are ready to harvest in about a week. The first 3D printed prototype is bubbling in VTT's plar biotechnology laboratory and research on the product ideas around the concer is underway.

New kind of food from the northern natural resources

The CellPod concept enables a totally new way of taking advantage of the diversity of the northern nature. Cells from e.g. arctic bramble, cloudberry and stone bramble are collected from VTT's extensive collection of strains. In cell cultivation even plants not traditionally used for food become potential healthy food. In future, you might even have birch for breakfast!



(Picture: Niko Räty

Plant cell cultivation enables the development of completely new types of design cells. When the actual plant physiology is no longer a constraint, it is possible to design cell cultures tailored to nutritional needs. The growing conditions, such as light, heat, and various signal molecules, also affect the compounds the plant cells produce – just like in nature. The more of these factors we know, the better we can influence the kind of food we can produce i the future.

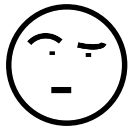
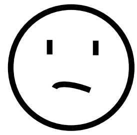
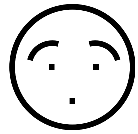
The future is designed in co-operation with the consumer

Food related new technologies generate a great deal of enthusiasm, but also suspicion and doubt. Food produced by the cell cultivation technique is unlikely to be an exception. Therefore the CellPod concept has been developed from start together with the consumer on VTT's open innovation platform Owela. Trough Owela everyone interested in CellPod, or other new cell culture-based methods of food production, was able to participate in the discussion and the development of the concept. The project can also be followed on Facebook an the project website www.TheCellPod.com.

The CellPod-concept is developed as part of VTT's Innovative Business of the Emerging Technologies (iBET) project. The target of iBET projects is to refine innovative future technologies from fresh new ideas generated at VTT.

*Written by **Niko Räty** and **Lauri Reuter** from the VTT Technical Research Centre of plant biotechnology group. Niko Räty is the designer who is working on his master's project at Aalto University's Creative Sustainability programme. Lauri Reuter is a researcher whose dissertation focuses on plant cells as protein-producing cell factories.*

DIFFERENT VIEWS

	Sceptic	Fearful	Suspicious
First impressions:	*I am cynical and really doubting this. Artificial, but perhaps bilberry would be interesting, bilberry soup costs only one euro in the store so…*	*Food should always taste good. My first impression is doubtful.*	*I'm an active food person, so I'm not interested in taking vitamins from a can or nutrition from a cell culture, if it's only function is to satisfy the need for food. Is this so called raw food or can it be used for cooking?*
Would you like to buy plant cells as ready product or would you rather grow your own plant cells?	*Somebody would more likely do it for me… But if it would be cheaper than vegetables at a grocery store I could re think about it. I will buy my vegetables from a shop that grow them at home in any form.*	*I am not interested of the growing or even buying*	*I would like to try growing. But I still don't understand if this is supposed to be so called raw food for cooking, or are these supposed to be ready meals. I am interested in the cooking abilities of this. If they are food supplements then my interest dramatically decreases. Of course this way they could be valuable for example to feed patients who are bedridden.*
What would you think about Finnish Orange juice that would be produced from plant cells that are grown in Finland, or how about home grown arctic bramble or birch as a drink?	*"Sab 2.0" from birch tree, again we are creating something "new" I am not interested about ecology or where food is from whatsoever. I am only interested about the price of food. I am more likely to do a group exercise than have any sort of "gardening" as my hobby.*	*Oh no, It would be scary to even drink that kind of thing.*	*If the outcome would be something like in the pictures then I wouldn't be interested even in the more rare things like arctic bramble. I'd get the feeling of this being artificial and industrial, that you'd be eating something artificially made substitute product. I'd rather find the real berries and eat them. But if you can actually grow the berries, then I would be interested.*

<table>
<tr><th colspan="4">Positive</th></tr>
<tr><td>I'm not interested in cooking, so it would be convenient to get a full meal from just a few spoonfuls of plant cells.</td><td>This is very interesting - is the nutritional value the same for cell culturing as it is picking from nature? Kitchens should be re-organized for different kinds of cell cultures...maybe some could even be grown in balconies.</td><td>I'm not that interested in growing things (I don't even have plants), but it is interesting that you could grow only the part of a plant that you need.</td><td>Healthiness, nutrition ja taste.</td></tr>
<tr><td colspan="2">I'd like to grow them myself. Maybe I'd buy a ready product the first time. If it tasted good, I'd grow my own food myself.</td><td colspan="2">I'd buy, especially if the price would be affordable when you can focus on growing the necessary part and you wouldn't have to pay for a part of a plant you don't need.</td></tr>
<tr><td>As long as the mush doesn't look disgusting.</td><td></td><td>I could try it - does this method allow people to start their own cell cultures tailored to my own needs?</td><td>Sound like fun! Does this mean you could grow anything in Finnish climate?</td></tr>
</table>

