INTRODUCTION

A few years ago the idea of the printed food on demand seemed very distant or even abstract, taken from science fiction films or associated with space missions. However, changes in this area occur very quickly. Nowadays, thanks to 3D printing technology both food and packaging can be printed.

The PERFORMANCE project (Development of Personalised food using Rapid Manufacturing for the nutrition of elderly Consumers) is currently one of the more important initiatives in this respect. It involves development of technologies for 3D printed food and was finalized in October of 2015. The Performance concept requires further development in order to be fully introduced to commercialization, but the products developed during the project will be commercialized as standalone solutions. 3D printed meals are designed for older people who have difficulty swallowing and chewing (1). 15-25% of elderly people suffer from problems with swallowing, which makes it necessary to look for the techniques to adapt the food. Food in the pure or pre-frayed form is a good option, but often does not look too appetizing and attractive. New printed products with a proper consistency and attractive design that imitate the traditional meals may be a solution (2).

Extensive research is also conducted in the field of food printing for space missions. Powders for printing used by NASA have best before dates of 30 years (3). Another potential purpose of 3D printing is the food sent to third world countries. Fresh food is unfortunately prone to fast degradation, but specially prepared for printing “cartridges” can have a much longer shelf life and selected nutritional compositions.

It is hard to predict how the market will accept 3D printing. Meanwhile, the pace of development and of course the price depends on the interest of consumers and their acceptance of new inventions. However, the 3D printer that you can buy for the household, is already available on the market. For the time being only simple things can be printed, such as the compositions of up to several components. Multimaterial printing is still in the early stages of development (1, 4-5). Engineers will need to spend a lot of time and work before one could print out a whole hamburger with all its ingredients and taste (4). However, work is in progress and the number of researchers interested in the subject is growing.

3D FOOD PRINTING TECHNOLOGIES

3D printing (3DP) is a process for producing physical, three-dimensional objects based on a computer model. The model is created in the program for graphic engineering (CAD) in the form of STL files. Initially, 3D printing was applied for rapid prototyping, but now with the development of technology it is also used for manufacturing final objects. 3D printing is young, its origins date goes back to the eighties of the twentieth century, when Charles Hull developed a Stereolithography (SLA). After that another techniques developed rapidly, for example Fused Deposition Modelling (FDM) or Selective Laser Sintering (SLS) (6-7). The basic materials in 3D printing are different kinds of plastic, but also metal, resins, rubber, concrete, paper and composites, ex. wood and plastic, plastic and plaster, as well as chocolate and other food components.
Additive Manufacturing (AM) also known as Solid Freeform Fabrication (SFF) or 3D Printing can be used in food printing, as well as in other three-dimensional objects printing. AM is a technology that build objects by adding layer-upon-layer of materials. It reduces down time, the capacity utilisation and overall operation costs (8). Three-dimensional food printing is also known as Food Layered Manufacturing (FLM) (9). Not only nutritional value and taste are important in the food, but also its appearance. We would eat something with relish if it looked attractive, the same ingredients in an unsightly form would taste significantly worse. With 3D printing, you can design and create new forms of food so far inaccessibly difficult to prepare, among others openwork spatial solids, a variety of geometric figures, carved ornaments or food logo.

In the printing process of food, it is important that the layer has sufficient strength to maintain its own weight as another layer without significant deformation and change of shape. Heat from the laser, hot air, heating element, or sprayed binder or solvent may be used for fusing and joining layers. Powder can be sintered or molten or the material can be extruded. 3D printing is to convert food in a semi-liquid, pure or powder form to normal food form. Part of the food after the printing process requires further processing such as cooking, baking or frying (8).

3D printing allows us to prepare meals with the same appearance, but with different nutritional value depending on the individual characteristics of the person for whom they are prepared. Knowing biometric data and health status, it is possible to prepare personalized meals (3-4). Furthermore, there is a growing need to personalize products on the market for some time. The stores increasingly have separate shelves with gluten-free, sugar-free, lactose-free, organic or bio foods, etc. (10).

The following technologies are applicable to food 3D printing:
- fused deposition manufacturing (hot melt extrusion),
- selective sintering technology,
- powder bed binder jetting,
- ink-jet printing (2).

