Synthesis and evaluation of anticancer, antiphospholipases, antiproteases, and antimetabolic syndrome activities of some 3H-quinazolin-4-one derivatives

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ABSTRACT

Some new 3H-quinazolin-4-one derivatives were synthesised and screened for anticancer, antiphospholipases, antiproteases, and antimetabolic syndrome activities. Compound 15d was more potent in reducing the cell viabilities of HT-29 and SW620 cells lines to 38%, 36.7%, compared to 5-FU which demonstrated cell viabilities of 65.9 and 42.7% respectively. The IC₅₀ values of 15d were /C24 20 /C24 mg/ml. Assessment of apoptotic activity revealed that 15d decreased the cell viability by down regulating Bcl2 and BclxL. Moreover, compounds, 8j, 8d/15a/15e, 5b, and 8f displayed lowered IC₅₀ values than oleanolic acid against proinflammatory isoforms of hGV, hG-X, NmPLA2, and AmPLA2. In addition, 8d, 8h, 8j, 15a, 15b, 15e, and 15f showed better anti-α-amylase than quercetin, whereas 8g, 8h, and 8i showed higher anti-α-glucosidase activity than allopurinol. Thus, these compounds can be considered as potential antidiabetic agents. Finally, none of the compounds showed higher antiproteases or xanthine oxidase activities than the used reference drugs.

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Introduction

Colorectal cancer (CRC) is the third-most common cancer and the fourth-most common cause of cancer-related death worldwide. One of the key features of cancer is deregulation of apoptosis of the altered cells. Apoptosis is mediated by a complex network of BCL-2 family of proteins, comprising two types of proteins, namely anti-apoptotic proteins, which include Bcl2, Bcxl, and Mcl-1, and pro-apoptotic proteins, which include Bax and Bak. Hence, inhibiting the anti-apoptotic BCL-2 proteins can be established as a mechanism of anticancer defence for the treatment of CRC.

Several in vitro and in vivo clinical studies have suggested a positive correlation between the activity of certain proteases, such as trypsin, cathepsin B, collagenases, thrombin, and neutrophil elastase and colorectal carcinogenesis, invasion, proliferation, and metastasis. Furthermore, three phospholipases, namely (hsPLA₂-IIA), group V, and group X are found to paly indirect pro-tumorigenic roles by promoting chronic inflammatory bowel diseases (IBD) that are common risk factors associated with CRC.

In addition, recent studies have linked the incidence of CRC to certain metabolic syndrome components, especially elevated
plasma glucose (type 2 diabetes mellitus)\textsuperscript{12}. Several enzymes are reported to be involved in glucose homeostasis, among them α-amylase, α-glucosidase\textsuperscript{13}, and xanthine oxidase\textsuperscript{14}. Hence, targeting these enzymes has high potential in preventing CRC.

The 3H-quinazolin-4-one scaffold is known to be an important building block of various bioactive natural products\textsuperscript{15}. In addition to this, many marketed drugs or experimental drug candidates incorporate this pharmacophore as part of the overall topography of the molecules\textsuperscript{16} such as isopinesib, nolatrexed, and raltitrexed (the anticancer agents); afloqualone with sedative and muscle relaxant effects, balaglitzalone with anti-diabetic activities, proguanine (as non-steroidal anti-inflammatory agent), and elinoreg (as reversible P2Y12 receptor antagonist) which is used for the treatment of acute coronary syndrome. Moreover, several new methodologies have been developed for the synthesis of 4-quinazolinone derivatives either using one pot multicomponent approaches\textsuperscript{17} or via multistep routes for investigating their pharmacological potential as dual EGFR/HER2 inhibitors\textsuperscript{18,19}, phosphoinositide 3-kinase inhibitors\textsuperscript{20}, and as anti-hypertensive\textsuperscript{21}, antioxidant\textsuperscript{22}, and anti-inflammatory\textsuperscript{23} agents.

Based on these observations, and in continuation to our ongoing research programme aims to identify new bioactive molecules\textsuperscript{24,25} herein, we report the synthesis, characterisation, and cytotoxicity screening (including evaluation of apoptotic activity), for a new series of 3H-quinazolin-4-one derivatives against HT-29 and SW620 cell lines derived from CRC. Furthermore, the inhibitory potentials of the synthesised compounds against certain phospholipases and proteases implicated in cancer and inflammatory disorders, in addition to α-amylase, α-glucosidase, and xanthine oxidase, managing metabolic syndrome are investigated with the aim of eradicating the risk factors for CRC or combatting the disease.