	Sceptic	**Fearful**	**Suspicious**
How you would feel about the possibility to customize plant cells that you could grow for food?	*If some machine or application would define my eating, no thanks.*	*Cell cultured food should be healthy. The taste should be in line with the appearance. So no raspberry flavored orange looking plants.*	*Can you get fibers in these cell cultures too? Where do the colors come from? First you eat something tailored to yourself super healthy cell culture mush. Then you get cravings, you eat mush and drink beer. Humans have the tendency to self deceit, that's why I don't believe in tailored nutritional values when talking about a healthy person. To a sick person, for example someone bedridden tailored nutritional values can be a really good thing, especially if the product is filled with nutrition, so a small amount would equal the nutritional need. The taste would of course have to be first class in this instance. In addition humans teeth need work through humans life, so would it be possible to get something to chew on and different kinds of textures for the mouth?*
Would you see the CellPod machine in your home in 2020?	*Again if the price would be competitive, then why not. But I am 99% sure that this is pricey, so no thank you.*	*It looks pretty so it would fit well, but I wouldn't dare to eat them.*	*Has this machine already been manufactured? Is it still in the prototype stage? When will it be produced? I'm not interested in watching something bubbling, I'd rather hope that the culturing could be done somewhere hidden from view. I would never put the machine in my living room or on the balcony. In the kitchen there's already too little space, so no more appliances to take up space, thank you. There should be another way.*

Positive	
What is the sufficient cell cultured nutrition amount and the amount to uphold and advance health?	*I need to continue here a discussion started in a another chain that talked about shaping the plant cells. I'd definitely be interested in growing something suited for me like allergen free vegetables, if they weren't otherwise available. I would even pay extra for them.*
I would do it sooner!	*If the allergens could be reduced, I'd be really happy. Otherwise wouldn't be interested, but I would grow allergen free vegetables.*

	Sceptic	**Fearful**	**Suspicious**
How about multifunctionality? What features you would like to include to the future appliance and what should be taken into consideration in the development process of the future product?	*Price, functionality and marketing? I am afraid that this invention is tried to be sold for the people who do not understand anything about it and also for people who do not really need this device.*	*I think that in the finished product there should be a special health aspect, something that speaks to people. I find it hard to believe, that an everyday family would take up growing these, at least not in the countryside or smaller cities.* *The most important criterion for buying food are 1) the price 2) how much time it takes 3) will the kids eat it. So the food being healthy doesn't even make it to top 3. There could be interested in people who fall into this because of their life views. There have been many easy gadgets for cooking in the past that have been forgotten pretty soon. What would be that main reason for cell culturing? Do you get health, saving money, saving time, new tastes, or something in exchange?*	
Would you be interested in ordering CellPod home bioreactor as service that would conform to your lifestyle changes?	*Price? Warranty? Care?*	*Care services would fit well into this. I think though that I would want it to cover more than just this one thing in my home.*	*It's hard to predict how consumers would react and what would be the right marketing argument. (renting for me doesn't feel better, because even the idea seems difficult with returns and etc. Would rather buy it.*
	I would wish that real people could do that one and only real pea soup, without anything extra nonsense. *If we only could focus on to the basic things, like example how children are eating and what kind of role models they are getting in their own homes. Back to basics.*		

