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SOLIDAGO CANADENSIS L. HERB EXTRACTS AND THEIR 3D-PRINTED DOSAGE FORMS – PROMISING AGENTS WITH ANTIMICROBIAL, ANTI-INFLAMMATORY AND HEPATOPROTECTIVE ACTIVITY

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Introduction. *Solidago canadensis* L., commonly known as Canadian goldenrod, is among the most widely distributed species of the *Solidago* genus within the Asteraceae family. This plant is recognized for its rich profile of biologically active constituents and has long been used in traditional medicine to treat disorders of the kidneys, liver, and urinary tract. Previous research demonstrated that the extract prepared by using 40% ethanol exhibited the most promising anti-inflammatory and hepatoprotective effects. Based on these findings, this particular extract was selected for further development into amino acid-based formulations and 3D-printed oral dosage forms. The present study aimed to gain knowledge on the chemical composition, toxicity, and biological activity, including antimicrobial, anti-inflammatory, and hepatoprotective properties of the dry extract, its amino acid-modified versions, and the resulting 3D-printed preparations.

Materials and Methods. Flowering tops of *S. canadensis* were harvested in Tartu, Estonia. To prepare the dry extract, 500 g of dried herb was macerated in 1000 ml of 40% aqueous ethanol at room temperature for 24 hours. Six amino acids: phenylalanine, L-arginine, glycine, L-lysine, β-alanine and valine, were added in triple equimolar ratios relative to the polyphenol content. Quantitative analysis of hydroxycinnamic acids, flavonoids, and total phenolic compounds was performed using a Shimadzu UV-1800 spectrophotometer (Shimadzu Corporation, Kyoto, Japan) following European Pharmacopoeia protocols and by HPLC. Antimicrobial activity was assessed using clinical isolates of pathogenic microorganisms. Anti-inflammatory effects were evaluated using the formalin-induced inflammation model. The hepatoprotective activity was studied using a tetrachloromethane-induced acute hepatitis model in rats. For 3D printing, aqueous gels containing 12% (w/w) polyethylene oxide (PEO) and *S. canadensis* extract were prepared for semi-solid extrusion (SSE) printing.

Results and Discussion. The dry extracts appeared as yellow-brown powders with a distinct herbal aroma. After a short-term storage and modification with alanine and glycine, the extracts transformed into a dark-brown viscous mass. A total of 18 phenolic compounds and 14 amino acids were identified. Dominant phenolics were neochlorogenic acid, chlorogenic acid and dicaffeoylquinic acid isomers (4,5-, 3,5-, and 3,4-dicaffeoylquinic acid). The most abundant amino acids were proline, histidine, serine, alanine, aspartic acid, lysine and glutamic acid. Toxicological evaluation classified the extracts as practically non-toxic (toxicity class V, LD_{50} > 5000 mg/kg). Moderate antimicrobial activity was observed against *Staphylococcus aureus*, *Enterococcus faecalis* and β-hemolytic *Streptococcus pyogenes*. The strongest hepatoprotective effects were found with the formulations containing phenylalanine, alanine and lysine at a dose of 25 mg/kg body weight. The most significant anti-inflammatory response was found in the extract combined with arginine. The gel inks containing 0.5–1.5 g of extract per 10 ml were successfully used in SSE 3D printing. The use of these printing inks resulted in a uniform lattice structure and disc-shaped dosage form. The compatibility of PEO with *S. canadensis* extract was confirmed, thus supporting its use as a carrier polymer in gel inks.

Conclusions. The *S. canadensis* dry extract studied here consists of 18 phenolic compounds and 14 amino acids. The present dry extract, as well as its amino acid-modified formulations, have been shown to exhibit anti-inflammatory and hepatoprotective activity in rodent models. The dry extract has also a moderate antimicrobial activity against *Staphylococcus aureus*, *Enterococcus faecalis* and β-hemolytic *Streptococcus pyogenes*. This study demonstrates the feasibility of using SSE 3D printing to develop innovative oral dosage forms based on *S. canadensis* extracts. Such formulations offer a promising approach for preparing personalised herbal supplements and therapeutic products with a controlled composition and release profile.