Materials and methods

Chemistry

The reactions were monitored and the purity of the final products was checked using thin layer chromatography (TLC) on pre-coated silica gel sheets (60 F254, Merck, Kenilworth, NJ). The developed plates were examined by exposure to ultraviolet light using VL-61C (254, 365 nm, 50/60 Hz). All the melting points were determined in open capillary tubes with a Gallenkamp melting point apparatus (°C). The infra-red (IR) spectra were recorded on a Perkin Elmer Fourier transform infra-red (FTIR) spectrophotometer (Spectrum BX 1000) in wave numbers (cm\(^{-1}\)) with potassium bromide (KBr) discs. Nuclear magnetic resonance (NMR) spectra were recorded on a Bruker NMR spectrometer: 1-Ascend 850 MHz for 1H and 213 MHz for 13C (Nuclear Magnetic Resonance Center, KAU, Jeddah, KSA), or on a Bruker Avance 500 spectrometer operating at 500 MHz for 1H and 125 MHz for 13C at 25°C (Research Unit, College of Pharmacy, Prince Sattam Bin Abdulaziz University, Alkhair, KSA), or on an Eclipse 300 FT NMR spectrometer operating at 300 MHz spectrometer for 1H and at 75 MHz for 13C at 25°C (KSU, Riyadh, KSA). The chemical shifts were expressed in (ppm) using tetramethylsilane as the internal standard; coupling constants (J) were expressed in Hz. Deuterochloroforo (CDCl\(_3\)) was used as solvent. The splitting patterns (multiplicities) in 1H NMR were designated as: singlet (s), broad singlet (br. s), doublet (d), double of doublet (dd), triplet (t), and multiplet (m). Mass spectra were recorded on Shimadzu Qp-2010 Plus mass spectrometer in ionisation mode: El (Micro Analytical Center, Cairo University, Egypt). Elemental analyses were obtained from the Microanalytical Data Unit at Cairo University, Giza, Egypt.

Compounds 3a,b\textsuperscript{26}, 3c\textsuperscript{27}, 3d\textsuperscript{28}, 6a\textsuperscript{29}, 6b\textsuperscript{30}, 13a, 13b, and 15a\textsuperscript{31} were reported previously.

2-Methyl-3-(3,4,5-trimethoxy-phenyl)-3H-quinazolin-4-one (5a)

Black powder, yield (53%), mp 88–90 °C; \(\nu_{max}\) (KBr)/cm\(^{-1}\) 3080 (CH- Ar), 2935 & 2837 (CH-aliphatic), 2737, 1619 (C=O); MS (EI) [M+H]+ m/z 345.10 (100), 299.10 (26.61), 299.10 (26.61), 222.10 (7.45), 195.10 (7.45), 168.10 (3.42), 131.10 (2.32), 117.10 (2.32), 91.10 (2.32), 79.10 (2.32), 67.10 (2.32), 55.10 (2.32), 45.10 (2.32); Anal. calcd. for C\(_{18}\)H\(_{17}\)FN\(_2\)O\(_4\) (344.12): C, 62.94; H, 4.98; N, 8.14. Found: C, 62.68; H, 4.63; N, 8.02.

General procedure for the preparation of compounds 5a–c\textsuperscript{32,33}

A mixture of the appropriate 2-methyl-benzo[d][1,3]oxazin-4-one derivative 3a-c (0.003 mol) and 3,4,5-trimethoxyaniline 4 (0.003 mol, 0.55 g) was fused in oil bath at 200 °C for 2h. After cooling down the temperature to 100 °C, 37% HCl (Conc) (3 ml) was added till all the material was dissolved completely. The reaction mixture was cooled down to room temperature and was made alkaline with diluted NaOH solution (25%). The crude precipitated solid in each case, was filtered, washed with water, dried, and recrystallised from ethanol to yield compounds 5a–c.

6-Fluoro-2-methyl-3-(3,4,5-trimethoxy-phenyl)-3H-quinazolin-4-one (5b)

Black crystals, yield (55%), mp 193–195 °C; \(\nu_{max}\) (KBr)/cm\(^{-1}\) 3079 (CH- Ar), 2931 & 2835 (CH-aliphatic), 2375, 2278, 1673 (C=O), 1601 & 1484 (C=C), 1425, 1374, 1339, 1313, 1235, 1183, 1125 (C–F), 1065, 1008, 966, 878, 843, 778, 752, 723, 674, 626, 558, 526, 458; \(\delta_H\) (500 MHz; CDCl\(_3\)) 7.84–7.82 (1H, m, CH\(_3\)-quinazolin-4-one), 7.67–7.65 (1H, m, CH\(_2\)-quinazolin-4-one), 7.49–7.45 (1H, m, CH\(_4\)-quinazolin-4-one), 6.52 (2H, s, H\(_2\) and H\(_2\)-trimethoxyphenyl), 3.91 (3H, s, OCH\(_3\)), 3.84 (6H, s, 2 \times OCH\(_3\)2), 3.23 (3H, s, CH\(_3\)2; \(\delta_C\) (125 MHz; CDCl\(_3\)) 163.02 (C = C), 159.65 (C\(_F\)), 154.20 (C = N), 153.65, 144.06, 138.48, 133.03, 129.23, 123.18, 122.99, 121.87, 105.19 (6 × C\(_{Ar}\) & 6 × C\(_2\)Ar), 60.96 (OCH\(_3\)), 56.27 (2 × OCH\(_3\)), 24.04 (CH\(_3\)); MS (EI) m/z (%) [M+H]+ 345.10 (2.50), [M+H]+ 328.10 (2.50), [M+H]+ 327.10 (16.69), [M+H]+ 326.10 (77.52), 311.10 (46.20), 297.10 (3.85), 279.05 (2.13), 265.05 (1.90), 183.05 (4.87), 168.10 (7.32), 147.65 (8.78), 144.10 (14.54), 143.10 (100.00), 134.10 (4.69), 116.10 (6.24), 102.05 (4.96), 77.00 (6.38), 57.05 (3.38). Anal. calcld for C\(_{18}\)H\(_{16}\)F\(_2\)N\(_2\)O\(_4\) (343.12); C, 62.25; H, 5.56; N, 8.58. Found: C, 66.23; H, 5.46; N, 8.66.
6-Chloro-2-methyl-3-(3,4,5-trimethoxy-phenyl)-3H-quinazolin-4-one (3c)