<table>
<tr><th colspan="4">Positive</th></tr>
<tr>
<td>There are great ideas here. I would say seedbeds too, something that can be stacked on top of others. I’d probably have to design my kitchen shelves and cabinets again to be able to fit all the different cell cultures. The size, shape, quantity, efficiency, price etc. of the seedbeds. I’m interested in minimizing the size of a healthy meal, increasing wellbeing and diversity….and in my own kitchen no less.</td>
<td>Can the machine be placed in a cupboard or does it need sunlight or artificial light? The machine looks okay, but I wouldn’t want to keep it on display.
The durability, design, size and price.</td>
<td colspan="2">Generally speaking with modularity you would achieve more “output” per house, and if the client wants to grow more food, stacking more modules would enable that. I as a potential client and a designer don’t get excited about a functional product if it’s build to work as an individual unit, because in the world today we are striving to optimize and make intelligent network structures. Build a functional and stylish product from the core level. Not art, design.</td>
</tr>
<tr>
<td>If the machine would be pretty and it could be used as decoration, I could rent one as a full service. Repair service would be a must, that would create more jobs too.</td>
<td>The warranty and care must be in order, as well as functionality at home. Then I would be ready to get this product. It’s interesting either way.</td>
<td>If it would be affordable and short term (like 1 month at a time). It would also be great if the machine had home delivery and pick-up service.</td>
<td>Modularity. For example to be able to stack the seedbeds, and move them for emptying and filling? This would make it possible to commercialise effectively? For example to be able to get seedbeds like 1 a month depending on need and funds, or borrow them to a friend or family to try before buying?</td>
</tr>
<tr>
<td colspan="2">The price of the cell capsules would change between the ingredient and the duration of the process. In the bean capsules (like chickpea capsules) have the affection of air in the stomach been removed, the taste and health affect remaining the same, if so I’d be ready to pay more for them that naturally grown chickpeas. If the properties of the cell capsules have been improved and developed, then it would be kind of like a new ingredient, this kind of capsule would probably cost more than naturally grown ingredient.</td>
<td colspan="2">The shelf life of the cell culture - fresh food every day - or weeks worth of food at once stays fresh. Do you move ready cell cultured food in the fridge? Can you use the same seedbed to culture different cells or does every ingredient need its own seedbed? I would happily culture cells in my own kitchen or balcony, depending on the need for warmth, light and even moisture and water.</td>
</tr>
</table>

Appendix 3

The CellPod survey

By participating in this survey you will help us to develop the CellPod-concept further and Niko to finalize his thesis. We really appreciate your time. Thanks!

Background

1. **Age** *
   Mark only one oval.
   - 18-25
   - 26-35
   - 36-45
   - 46-55
   - 56-60+

2. **Living in** *
   Mark only one oval.
   - Countryside
   - Village
   - Suburb
   - Small Town
   - City

3. **Country**

4. **Kids?** *
   Mark only one oval.
   - Yes
   - No

5. **I am familiar with**
   (select all you know)
   Check all that apply.
   - In vitro foods
   - Cellular agriculture
   - Urban farming
   - Vertical farming
   - Hydroponics
   - Aquaponics
   - Entomophagy
   - None

Plant cells as food

6. **Plant cells as food is** *
   Mark only one oval.
   - A scary idea
   - Suspicious
   - Delicious
   - An inspiring idea
   - Sustainable
   - The future
   - I don't know what it is
   - Other:

7. **I could imagine using plant cells...**
   Check all that apply.
   - In a smoothie
   - Fresh in my yoghurt
   - As an ingredient in a snackbar
   - As a dietary supplement
   - In baking
   - Other:

8. **Growing plant cells for food is interesting bec**
   Check all that apply.
   - Technical innovations are interesting in gene
   - I want to be at the forefront of development
   - It is a new way of producing food
   - Because of new flavors
   - Positive impacts to the environment
   - It is an interesting concept
   - Because of healthy compounds
   - Nope. Not interested at all!
   - Other:

8. **Growing plant cells for food is interesting because**
   Check all that apply.
   - Technical innovations are interesting in general
   - I want to be at the forefront of development
   - It is a new way of producing food
   - Because of new flavors
   - Positive impacts to the environment
   - It is an interesting concept
   - Because of healthy compounds
   - Nope. Not interested at all!
   - Other:

9. **I would NOT try growing plant cells at home because**
   Check all that apply.
   - I don't trust technical innovations in general
   - I want some one else to try it first
   - I´m not sure if the plant cells are safe to eat
   - I'm afraid of negative impacts to the enviorment
   - It's just not interesting enough
   - I don´t want to mess with the nature
   - What do you mean? I totally would!
   - Other:

The future of food. What is important?

Think about the future. What are the most important aspects?

10. **Production of healthy compounds** *

Mark only one oval.

	1	2	3	4	5	
Not important	◯	◯	◯	◯	◯	Very important

11. **Active role of the consumer in the food chain** *

Mark only one oval.

