A milk-jet printer?

TEAGASC researchers are examining how 3D food printing could revolutionise dairy-based foods and snacks.

What is 3D printing?

At its simplest, 3D printing is a process for successive deposition of thin layers of a material or printing formulation, sometimes referred to as an ink, into a self-supporting 3D structure of a desired shape and dimensions using a printing machine. Essentially, the feed stream is subjected to conditions that induce controlled aggregation (sticking/fusion) of the material following deposition, to enable the formation of the desired structure with functional characteristics, using a wide range of materials (e.g., plastic, metal, wax, food, biomaterials). In modern large-scale manufacturing industries, production of customised products generally implies an increase in production costs. However, 3D printing enables economical use of ingredients and manufacture of customised products in small quantities.

Types of 3D food printers

In the 3D printing process, a digital template of the desired 3D shape is produced by digitally slicing the design/shape into layers (<2mm), from which the 3D structure is built, layer by layer. There are different techniques for how the layers of the 3D structures are printed. These are based on the physical state of the printing formulation (solid or liquid) and the technique to aggregate it. Generally, in the food field, the most common 3D printing techniques are selective sintering, binder jetting, inkjet, and extrusion-based printing. Selective sintering and binder jetting printing fuse powder particles, layer by layer, into a 3D structure. The former applies a laser or hot air, and the latter a liquid, to bind the individual particles of the powder (e.g., sugar or sugar-rich powders) into complex structures. In extrusion printing, the printing formulation is typically an aqueous dispersion of food components (e.g., proteins, polysaccharides and fat); it is extruded through a moving nozzle, or series of nozzles, which trace its deposition at a controlled rate onto a platform, which may be temperature regulated. Depending on the materials used, the transition from a liquid to a solid may occur as a result of the aggregation of one of the food components (e.g., protein), cooling-induced solidification (e.g., fat), or hydrogel formation (e.g., polysaccharide- or protein-induced swelling). Inkjet printing is applied as a means of dispensing a stream of droplets of decorative liquid or molten materials (e.g., chocolate, jams, sauces) to specific surface regions of the food structure for decoration purposes.

Adapting 3D printing in the dairy industry

In a food context, 3D printing enables the printing of structures from specific formulations comprised of proteins, fats, carbohydrates, and other materials. Recently, the food sector has begun to examine the potential of 3D food printing as a means of creating customised food designs, and personalised and digitalised nutrition. Dairy ingredients are potentially very amenable to 3D printing, owing to the presence of proteins (caseins and whey proteins) whose aggregation behaviour can be manipulated by alteration of the printing formulation.

Critical factors in the development of 3D dairy structures are the provision of ingredients which, on reconstitution, have the desired viscosity and aggregation behaviour that support uniform printing characteristics, i.e., controlled flow through printer nozzles, ideally forming self-supporting structures within the timeframe of printing, and forming a product with the desired functional attributes (e.g., texture and mouth-feel attributes). Developing dairy printing formulations requires evaluation of the aggregation behaviour of dairy ingredients (e.g., milk protein concentrates, micellar caseins, whey protein concentrates/isolates, and caseins) or mixtures when subjected to different conditions or variables, such as:

- ingredient concentration and solvent quality (e.g., pH, ionic strength, type of ions), in which the ingredients are dispersed;
- the method used to induce aggregation (e.g., enzymatic cleavage, acidification, heat, enzymatic-induced cross-linking);
- additives (e.g., hydrocolloids, modified starches); and,
- printing conditions (e.g., nozzle diameter, flow rate, time, temperature, pressure).

Potential applications/innovations

The commercial adoption of 3D printing provides the dairy industry with an increased opportunity to supply ingredients with specific functionalities that enable the development of novel foods and snacks. 3D food printing offers the means of creating products with personalised nutrition requirements. Food printing can personalise nutrition in two ways: by controlling the amount of food to be printed; and, by regulating nutritional ingredients used in the printing formulation. Customised 3D printing of dairy snacks designed specifically for seniors, athletes, and expectant mothers, allows tailored foods that encompass the macro and micronutrients required for the individual's health status and body type by altering the types and levels of nutrients in the printing formulation. Moreover, the customisation of 3D-printed foods can be synchronised with online information from motion sensors (e.g., pedometers and accelerometers) and heart rate monitors, thereby allowing the printing of a food to meet the nutritional requirements according to the outputs from these devices.

The current project, entitled 'Exploitation of dairy ingredients in the development of 3-dimensional structured dairy snacks', has recently received funding from the Department of Agriculture, Food and the Marine (DAFM). The goals of the project, which continues until 2022, are to establish the technological properties of dairy ingredients to generate the ideal printing material and their ability to form 3D structures, develop a high-quality food-grade 3D printer designed specifically for processing dairy-based formulations, and characterise the composition, functionality, sensory characteristics, and consumer acceptability of the end 3D snacks.

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Authors

Ricardo Uribe Alvarez
PhD student, Department of Food Chemistry and Technology, Teagasc Food Research Centre, Moorepark, Fermoy, Co. Cork

Tim Guinee
Principal Research Officer, Department of Food Chemistry and Technology, Teagasc Food Research Centre, Moorepark, Fermoy, Co. Cork

John Tobin
Senior Research Officer, Department of Food Chemistry and Technology, Teagasc Food Research Centre, Moorepark, Fermoy, Co. Cork

Norah O'Shea
Research Officer, Department of Food Chemistry and Technology, Teagasc Food Research Centre, Moorepark, Fermoy, Co. Cork
Correspondence: norah.o'shea@teagasc.ie