Black powder, yield (60%), mp 188–190 °C; \( \nu_\text{max} \) (KBr)/cm\(^{-1}\): 3075 (CH-Ar), 2934 & 2839 (CH-aliphatic), 1680 (C = O), 1598 & 1504 (C = O), 1467, 1423, 1375, 1312, 1236, 1126, 998, 948, 892, 834 (C=Cl), 771, 736, 692, 613, 524, 452; \( \delta_\text{H} \) (500 MHz; CDCl\(_3\)) 8.18 (1H, d, \( J = 2.4 \)) (CH-quinazolin-4-one), 7.69 (1H, dd, \( J = 8.7, 2.4 \)), CH-quinazolin-4-one), 7.60 (1H, d, \( J = 8.7 \)) (CH-quinazolin-4-one), 6.51 (2H, s, H\(^{\text{H}}\) and H\(^{\text{H'}}\)-trimethoxy-phenyl), 3.92 (3H, s, OCH\(_3\)) (1.26). Anal. calcd. for C\(_{20}\)H\(_{14}\)BrN\(_3\)O (391.03): C, 61.24; H, 3.60; N, 15.18, 124.25, 112.90, 112.54, 112.49, 105.09 (5 \( \times \) CH-Ar & 7 \( \times \) C(q-Ar)), 60.93 (OCH\(_3\)), 56.28 (2 \( \times \) OCH\(_3\)), 24.02 (CH\(_3\)); MS (EI) m/z (%) [(M\(^+\) + 1) 314.0 (0.44), [(M\(^+\)]\(^{-}\)) 313.10 (1.41), 161.05 (10.24), 160.10 (100.00), 153.10 (14.99), 139.10 (4.10), 127.10 (8.79), 118.10 (11.47), 90.05 (11.47), 76.00 (13.65), 63.00 (2.80), 50.00 (3.12). Anal. calcd. for C\(_{20}\)H\(_{14}\)BrN\(_3\)O (391.03): C, 61.24; H, 3.60; N, 15.18.

Synthesis of Schiff’s base derivatives (8a–j)\(^{4a}\)

A mixture of 3-amoino-2-methyl-3H-quinazolin-4-one derivatives 6a,b (0.002 mol) and the appropriate aromatic aldehyde 7a–e, namely, 2-naphthaldehyde, 4-(pyridin-2-yl) benzaldehyde, 3-methoxy-2-nitrobenzaldehyde, 4-formylbenzonitrile, and 1,1′-biphenyl-4-carbaldehyde (0.002 mol in absolute ethanol (20 ml) containing (3 ml) glacial acetic acid was heated under reflux for 10 h. The excess solvent was removed under reduced pressure. The obtained solid in each case was washed with water, air dried, and recrystallised from the appropriate solvent to obtain the corresponding Schiff’s base.

(E)-2-Methyl-3-[(4-pyridin-2-yl-benzylidene)-amino]-3H-quinazolin-4-one (8c)

Beige powder (benzene), yield (85%), mp 188–190 °C; \( \nu_\text{max} \) (KBr)/cm\(^{-1}\): 3042 (CH-Ar), 2940 (CH-aliphatic), 1675 (C = O), 1600 & 1468 (C = C), 1436, 1378, 1327, 1230, 1181, 1154, 1108, 987, 939, 875, 847, 772, 718, 688, 663, 626, 589, 479; \( \delta_\text{H} \) (500 MHz; CDCl\(_3\)) 9.12 (1H, s, CH-Ar), 7.84 (1H, d, \( J = 4.7 \), CH-Ar), 8.30 (1H, d, \( J = 7.9 \)), CH-Ar), 8.15 (2H, d, \( J = 8.2, 2 \times \) CH-Ar), 8.00 (2H, d, \( J = 8.2, 2 \times \) CH-Ar), 7.80–7.73 (3H, m, 3 \( \times \) CH-Ar), 7.68 (1H, d, \( J = 8.1 \), CH-Ar), 7.48 (1H, t, \( J = 7.5 \), CH-Ar), 7.36–7.28 (1H, m, CH-Ar), 2.69 (3H, s, CH\(_3\)); MS (EI) m/z (%) [(M\(^+\) + 1) 314.10 (0.69), [(M\(^+\)]\(^{-}\)) 310.40 (1.39), 181.05 (4.88), 161.05 (10.51), 160.10 (100.00), 145.10 (2.83), 132.10 (3.91), 118.10 (12.08), 90.00 (5.53), 76.00 (16.01), 50.00 (3.71). Anal. calcd. for C\(_{20}\)H\(_{14}\)BrN\(_3\)O (391.03): C, 74.10; H, 4.74; N, 16.46. Found: C, 73.92; H, 4.63; N, 16.28.