	1	2	3	4	5	
Not important	◯	◯	◯	◯	◯	Very important

12. **Knowing where the food comes from** *

Mark only one oval.

	1	2	3	4	5	
Not important	◯	◯	◯	◯	◯	Very important

13. **Self-sufficiency** *

Mark only one oval.

	1	2	3	4	5	
Not important	◯	◯	◯	◯	◯	Very important

14. **Circular economy (resource efficiency)** *

Mark only one oval.

	1	2	3	4	5	
Not important	◯	◯	◯	◯	◯	Very important

15. **Easy access (delivery)** *

Mark only one oval.

	1	2	3	4	5	
Not important	◯	◯	◯	◯	◯	Very important

16. **Low impact on the environment** *

Mark only one oval.

	1	2	3	4	5	
Not important	◯	◯	◯	◯	◯	Very important

17. **What would be the right price of the cell culture starter kits (capsules) that can produce 500g of plant cell ingredients?**

Mark only one oval.

◯ 5e - 10e
◯ 10 -15e
◯ 20e - 25e
◯ 30e - 35e
◯ 40 - 50e
◯ I don't care about the price
◯ Other: ____________________

he future kitchen appliance

ink about your needs. What do you find important?

8. **Possibility to add or remove features (Modularity)** *

Mark only one oval.

	1	2	3	4	5	
Not important	◯	◯	◯	◯	◯	Very important

9. **Multi-functional devices** *

Mark only one oval.

	1	2	3	4	5	
Not important	◯	◯	◯	◯	◯	Very important

0. **Movable appliances** *

Appliance that can be moved to different loactions

Mark only one oval.

	1	2	3	4	5	
Not important	◯	◯	◯	◯	◯	Very important

1. **Small size of the appliances** *

Mark only one oval.

	1	2	3	4	5	
Not important	◯	◯	◯	◯	◯	Very important

2. **Devices integrated to kitchen** *

Mark only one oval.

	1	2	3	4	5	
Not important	◯	◯	◯	◯	◯	Very important

23. **What would be price of the device?**

Mark only one oval.

- ◯ 50e
- ◯ 100e -150e
- ◯ 200e - 300e
- ◯ 300e - 400e
- ◯ 500 -1000e
- ◯ I don't care about the price
- ◯ Other: ____________________

Appliances as service

Music, movies and transportation are increasingly consumed as services.

24. **In the future, do you want to own your appliances?**

Mark only one oval.

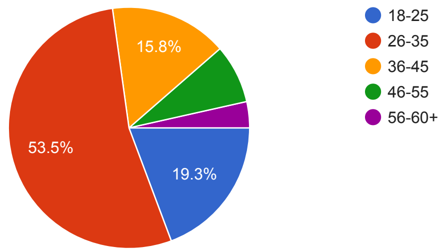
	1	2	3	4	5	
I want to own it!	◯	◯	◯	◯	◯	I don´t want to own it, but use it as a service.

The CellPod survey

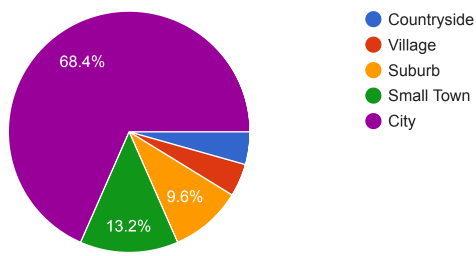
114 responses

Background

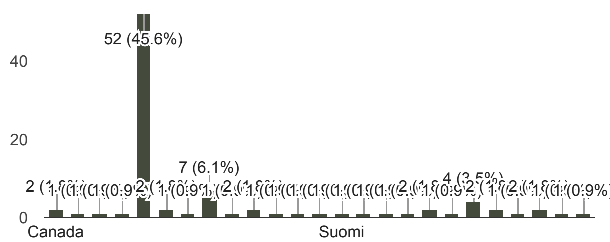
Age (114 responses)



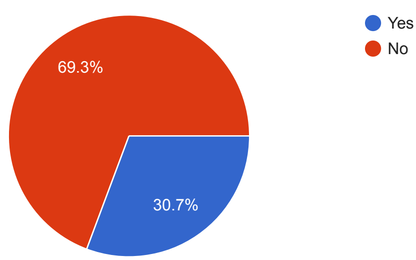
Living in (114 responses)

