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Biomacromolecules as novel green flame retardant systems for textiles: an overview

Giulio Malucelli*[1], Francesca Bosco[2], Jenny Alongi[1], Federico Carosio[1], Alessandro Di Blasio[1], Chiara Mollea[2], Fabio Cuttica[1], Annalisa Casale[1, 2]

[1]Politecnico di Torino, Dept. of Applied Science and Technology, Viale T. Michel 5, 15121 Alessandria, Italy
[2]Politecnico di Torino, Dept. of Applied Science and Technology, C.so Duca degli Abruzzi 24, 10129 Torino, Italy

*corresponding author, Phone/Fax: +390131229369/+390131229399 e-mail: giulio.malucelli@polito.it

SUPPLEMENTARY INFORMATION

Materials

Cotton (COT, 200 g/m^2), polyester (PET, 175 g/m^2) and a blend consisting of 65% PET and 35% COT (PET-COT, 245 g/m^2) were purchased from Fratelli Ballesio S.r.l. (Torino, Italy).

DNA from herring sperm, caseins (12-15 α-s_1, 3-4 α-s_2, 9-11 β and 2-4 κ) and chitosan powders (all reagent grade) were purchased from Sigma-Aldrich S.r.l. (Milano, Italy) and stored at 4°C before its application to the fabrics.

A commercial hydrophobin solution (H Star Protein B liquid®) was kindly supplied from BASF (Italy). The aqueous solution contains 5% hydrophobins (a mixture of class I and class II: the composition is unknown).

WPI powder (93.5 wt.% protein) was purchased from Anderson Research (Cervaro (FR), Italy); its overall composition also includes lipids (ca. 0.5 wt.%), carbohydrates (ca. 1 wt.%), ash (ca. 2.2 wt.%), and moisture (ca. 2.8 wt.%).

The structures of DNA, α-caseins and hydrophobins (class II) are schematized in Figure S1.

All the suspensions/solutions of these biomacromolecules were prepared using 18.2 MΩ deionized water supplied by a Q20 Millipore system (Milano, Italy).

Characterization techniques

The surface morphology of the treated samples was studied using a LEO-1450VP Scanning Electron Microscope (beam voltages: 5 and 20 kV for fabrics and residues,

respectively); an X-ray probe (INCA Energy Oxford, Cu-Kα X-ray source, k=1.540562 Å) was used to perform elemental analysis. Fabric pieces (5x5 mm^2) were cut and fixed to conductive adhesive tapes and gold-metallized.

The thermal and thermo-oxidative stability of the fabrics was evaluated by thermogravimetric (TG) analyses in nitrogen and in air, respectively, from 50 to 800°C with a heating rate of 10°C/min. A TAQ500 analyzer was used, placing the samples (about 10 mg) in open alumina pans, in inert or oxidative atmosphere (gas flux: 60 ml/min). In the followings, $T_{onset10\%}$ and T_{max} will be defined as the temperature corresponding to a weight loss of 10% and the maximum weight loss rate, respectively.

Flammability tests in horizontal configuration were carried out by applying a 25 mm methane flame for 3 s on the short unclamped side of the specimen (25x100x0.5 mm^3), which was clamped in its three quarters by using a U-shaped metallic frame. These tests were repeated 3 times for each formulation. Total burning time (s), char length (mm), total burning rate (calculated as the ratio between the char length and total burning rate, mm/s) after the flame application, as well as the final residue (%) were evaluated.

In addition, LOI (Limiting Oxygen Index) tests were performed with a FIRE oxygen index apparatus according to the ASTM D2863 standard.

The combustion behaviour of square fabric samples (50x50x0.5 mm^3) was investigated by cone calorimetry (Fire Testing Technology, FTT). The measurements were carried out under two irradiative heat fluxes (35 or 50 kW/m^2), in horizontal configuration, following the procedure described elsewhere (Tata J, Alongi J, Carosio F, Frache A. Optimization of the procedure to burn textile fabrics by cone calorimeter: part I. Combustion behavior of polyester. Fire and Materials 2011;35(6):397-409.). Such parameters as Time To Ignition (TTI, s), Flame Out (FO, s) and peak of Heat Release Rate (pkHRR, kW/m^2) were measured. The experiments were repeated four times for each material investigated to ensure reproducible and significant data; the experimental error was within 5%.

