**Effect of printing parameters on extrusion 3D printing of oral nutraceuticals formulated with oleogels**

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ABSTRACT

3D printing (3DP) is one of the most promising emerging technologies for the development of functional foods and nutraceutical products, as it can produce customized formulations with “tailor-made'' nutritional contents and desired characteristics. Extrusion-based 3D printing (3DP-EXT) is the most commonly used technique in the food field due to the wide availability of food ingredients that can be extruded through a syringe and then deposited layer by layer to form printed products. Printing parameters play a key role in 3DP-EXP, since they determine the shape accuracy, microstructure, and final product quality. On the other hand, oleogels are semi-solid materials that have demonstrated excellent potential as printing materials for 3DP-EXT because of their gelation behavior and their mechanical and structural properties. Furthermore, due to their hydrophobic nature, oleogels can dissolve large amounts of lipid-soluble bioactive molecules, allowing their release via various physiological pathways. For the reasons stated above, the aim of this work was to investigate the effect of three of the most critical printing process parameters on geometrical dimensions, weight and hardness of printed oral solid forms. Molten oleogels of monoglycerides containing phytosterols as liposoluble compounds were used as printing material. To obtain the oleogel, high oleic sunflower oil and saturated monoglycerides (10 % w/w) were mixed at 90 °C; then 20 % w/w of phytosterols were added allowing their solubilization. The mixture was placed into the printer’s heated syringe and extruded on a temperature-controlled platform. Following a CAD design, different printing runs were performed by varying the amount of extruded material (flow, 70, 85 and 100 %), building platform temperature (Tp, 8, 15 and 20 °C) and extrusion speed (1, 3 and 6 mm/s). After printing, each solid form was characterized by measuring its dimensions and weight. A texture test was performed after 72 hours to determine its hardness. Among the most important results are the following. The weight of printed solid forms was only affected by flow rate; the greater the flow, the greater the weight. The extrusion speed and the Tp modified the self-supporting ability of the deposited layers, indicating that these parameters would be affecting gelation and crystallization process of the printing material. Regarding mechanical behavior, the highest Tp resulted in the strongest printed forms. For the best printing configuration (flow 100%, Tp 8 °C and speed 1 mm/s), the dimensions (height, length and width) of the printed forms were not significantly different from those of the CAD design. To analyze the microstructure of these printed forms, polarized light optical microscopy, x-ray diffraction and differential scanning calorimetry were used. Even if some morphological differences were observed between crystalline formations corresponding to the bottom and top parts of the forms, crystals of both sections showed the same polymorphisms, 𝞫 y 𝞫’, which are thermodynamically stables. In conclusion, the evaluated printed conditions affected the physical properties of the oral forms, being critical when defining product quality.

Keywords: Additive manufacturing, oral solid forms, phytosterols, food supplements, printing settings.