Fused deposition manufacturing involves applying material extruded from the nozzle layer-by-layer, and the nozzle may be heated. This technique is the most applicable for 3D chocolate printing, although other materials may be used. The extruded material is heated slightly above its melting temperature, to allow quick and easy cooling when combined with the previous layer. This is the technology most widely used for three-dimensional food printing. This type of printer can be equipped with one or more extruders, which enables simultaneous printing of several components. Also dual-feed extruder may be used, which makes it possible to obtain a third colour by an extrusion in correct proportions of two materials with different colours (7).

Selective sintering technology is based on melting together the particles of powder layer-by-layer. The most common shapes are formed from sugar or powder rich in sugars. A very thin layer of powder is applied evenly on the bed, and with a heat source, which may be a laser or hot air moving along the x and y axes; the particles are melted and sintered together. The substrate is slightly lowered and another layer of powder is applied and sintered in an analogous manner. The process of applying the powder and sintering is repeated to form the final product, which is then purified from unfixed powder. Excess powder during the process was a structural support. It is a technology that does not require post-processes.

Powder bed jetting binder involves applying uniform layer of powder and combining it using a liquid binder sprays. As in the case of selective sintering technology, the process is repeated until the final product, and excess powder is removed. However, unlike the first technology, a finishing process may be required, involving additional curing and improvement of the connection layers. Ink-jet printing technology used in the food printing is similar to the traditional one used to print e.g. books, booklets, labels in the industry, or ink-jet printers used at home or office, with the difference that instead of the printing ink, the edible ink is used. The print heads working in drop-on-demand technologies are used (2, 7).

**MAJOR FOOD COMPONENTS**

FOOD COMPONENTS FOR 3D food printing are solid or semi-solid for extrusion or in the form of powders. Chocolate is an interesting, commonly used material, creating great opportunities in the market of personalized products. The 3D chocolate printing technology was developed at the University of Exeter and is a quite well known material (11-12). Frosting, cheese (13) and ice cream (7) are beside chocolate other food components used for 3D printing which do not require any finishing processing.

Components for food printing are divided into three categories:
- natively printable materials,
- non-printable traditional food materials,
- alternative ingredients (2).

In the first group there are mainly materials directly extruded from a syringe, such as chocolate, icing, hydrogel, cheese, hummus, pasta dough, butter, jelly, etc. However, these include also the materials in the form of powder, such as sugar, starch, etc. Non-printable traditional food materials include meat, rice, vegetables and fruits. In order to make them suitable for extrusion used in 3D printing, the hydrocolloids are added to these. Xanthan gum and gelatine are examples of commonly used hydrocolloids. Insect powder may be an alternative additive, which was studied as a protein source to replace traditional meat (2, 14-15).

An important point in food is mouth feels and its perceptible texture. Different amount of hydrocolloids allows to change the perception of food from smooth to granular and from hard to soft (14). People (13) believe that printable food material must be compatible with traditional techniques of cooking (boiling, baking or frying). Traditional foods like turkey, celery and scallops after grinding and modifying by additives (agar for vegetables and transglutaminase for meat) can be successfully 3D printed and subjected to various processing steps.

The viscosity, consistency and solidifying are the properties that determined the printability of food components.

**PRINTERS AVAILABLE ON THE MARKET AND FUTURE PROJECTS**

Commercially available 3D printers are becoming available on the market, although as with any technological innovations, their price is still a little bit high. In 2012, the first commercially available 3D chocolate printer was launched officially to the market by a company the Choc Edge.
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INVITATION

- Gluten Free
- Lactose Free
- Dairy Free
- Yeast Free
- Wheat Free
- Vegan
- Fat Free
- Nut Free
- Soy Free
- Salt Free
- GM Free
- Egg free
- No Sugar
- No Additives
- No Preservatives
- ...and many more

- Vitamins
- Food Supplements
- Nutritional Supplements
- Protein Supplements
- Protein Snacks
- Carbohydrate Shakes
- Nutritions
- Sports Nutrition, Gels & Powder
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- Amino Acids
- Omega 3
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Device called Choc Creator works in FDM technology and creates 3D edible chocolate models. Melted and heated in the syringe, the chocolate is applied layer by layer to obtain the final product. Since then, new models were introduced by this and other companies. For example an improved model of the device is currently available on the market, more reliable and easier to use. Its price is £ 2,380 [16-17].

Power WASP EVO is also dedicated to chocolate printing. This is a printer at a price less than £ 1,000. Tests are carried out on the use of other food components for printing on this printer (18-19).