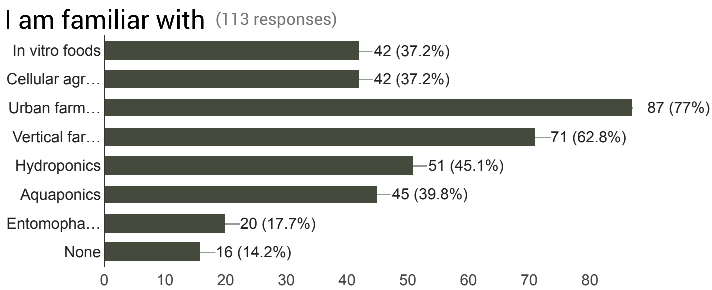


Country (91 responses)

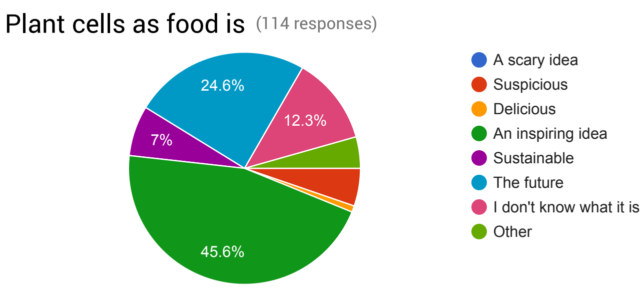


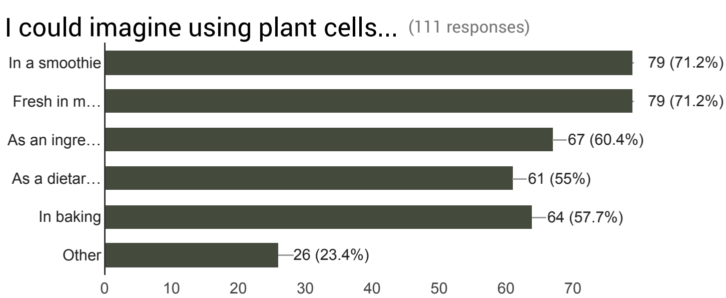
Kids? (114 responses)

