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Review

Fluorescence probes used for detection of reactive oxygen species

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Abstract

Endogenously produced pro-oxidant reactive species are essential to life, being involved in several biological functions. However, when overproduced (e.g. due to exogenous stimulation), or when the levels

Abbreviations: ROS, reactive oxygen species; $O_2^{\bullet -}$, superoxide radical; $HO_2^{\bullet}$, hydroperoxyl radical; $HO^{\bullet}$, hydroxyl radical; $ROO^{\bullet}$, peroxyl radical; $RO^{\bullet}$, alkoxyl radical; H_2O_2, hydrogen peroxide; $^1O_2$, singlet oxygen; HOCl, hypochlorous acid; UV, ultraviolet; RNS, reactive nitrogen species; $^{\bullet}NO$, nitric oxide; $^{\bullet}NO_2$, nitrogen dioxide radical; $ONOO^-$, peroxynitrite anion; ONOOH, peroxynitrous acid; $ONOOCO_2^-$, nitrosoperoxycarbonate anion; NO_2^+, nitronium cation; N_2O_3, dinitrogen trioxide; HE, hydroethidine; E^+, ethidium; DNA, deoxyribonucleic acid; HPLC, high-performance liquid chromatography; DPBF, 1,3-diphenylisobenzofuran; SOD, superoxide dismutase; OCl^-, hypochlorite anion; PDA, 12-(1-pyrene)dodecanoic acid; DCFH, 2,7-dichlorodihydrofluorescein; DCF, 2,7-dichlorofluorescein; DCFH-DA, DCFH diacetate form; HRP, horseradish peroxidase; $DFC^{\bullet -}$, DCF's semiquinone radical; NADH, nicotinamide adenine dinucleotide; NADPH, nicotinamide adenine dinucleotide phosphate; GSH, glutathione; K_m, Michaelis–Menten constant; HVA, homovanillic acid; DHR, dihydrorhodamine 123; EDTA, ethylenediaminetetraacetic acid; DPAX, 9-[2-(3-carboxy-9,10-diphenyl)anthryl]-6-hydroxy-3H-xanthen-3-one; DPA, 9,10-diphenylanthracene; DPAX-EP, DPAX endoperoxide; EP-1, 3-(4-methyl-1-naphthy)propionic acid endoperoxide; DMA, 9,10-dimethylanthracene; DMA-EP, DMA endoperoxide; DMAX, 9-[2-(3-carboxy-9,10-dimethyl)anthryl]-6-hydroxy-3H-xanthen-3-one; DMAX-EP, DMAX endoperoxide; $^{\bullet}CH_3$, methyl radical; CHD, 1,3-cyclohexanedione; 7-OHC, 7-hydroxycoumarin; 3-CCA, coumarin-3-carboxylic acid; SECCA, 3-CCA's succinimidyl ester; HPF, 2-[6-(4′-hydroxy)phenoxy-3H-xanthen-3-on-9-yl]benzoic acid; APF, 2-[6-(4′-amino)phenoxy-3H-xanthen-3-on-9-yl]benzoic acid; MPO, myeloperoxidase; FL, fluorescein; HORAC, hydroxyl radical averting capacity; *cis*-PnA, *cis*-parinaric acid; C_{11}-BODIPY$^{581/591}$, 4,4-difluoro-5-(4-phenyl-1,3-butadienyl)-4-bora-3a,4a-diaza-*s*-indacene-3-undecanoic acid; AMVN, 2,2′-azobis-2,4-dimethylvaleronitrile; AAPH, 2,2′-azobis(2-amidinopropane) dihydrochloride; C_{11}-fluor, 5-(*N*-dodecanoyl)aminofluorescein; fluor-DHPE, dihexadecanoylglycero-phosphoethanolamine; DPPP, diphenyl-1-pyrenylphosphine; DPPP═O, diphenyl-1-pyrenylphosphine oxide; PMNs, polymorphonuclear leukocytes; PMA, phorbol 12-myristate 13-acetate; DCFH-DA, 2,7-Dichlorodihydrofluorescein diacetate; DCF, 2,7-dichlorofluorescein; TRAP, total peroxyl radical trapping potential; ORAC, oxygen radical absorbance capacity; AUC, area under curve; RMCD, randomly methylated β-cyclodextrins.

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of antioxidants become severely depleted, these reactive species become highly harmful, causing oxidative stress through the oxidation of biomolecules, leading to cellular damage that may become irreversible and cause cell death. The scientific research in the field of reactive oxygen species (ROS) associated biological functions and/or deleterious effects is continuously requiring new sensitive and specific tools in order to enable a deeper insight on its action mechanisms. However, reactive species present some characteristics that make them difficult to detect, namely their very short lifetime and the variety of antioxidants existing in vivo, capable of capturing these reactive species. It is, therefore, essential to develop methodologies capable of overcoming this type of obstacles. Fluorescent probes are excellent sensors of ROS due to their high sensitivity, simplicity in data collection, and high spatial resolution in microscopic imaging techniques. Hence, the main goal of the present paper is to review the fluorescence methodologies that have been used for detecting ROS in biological and non-biological media.

Keywords: Fluorescence probe; Reactive oxygen species; Free radical; Antioxidant; Oxidative stress; Scavenging activity

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