(E)-4-Bromo-2-methyl-3-[(4-pyridin-2-yl-benzylidene)-amino]-3H-quinazolin-4-one (8d)

Beige powder (benzene), yield (77%), mp 209–210 °C; \( \nu_\text{max} \) (KBr)/cm\(^{-1}\): 3149 & 3060 (CH-Ar), 2952 (CH-aliphatic), 1670 (C = O), 1640 & 1465 (C = C), 1375, 1319, 1278, 1240, 1208, 1158, 1124, 1061, 1035, 987, 876, 833, 775, 727, 674 (CH\(_{3}\)), 645, 564; \( \delta_\text{H} \) (850 MHz; CDCl\(_3\)) 9.10 (1H, s, CH-Ar), 8.77 (1H, d, \( J = 4.3 \)); CH-Ar), 8.41 (1H, d, \( J = 7.6 \)); CH-Ar), 8.17 (2H, d, \( J = 7.7, 2 \times \) CH-Ar), 8.01 (2H, d, \( J = 7.7, 2 \times \) CH-Ar), 7.85–7.79 (3H, m, 3 \( \times \) CH-Ar), 7.55 (1H, d, \( J = 8.5 \), CH-Ar), 7.36–7.32 (1H, m, CH-Ar), 2.68 (3H, s, CH\(_3\)); MS (EI) m/z (%) [(M\(^+\) + 1) 419.05 (1.37), [(M\(^+\)]\(^{-}\)) 418.00 (2.03), 2400.00 (11.07), 239.95 (100.00%), 237.95 (98.10), 199.90 (2.69), 197.90 (63.87), 180.15 (65.55), 179.05 (4.60), 154.05 (13.02), 152.05 (1.88), 139.10 (3.04), 127.10 (6.15), 116.10 (3.42), 90.05 (4.15), 78.05 (3.66), 75.00 (17.16). Anal. calcd. for C\(_{20}\)H\(_{14}\)BrN\(_3\)O (418.04): C, 60.16; H, 3.61; N, 13.36. Found: C, 60.03; H, 3.43; N, 13.11.

(E)-3-[(3-Methoxy-2-nitro-benzylidene)-amino]-2-methyl-3H-quinazolin-4-one (8e)

Beige powder (ethanol), yield (55%), mp 178–180 °C; \( \nu_\text{max} \) (KBr)/cm\(^{-1}\): 3017 (CH-Ar), 2975 & 2935 (CH-aliphatic), 1680 (C = O), 1615 & 1571 (C = C), 1537, 1464, 1428, 1376, 1283, 1227, 1156, 1107, 1055, 1029, 964, 933, 875, 850, 772, 743, 691, 651, 589, 471, 419;
(E)-6-Bromo-3-[(3-methoxy-2-nitro-benzylidene)-amino]-2-methyl-3H-quinazolin-4-one (8f)

Beige powder (ethanol), yield (66%), mp 234–235 °C; \( \nu_{\text{max}} \) (KBr)/cm\(^{-1}\) 3070 & 3012 (CH=Ar), 2977 & 2982 (CH=Aliphatic), 1677 (C-O), 1601 & 1533 (C=C), 1464, 1436, 1373, 1303, 1207, 1153, 1104, 1063, 973, 937, 897, 730, 779, 739, 670 (C-Br), 639, 589; \( \delta_H \) (850 MHz; CDCl\(_3\)) 9.35 (1H, s, CH = N), 8.38 (1H, d, J = 2.6, CH=Ar), 7.82 (1H, dd, J = 8.5, 2.6, CH=Ar), 7.58–7.56 (2H, m, 2 CH=Ar), 7.48 (1H, d, J = 8.5, CH=Ar), 7.25 (1H, d, J = 8.5, CH=Ar), 3.97 (3H, s, OCH\(_3\)), 2.63 (3H, s, CH\(_3\)); \( \delta_C \) (125 MHz; CDCl\(_3\)) 159.28 (C-N), 157.93 (HC = N), 155.38 (C=C= N), 151.47, 144.56, 139.68, 137.94, 131.36, 129.85, 128.57, 125.86, 122.76, 122.14, 120.31, 116.16 (6 x CH=Ar & 6 x C=Br), 56.80 (OCH\(_3\)), 22.63 (CH\(_3\)); MS (EI m/z %) [M\(^+\)] 480.48 (4.65), [M\(^+\), 13Br] 418.00 (4.58), 401.00 (6.90), 399.00 (6.60), 370.00 (5.89), 368.00 (5.13), 341.00 (1.54), 334.00 (1.46), 265.95 (2.41), 263.95 (2.42), 239.90 (97.78), 237.95 (100.00), 197.90 (8.61), 195.95 (6.33), 169.95 (3.24), 167.95 (2.54), 155.95 (7.13), 153.95 (7.22), 133.10 (1.53), 131.10 (3.71), 117.10 (7.38), 116.10 (5.63), 101.10 (4.34), 89.00 (4.73), 76.00 (9.56), 59.05 (13.18), 57.05 (4.20). Anal. calc. for C\(_{17}\)H\(_{13}\)N\(_4\)O\(_4\) (384.10): C, 60.03; H, 3.94; N, 16.37. Found: C, 60.03; H, 3.94; N, 16.37.

(2-Methyl-4-oxo-4H-quinazolin-3-ylino)-methyl]benzonitrile (8g)