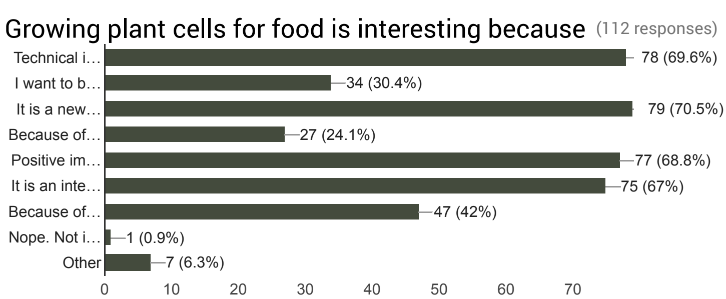


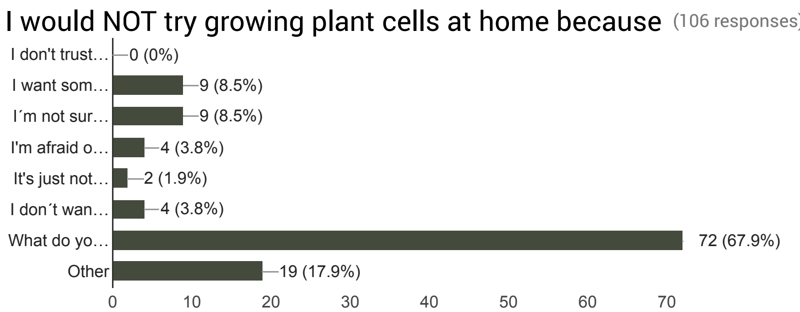


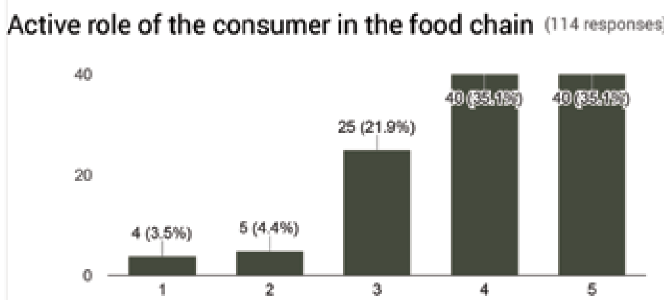
Plant cells as food

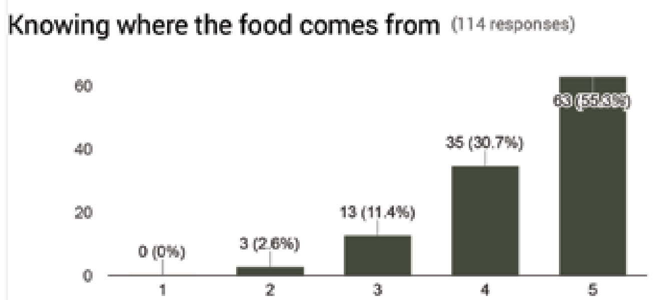


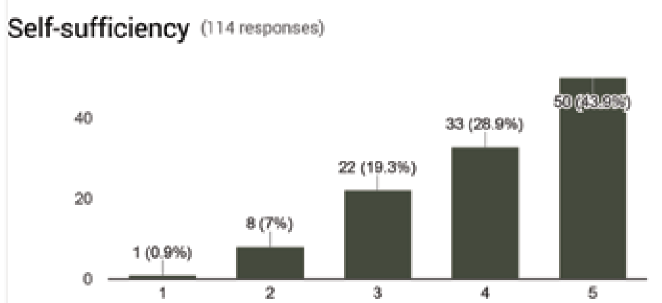




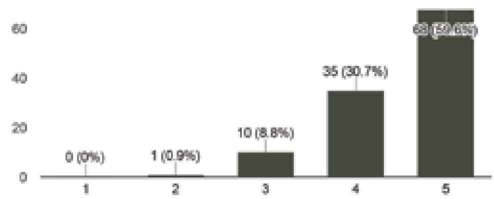

I would NOT try growing plant cells at home because (106 responses)
I don't trust…
I want som…
I´m not sur…
I'm afraid o…
It's just not…
I don´t wan…
What do yo…
Other
0 (0%)
9 (8.5%)
9 (8.5%)
4 (3.8%)
2 (1.9%)
4 (3.8%)
72 (67.9%)
19 (17.9%)
0
10
20
30
40
50
60
70


Active role of the consumer in the food chain (114 responses)
40
20
0
4 (3.5%)
5 (4.4%)
25 (21.9%)
40 (35.1%)
40 (35.1%)
1
2
3
4
5

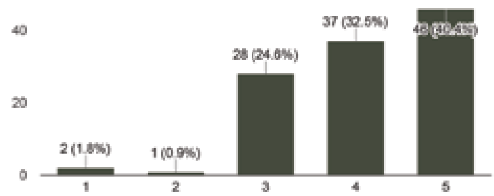

Knowing where the food comes from (114 responses)
60
40
20
0
0 (0%)
3 (2.6%)
13 (11.4%)
35 (30.7%)
63 (55.3%)
1
2
3
4
5


Self-sufficiency (114 responses)
40
20
0
1 (0.9%)
8 (7%)
22 (19.3%)
33 (28.9%)
50 (43.9%)
1
2
3
4
5

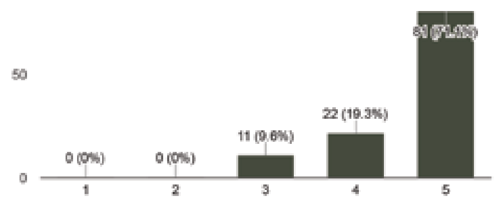
Circular economy (resource efficiency) (114 responses)



Easy access (delivery) (114 responses)

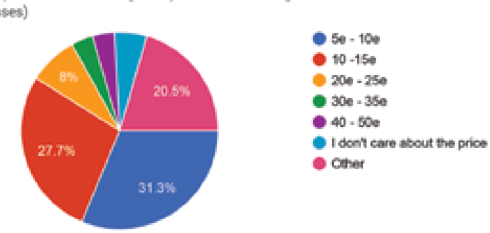


Low impact on the environment (114 responses)



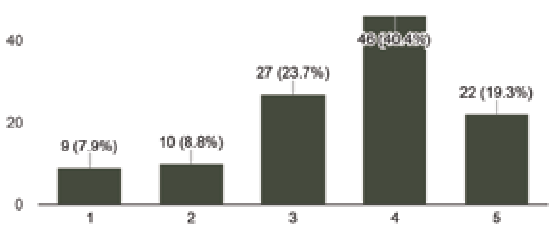
What would be the right price of the cell culture starter kits (cap that can produce 500g of plant cell ingredients?

