3D printing of meat analogues containing hydrocolloids, texturized pea protein and single cell protein: anisotropic structures by protein fibril alignment

CALTON A. (1), LILLE M. (1), SOZER N. (1)
1 VTT Technical Research Centre of Finland Ltd, Espoo, Finland

Objectives

The aims of this work were to a) formulate printing pastes suitable for extrusion-based 3D printing and to characterise their rheological properties, b) to study the direction-dependent (anisotropic) textural and microstructural properties of 3D printed, calcium-crosslinked meat analogues.

Methods

Meat analogue printing pastes were prepared with water (77.2 wt%), locust bean gum (LBG; 0.8 wt%) and/or sodium alginate (SA; 2-2.8 wt%), disintegrated texturized pea protein (TPP; 10-15 wt%) and single cell protein (SCP; 5-10 wt%). Viscoelastic properties were determined by stress sweep measurements. The printing toolpath was designed to print parallel strands, with interlayer staggering, using a 1.5mm nozzle. Prints were solidified by crosslinking with a calcium lactate solution (5 wt%). Textural properties were determined by cutting test in both longitudinal and transversal direction, and uniaxial compression testing. Microstructural properties of lyophilised samples were examined by X-ray microtomography.

Results

In all printing pastes, the storage modulus G' exceeded the loss modulus G'' and ranged between 4000-6000 Pa, indicating elastic-dominant, solid-like behaviour. Substituting portion of SA with LBG significantly increased G' (4049-4226 Pa to 5497-5909 Pa) and yield stress (24-39 Pa to 62 Pa), implying improved printing performance. All crosslinked meat analogues showed anisotropy as a significantly higher transversal than longitudinal cutting force. Presence of LBG significantly decreased cutting forces in both orientations compared to SA alone. Higher TPP:SCP ratio significantly decreased cutting forces and compression force in presence of LBG but was not significantly lower with SA alone. With SA alone, the anisotropy index AI ($AI= F_{Transversal}/F_{Longitudinal}$) was lower (1.3-1.4) compared to when LBG was present (1.7-1.9). Higher TPP:SCP ratio increased AI from 1.7 to 1.9 in presence of LBG and 1.3 to 1.4 with SA alone. Microstructural analysis and visual inspection revealed alignment of TPP fibrils along the path of the printing nozzle.

Conclusions

The created meat analogues are hydrocolloid-SCP gels reinforced with unidirectionally aligned TPP fibrils, determined by the toolpath. Anisotropy and meat-like appearance are mainly influenced by gel strength and aligned protein fibrils. Protein fibril alignment by 3D printing is a promising structuring technique for meat analogues mimicking whole-muscle meat cuts.