White powder (acetone), yield (97%), mp 208–210 °C; \( \nu_{\text{max}} \) (KBr)/cm\(^{-1}\) 3058 (CH=Ar), 2920 (CH=Aliphatic), 1676 (C-O), 1604 & 1647 (C=C), 1373, 1319, 1276, 1236, 1206, 1180, 1154, 1074, 1007, 907, 875, 831, 757, 689 (C-Br), 644, 555, 467; \( \delta_H \) (500 MHz; CDCl\(_3\)) 9.35 (1H, s, CH = N), 8.14 (1H, d, J = 2.3, CH=Ar), 7.96 (2H, d, J = 8.3, 2 CH=Ar), 7.82 (1H, dd, J = 8.7, 2.3, CH=Ar), 7.73 (2H, d, J = 8.3, 2 CH=Ar), 7.66 (2H, d, J = 7.3, 2 CH=Ar), 7.54 (1H, d, J = 8.7, CH=Ar), 7.49 (2H, t, J = 7.3, 2 CH=Ar), 7.41 (1H, t, J = 7.3 CH=Ar), 2.63 (3H, s, CH\(_3\)); \( \delta_C \) (125 MHz; CDCl\(_3\)) 166.41 (C-O), 157.64 (HC = N), 154.61 (C=C= N), 145.45, 143.54, 139.92, 137.49, 131.44, 129.71, 129.43, 129.02, 128.81, 122.55, 122.67, 122.23, 122.97, 119.87 (12 x CH=Ar & 6 x C=Br), 22.94 (CH\(_3\)); MS (EI m/z %) [M\(^+\)] 419.05 (1.70), [M\(^+\), 13Br] 347.05 (1.67), 239.95 (100.00), 237.95 (98.77), 197.90 (6.94), 195.95 (4.46), 179.05 (24.10), 165.10 (56.04), 152.10 (13.04), 131.10 (2.31), 116.10 (3.58), 116.10 (3.58), 90.05 (3.62), 75.00 (15.91), 63.00 (3.20), 57.05 (2.43). Anal. calc. for C\(_{23}\)H\(_{18}\)BrN\(_3\)O\(_4\) (417.05): C, 63.17; H, 3.86; N, 10.05. Found: C, 62.97; H, 3.63; N, 9.89.

Synthesis of (2-methyl-4-oxo-4H-quinazolin-3-yl)-carboxylic acid isobutyl ester (10)

A mixture of 3-amino-2-methyl-H3-quinazolin-4-one 6a (0.0028 mol, 0.5 g) and isobutyl chlorofluorate 9 (13.6 equiv., 0.038 mol, 5.2 g, 4.94 ml) was refluxed for 10 h\(^{35}\). The excess reagent was evaporated under reduced pressure and the remaining residue was treated with diethyl ether. The precipitated solid was filtered, washed with water, and purified by recrystallisation from benzene to obtain the title compound as a beige powder with 50% yield, mp 168–170 °C; \( \nu_{\text{max}} \) (KBr)/cm\(^{-1}\) 3223 (NH), 3080 (CH=Ar), 2963 & 2875 (CH=Aliphatic), 1755 (C-O), 1694 (C-O), 1651 (C-N), 1606 & 1508 (C=C), 1468, 1380, 1322, 1108, 1046, 988, 942, 872, 772, 719, 695, 633, 520, 462; \( \delta_H \) (850 MHz; CDCl\(_3\)) 8.19 (1H, d, J = 7.7, CH=Ar), 7.75 (1H, app. t, J = 7.7, CH=Ar), 7.64 (1H, d, J = 8.5, CH=Ar), 7.62 (1H, br, s, NH), 7.44 (1H, t, J = 7.7, CH=Ar), 4.00 (2H, apparent s, O–CH=CH–(CH\(_2\))\(_2\)), 2.60 (3H, s, CH\(_3\)), 1.96–1.93 (1H, m, O-C\(_2\)-CH–(CH\(_2\))\(_2\)), 0.94 (6H, d, J = 6.0, O–CH\(_2\)-CH–(CH\(_2\))\(_2\)); \( \delta_C \) (125 MHz; CDCl\(_3\)) 160.78 (C-O), 156.28.
A mixture of the appropriate derivative of 2-mercapto-3-phenyl-1,3,4-thiadiazole and 3-phenyl-3H-pyrazole-5-carboxaldehyde (1H, 0.0028 mol, 0.0151 g) and N,N-dimethylformamide dimethyl acetal (11.53, 0.55 mol, 551.09 g, 119.05 (21.00), 105.10 (2.87), 91.05 (12.43). Anal. calcd. for C22H17N3O2S (415.14): C, 69.37; H, 5.09; N, 10.11. Found: C, 69.18; H, 4.92; N, 10.00.

Synthesis of 2-(4-chloro-benzylsulfanyl)-6-methyl-3-phenyl-3H-quinazolin-4-one (15a-f)

A mixture of the appropriate derivative of 2-mercapto-3-phenyl-3H-quinazolin-4-one (13a,b') (0.0018 mol) and 4-chlorobenzyl chloride (14a or chloroacetamide derivatives (14b,c), 0.1 equiv., 0.0018 mol) and potassium carbonate (2.5 equiv., 0.0045 mol, 0.62 g) in dry acetyl (20 ml) was refluxed for 6 h. The hot reaction mixture was filtered and the filtrate was concentrated under reduced pressure. The resulting solid in each case was washed with water, air dried, and recrystallized from ethanol to obtain compounds 15a-f.

2-(4-Chloro-benzylsulfanyl)-6-methyl-3-phenyl-3H-quinazolin-4-one (15b)

White powder, yield (96%), mp 164–165°C; \( \nu_{\text{max}} \) (KBr/cm\(^{-1} \)) 1325 (4.30); 1273 (10.37), 51.00 (11.84). Anal. calcd. for C25H22N3O4S (429.15): C, 69.91; H, 5.40; N, 9.78. Found: C, 69.76; H, 5.32; N, 9.64.