(112 responses)

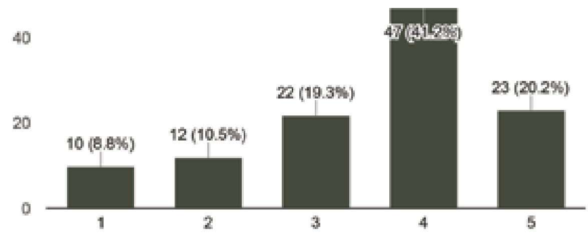


The future kitchen appliance

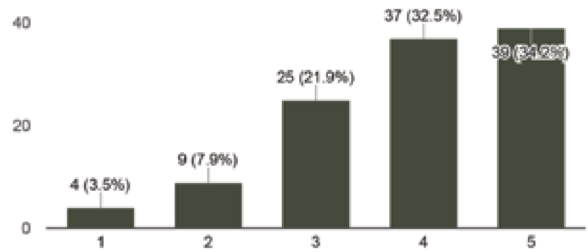
Possibility to add or remove features (Modularity) (114 responses)



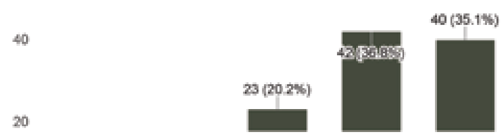
Multi-functional devices (114 responses)



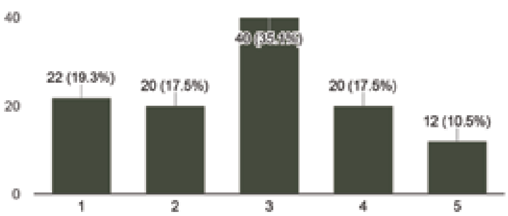
Movable appliances (114 responses)



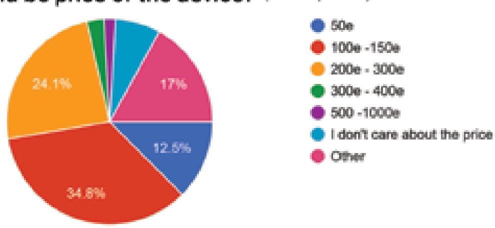
Small size of the appliances (114 responses)



Devices integrated to kitchen (114 responses)



What would be price of the device? (112 responses)



MEDIA LINKS

- *http://www.vtt.fi/medialle/uutiset/uudenlainen-l%C3%A4hiruoka-kasvaa-omassa-keitti%C3%B6ss%C3%A4*

- *http://www.biotalous.fi/cellpod-kasvattaa-tulevaisuuden-avaruusruokaa-kotonasi/*

- *http://yle.fi/uutiset/3-9446757*

- *http://www.hs.fi/kotimaa/art-2000002926183.html*

- *http://www.hs.fi/nyt/art-2000005009198.html*

- *http://acs.aalto.fi/swd/cellpod-re-think-urban-farming/*

- *https://www.forbes.com/sites/phillempert/2016/12/14/the-supermarketgurus-2017-food-trend-forecast/print/*

- *http://www.designmuseum.fi/en/exhibitions/enter_and_encounter-2/*

Videos

- *http://makingoftomorrow.com/3d-printed-china-set-and-a-bioreactor-in-our-own-kitchen/?utm_campaign=589ad72cd4dbac372702739b&utm_content=58c15216ce0efa79250001c3&utm_medium=smarpshare&utm_source=generic*

- *https://www.katsomo.fi/#!/jakso/33006223/olipa-kerran-elama/719402/sini-merikallio-rakel-liekki-ja-essi-hellen*

- *http://areena.yle.fi/1-3260120*

- *https://www.youtube.com/watch?v=oacfNXH2aGY*

- *http://www.reuters.com/video/2016/11/07/grow-food-at-home-from-plant-cells?videoId=370384760&videoChannel=118065&channelName=Moments+of+Innovation*

VTT

- *http://culturecollection.vtt.fi/*

- *https://vttindustrialbiotechnology.com/tag/plant-cell-cultures/*

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School of Arts, Design
and Architecture