Another device for liquid mass extruding is Zmorph cake and chocolate extruder. It is a very simple and cheap solution (less than £ 350). It can be used in decorating cakes. It can produce three-dimensional ornamental designs to an existing product [18-19].

Another printer, currently in prototype phase, XYZPrinting food printer should be available on the market in the second quarter of 2015 (the launched date has since been postponed). Its price was projected at around $ 2,000 [20-21].

ChefJet series printers also were to be available around the same time as food XYZPrinting printers. Depending on the model their price was projected to be about $ 1,000 for monochrome printer and about $ 5,000 for a multi-coloured one (22). When they were finally introduced to the market, they turned out to be more expensive than expected. Relatively high price compared to other printers available may result from different technology (sintering), and is the first commercially available professional 3D printer able to create three-dimensional edible creations with sugar with such high level of complexity. Printed products may have different flavours, such as chocolate, vanilla, mint, apple, watermelon or cherries.

Another sample of selective sintering technology which is dedicated to building 3D prototypes from sugar is CandyFab 3D printer. However, it is not designed for printing edible items [14, 16]. In addition to printers dedicated to chocolate, confectionery products and sweets, there are printers designed for other food components available on the market. Fab@Home 3D printer is a multihread printer and can print using a wide range of materials – the only limit is the ability to place food components in the syringe [2, 4, 14, 23].

Another example is a Bocusini 3D food printing system, which is a simple, economical printer, that can be ordered now, and received after the shipping starting in March 2016. Earlier prototypes have been sold. The company offers thirty different cartridges with different products: sugar, chocolate, sweet jellies, pastries and marzipan, cheese, mashed potatoes and vegetables, as well as ground meat. In addition to products in the form of flowers and figures, the printer can create patterns and inscriptions on user’s request. The cost of the printer is less than € 1,200 [24-25]. At the beginning of the year the presale of Foodini printer produced by Natural Machines is also planned. The expected price is approximately $ 1,500. The machine will offer the possibility to apply a variety of products such as meat, pasta, chocolate, cake or mixed fruit. The printer is equipped with a 5 capsules that are filled with printed material (18, 26).

These 3D printers are not yet widespread digital gastronomy, but perhaps just the beginning of changes that will occur in our kitchen. However, future changes will probably not be limited to new ways of preparing food, but also will include new food components used to prepare meals. This is what for example Ikea started to look into. 3D printing creates for example the possibility of replacing meat protein in a diet by a protein acquired from raw materials, such as beet leaves and insects, which now not widely used due to our eating habits or a feeling of disgust [27].

**ADVANTAGES OF 3D FOOD PRINTING**

Among the advantages of 3D food printing, the following may be mentioned:

- food personalization,
- meal composition adapted to individual diet,
- the use of new components, which are not used or are not popular among consumers,
- ease and simplicity of preparation of meals,
- both aesthetic and functional customization can be achieved at the same time,
- novel food textures,
- longer shelf life,
- ease of transportation even to the most remote corners of the world or into space (NASA),
- new opportunities to create dishes, their artistic design - creating culinary works of art,
- the ability to design your own food – being a food designer,
- economical and efficient technique of mass personalization.

**SUMMARY**

The future of 3D printing will be developed in the coming years. Undoubtedly, food printing can have many advantages, but whether the market is ready for such a big change and the technology will grow fast enough are the questions. Can the 3D printed food replace traditional meals? Certainly not today, but it may already be an interesting alternative to traditional meals, as well as an edible decoration limited only by our imagination, difficult or impossible to prepare in other ways. The rest is up to the technology development, lower prices of printers, extent of the food components palette useful for printing, as well as development and availability of recipes.

An important aspect in the promotion of 3D printed food may be the ecological and health aspects. Also it seems to be the right solution to meet the needs of today’s consumers, who increasingly have too little time to prepare meals on their own, especially in small or single-person households. In the future, ready, healthy meal, tailored to their individual needs, will be waiting when coming home. It will be prepared by a previously programmed device thanks to 3D printing technology, or even the printers will be programmed remotely via mobile phone, from office or on the way home. Furthermore, no food will be wasted: a portion will be one, fresh and prepared especially for us, at a time when the need arises.
REFERENCES

Where healthy ingredients meets nutraceuticals collaborates with manufacturing and develop ideas about food retail at **food matters live...**

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