N-(2,6-Dimethyl-phenyl)-2-(4-oxo-3-phenyl-3,4-dihydro-quinazolin-2-ylsulfanyl)-acetamide (15c)

White crystals, yield (55%), mp 218–220°C; \( \nu_{\text{max}} \) (KBr/cm\(^{-1} \)) 3259 (NH), 3000 (CH-Ar), 2925 (CH-aliphatic), 2371, 2341, 1647 (C-O), 1574 & 1545 (C-C), 1487, 1400, 1363, 1204, 1172, 1035, 932, 872, 750, 694, 651, 598, 523, 468; \( \delta_h \) (850 MHz; CDCl\(_3\)) 8.66 (1H, br. s, NH), 8.27 (1H, d, \( J = 7.7, \text{CH-Ar} \)), 7.76 (1H, t, \( J = 7.7, \text{CH-Ar} \)), 4.04 (2H, d, \( J = 9.2, \text{CH-Ar} \)), 2.03 (3H, s, CH\(_3\)), 1.86 (6H, s, 2 \times CH\(_3\)); \( \delta_c \) (312 MHz; CDCl\(_3\)) 166.94 (C0), 163.13 (C0), 157.8 (C0), 146.99, 135.26, 135.19, 135.55, 130.55, 130.05, 129.02, 128.27, 127.66, 127.38, 126.73, 127.3, 119.91 (12 \times CH-Ar, 6 \times Cq-Ar), 35.49 (CHj), 18.33 (2 \times CH\(_3\)); MS (EI) m/z (%) \[M^+ \] + 1 416.15 (1.05), \[M^+ \] \(^{15} \text{N} \] 415.15 (2.86), 410.00 (9.45), 296.05 (20.13), 295.05 (1.00), 268.05 (28.58), 235.05 (10.77), 235.10 (30.01), 221.05 (5.97), 177.05 (7.25), 162.00 (2.47), 148.05 (3.93), 132.10 (20.59), 119.05 (11.21), 105.10 (2.87), 91.05 (12.43). Anal. calcd. for C25H22N3O4S (429.15): C, 69.37; H, 5.09; N, 10.11. Found: C, 69.18; H, 4.92; N, 10.00.
In vitro evaluation of antiphospholipases activities

The inhibitory activities of the synthesised 3H-quinazolin-4-one derivatives against a group of phospholipases were investigated according to the method of De Aranjo and Radvany45 using five sPLA2s: human group IIA (hG- IIA), human group V (hG-V), human group X (hG-X), Apis mellifera bee venom (AmPLA2) and Naja mossambica mossambica sPLA2 (NmPLA2). Ten microliters of each sPLA2 solution (20 μg/ml) was mixed with 10 μl of each compound at different concentrations (0–50 μg/ml) and the mixture was incubated for 20 min at room temperature. Then, 1 ml of the PLA2 substrate (3.5 mM lecithin suspended in 100 mM NaCl, 10 mM CaCl2, 3 mM NaTDC, and 0.055 mM red phenol, pH 7.6) was added. The hydrolysis kinetics was followed spectrophotometrically for 5 min at 558 nm. The results were reported as the inhibition percentage that was calculated by comparison with a control experiment (absence of compound) and the IC50 values were determined from the curve. Oleanolic acid (Sigma) was used as the positive control.

In vitro evaluation of antiproteases activities

The inhibitory effects of 21 3H-quinazolin-4-one derivatives on several available therapeutically important proteases such as cathepsin-B, collagenase, elastase, thrombin, and trypsin were investigated. The inhibition of the enzymes in the presence of test compounds was evaluated by adding different concentrations of each compound (0–75 μg/ml) to the respective reaction mixture, preincubating for 15 min and then measuring the remaining enzyme activity as previously described46. The protease inhibitory activity was expressed as inhibition percentage, which was determined by comparison with a control experiment. The results were expressed as IC50 values that were determined from the standard curve. A protease inhibitor cocktail (Sigma) was used as the positive control.

In vitro inhibition of α-amylase activity

The α-amylase inhibitory activity of the tested compounds was investigated according to the reported method by Subramani47. Briefly, 10 μL of α-amylase (3,3 U) (Sigma) was mixed with 10 μl of different concentrations (20–200 μg/ml) of each compound, the appropriate solvent, or quercetin (positive control), and incubated at 37°C for 5 min. After adding 180 μl of Labtest (amylase substrate), the samples were incubated for 8 min and the absorbance of first reaction was measured at 620 nm. Then, 100 μl of the reaction mixture was incubated for more five additional minutes at 37°C and the absorbance of the second reaction was measured. Labtest was diluted in distilled water (1:1) before being added to the microplate. The concentration of quercetin used was same as those of the test compounds. The α-amylase inhibition percentage was calculated as follows: % inhibition = 100 × (X2 sample _ X1 sample/X2 control _ X1 control) × 100 where X1 is the absorbance of the initial reading and X2 is the absorbance of the final reading. The results were expressed as IC50 determined from the curve.

In vitro inhibition of α-glucosidase activity

The α-glucosidase inhibitory activity of the tested compounds was evaluated according to the method described by Andrade-Cetto and collaborators48 based on the release of 4-nitrophenol α-D-glucopyranoside (4 NPGP). Briefly, 20 μl of different concentrations (ranging from 0 to 50 μg/ml) of each compound, the appropriate solvent, or quercetin (positive control) was mixed with 180 μl of the α-glucosidase enzyme from Saccharomyces cerevisiae (Sigma)
and the obtained mixture was incubated at 37 °C for 2 min, followed by additional incubation for more than 15 min at 37 °C after the addition of 150 μl of the colour reagent NPGP. The colorimetric assay included 2 U of α-glucosidase, 5 mM of 4-NPGP, and 10 mM potassium phosphate buffer, pH 6.9. The concentration of quercetin used was identical to that of the tested compounds. The reading assay was performed using a microplate reader at 405 nm. The α-glucosidase inhibition percentage was calculated as follows: % inhibition = 100 _ (X2 sample _ X1 sample/X2 control _ X1 control) / 100 where X1 is the absorbance of the initial reading and X2 is the absorbance of the final reading. The results were expressed as IC50 determined from the curve.