Prior to flammability and combustion tests, all the specimens were conditioned at 23±1°C for 48 h at 50% R.H. in a climatic chamber.

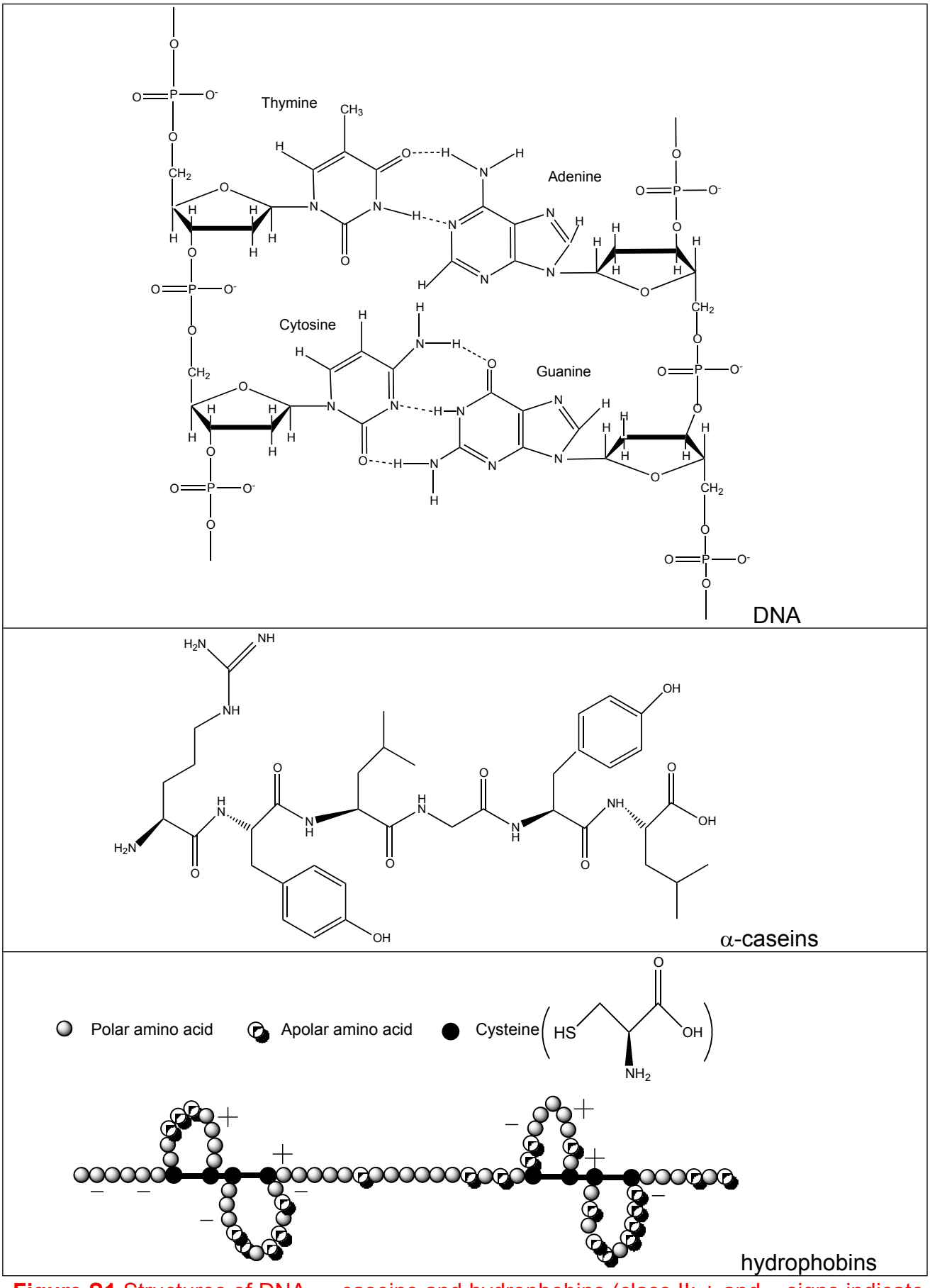

Figure S1 Structures of DNA, α-caseins and hydrophobins (class II; + and – signs indicate charged amino acids)