In vitro inhibition of xanthine oxidase

The xanthine oxidase inhibitory activities of the examined chemical compounds were determined by following the formation of uric acid from xanthine according to the reported method by Bondet and co-workers. Forty microliters xanthine oxidase (667 mM) and 15 μl of each compound (0–150 μg/ml), allopurinol (positive control), or appropriate solvent (negative control) were added to each microplate well and preincubated for 5 min at 37 °C. Then, 95 μl of reagent 1 (mixture of hydroxylamine (0.2 mM), EDTA (0.1 mM), and xanthine oxidase (667 mM) in 50 mM phosphate buffer solution (pH 7.5) were added to the reaction mixture and incubated at the same temperature for 30 min. Subsequently, the absorbance was measured at 295 nm using a microplate reader. Finally, after addition of 150 μl of uric acid reagent, the absorbance was measured again. The concentration of allopurinol used was same as that of the tested compounds. Xanthine oxidase inhibition was calculated as follows: % inhibition = 100 _ (X2 sample _ X1 sample/X2 control _ X1 control) / 100 where X1 is the absorbance of the initial reading and X2 is the absorbance of the final reading. The results were expressed as IC50 determined from the curve.
Results and discussion

Chemistry

The main targets of this investigation were 3H-quinazolin-4-one derivatives possessing general structure 1.

Two synthetic approaches were used for the synthesis of these scaffolds. The first synthetic approach featured the preparation and chemical transformations of the key intermediates benzol[d][1,3]oxazin-4-one derivatives 3a-d to various 3H-quinazolin-4-one derivatives as depicted in Scheme 1.

The conventional methods available for the synthesis of compounds 3a-d via cyclocondensation of antranilic acid derivatives 2a-d with acetic anhydride were time consuming, therefore, these compounds were synthesised using the more efficient microwave-assisted method. Fusion of oxazinones 3a-c with 3,4,5-trimethoxyaniline 4 yielded 2-methyl-3-(3,4,5-trimethoxyphenyl)-3H-quinazolin-4-one derivatives 5a-c. The assigned molecular structures of these new quinazolin-4-one derivatives were in full agreement with their spectroscopic and elemental analyses. Thus the IR spectrum (KBr) of compound 5c, for example, displayed absorption bands at $\nu_{\text{max}}$ 3075, 2934; 2839, 1680, 1598; 1504 and 834 cm$^{-1}$ for aromatic-CH, aliphatic-CH, the carbonyl group, C=C and C–Cl, respectively. The $^{1}$H NMR spectrum of compound 5c revealed the presence of five aromatic protons, which were displayed as: a one proton doublet signal at $\delta$ 8.18 ppm with coupling constant $J$ of 2.4 Hz corresponding to CH$_{2}$-quinazolin-4-one, a one-proton double-doublet signal at $\delta$ 7.69 ppm with coupling constant $J$ of 8.7, 2.4 Hz due to CH$_{2}$-quinazolin-4-one, a one-proton doublet signal at $\delta$ 7.60 ppm with coupling constant $J$ of 8.7 Hz corresponding to CH$_{2}$-quinazolin-4-one, and a two-protons singlet peak at $\delta$ 6.51 ppm, which was attributed to the two methine protons of 3,4,5-trimethoxyphenyl moiety (H2 and H5). The nine protons of the three methoxy groups were displayed as a three-protons singlet at $\delta$ 3.92, and a six-protons singlet at $\delta$ 3.88 ppm. Finally, the three protons of the methyl group were characterised by a three-protons singlet signal at $\delta$ 2.32 ppm. Moreover, the $^{13}$C NMR spectrum also confirmed the assigned structure based on the emergence of fifteen spectral lines at $\delta$C 161.28 (CO), 154.75 (C=N), 154.25, 145.91, 138.56, 135.02, 132.95, 132.36, 128.52, 126.23, 121.73, 105.09 (5 x CH-Ar & 7 x C$_{6}$-Ar), 60.93 (OCH$_{3}$), 56.28 (2 x OCH$_{3}$) and 24.02 (CH$_{3}$-quinazolin-4-one). The mass spectrum (El) of compound 5c indicated the presence of the expected molecular ion peak [M$^{+}$] at m/z 360.10 (100%).

Reflexing of oxazinones 3a-d with excess hydrazine hydrate in ethanol yielded 3-aminooxazinones 6a-b, which were converted to certain novel Schiff bases 8a-j via condensation with a series of aryl aldehydes 7a-e in absolute ethanol containing catalytic amount of glacial acetic acid. The structures of the new Schiff’s bases were verified by their IR, $^{1}$H NMR, $^{13}$C NMR, mass spectroscopic (MS) data, and CHN analyses. The IR spectra of compounds 8a-j indicated disappearance of the stretching bands of the amino groups in 3-aminoquinoxalin-4-one derivatives 6a-b. The $^{1}$H NMR spectra were characterised by the disappearance of the two-protons singlet signals corresponding to the amino protons of starting materials, which resonated at $\delta$ 5.79 and 4.89 ppm, accompanied by emergence of new one-proton singlet signals attributed to azomethine protons (CH$_{2}$=N) at $\delta$ 9.41-8.70 ppm range. In addition, the $^{13}$C NMR spectra displayed the expected spectral lines for each compound with the signals corresponding to (CH$_{2}$=N) groups resonating at $\delta$C 159.10-156.46 ppm.

Furthermore, the amino group of 3-amino-2-methyl-3H-quinazolin-4-one 6a was transformed to the corresponding carbamate group via direct nucleophilic substitution reaction for isobutyl chloroformate 9 to yield the new carbamate derivative 10. The structure of the latter product was established on the basis of its IR, $^{1}$H NMR, $^{13}$C NMR, MS and HCN elemental analyses. The IR spectrum displayed the characteristic stretching absorption bands at $\nu_{\text{max}}$ 3223, 1755, and 1694 cm$^{-1}$ indicating the presence of NH and two C=O groups. The $^{1}$H NMR spectrum of compound 10 was characterised by the presence of a one-proton broad singlet at $\delta$ 7.62 ppm due to NH group, in addition to the presence of a two-protons apparent singlet signal, a one-proton multiplet, and a six-protons doublet signal with coupling constant value of 6.0 Hz at $\delta$ 4.00, 1.96-1.93 and 0.94 ppm, respectively corresponding to (O-CH$_{2}$-CH(CH$_{3}$)$_{2}$) isobutoxy group. Moreover, the $^{13}$C NMR spectrum of carbamate 10 revealed the emergence of a new spectral line at $\delta$C 156.28 ppm attributable to the C=O of the carbamate functional group. The methylene, methine and two methyl groups of isobutoxy moiety demonstrated three spectral lines at $\delta$C 72.71, 27.78, and 18.72 ppm, respectively. Finally, the mass spectrum (El) of compound 10 showed the anticipated molecular ion peaks [M$^{+}$ + 1] at m/z 276.10 (21.00%) for C$_{12}$H$_{14}$N$_{4}$O$_{3}$ and [M$^{+}$] at 275.10 (100.00%).

Next, 3-amino-2-methyl-3H-quinazolin-4-one 6a was transformed to the corresponding N,N-dimethylformamidine derivative 12 by refluxing with excess N,N-dimethyl formamide dimethyl acetal (DMF-DMA) in absolute ethanol. The structure of this new compound was deduced from its IR, $^{1}$H NMR, $^{13}$C NMR, MS data, and elemental analyses. The IR spectrum revealed the presence of absorption bands at $\nu_{\text{max}}$ 3010, 2924; 2807, 1660, 1621, 1589; 1475 cm$^{-1}$ which were attributed to CH-aromatic, CH-aliphatic, C=O, C=N, and C=C, respectively. In addition, the $^{1}$H NMR spectrum of formamidine 12 was characterised by the presence of a new one-proton singlet signal at $\delta$ 7.74 ppm attributed to azomethine proton (HC$\equiv$N) and two singlet signals, each integrating to three protons resonating at $\delta$ 3.08 and 3.04 ppm, corresponding to the two methyl groups in dimethylamino N(CH$_{3}$)$_{2}$ moiety. Furthermore, the $^{13}$C NMR spectrum of compound 12 demonstrated three new peaks at $\delta$C 160.08, 40.88, and 34.53 ppm which were attributed to HC$\equiv$N-N(CH$_{3}$)$_{2}$ and, two carbons of the methyl groups in N(CH$_{3}$)$_{2}$ moiety, respectively. The mass spectrum (El) of compound 12 showed the anticipated molecular ion peak [M$^{+}$] at m/z 230.00 (34.52%) for C$_{12}$H$_{14}$N$_{2}$O$_{3}$.

The second synthetic approach for preparation of 3H-quinazolin-4-one derivatives involved the synthesis of compounds 15a-f via nucleophilic attack by 2-mercapto-3-phenyl-3H-quinazolin-4-one derivatives 13a-f on 4-chlorobenzyl chloride 14a or chloroacetamide derivatives 14b-c to yield compounds 15a-f by adapting modified procedure to what was reported by Salman et al. as illustrated in Scheme 2.

Structures of the new quinoline derivatives 15b and 15d were verified based on their respective IR, $^{1}$H NMR, $^{13}$C NMR, MS data, and elemental analyses. The IR spectra (KBr) of these products were characterised by the disappearance of the absorption bands at $\nu_{\text{max}}$ 3245 and, 3169 cm$^{-1}$ for the NH group (NH, SH exchangeable) and at $\nu_{\text{max}}$ 1195 cm$^{-1}$ for the thio carbonyl group (C=S) of starting substrates 13a-b. Furthermore, their $^{1}$H NMR spectra indicated the disappearance of the signals at $\delta$ 13.05 and 12.99 ppm due to the thiol protons of the starting materials. In addition, the spectrum of compound 15b showed characteristic two-protons singlet signal at $\delta$ 4.32 corresponding to the benzylidene methylene.
group. Analogously, the spectra of compounds 15df were characterised by the emergence of new one-proton broad singlet signals at δ 8.70 and 8.90 ppm corresponding to NH groups, and two-protons singlet signals at δ 3.96 and 3.97 ppm corresponding to methylene groups. In addition, the two methyl groups of the acetamide moieties were represented by a six-protons singlet signal at δ 2.16 ppm for compound 15d, and two singlet signals each integrating to three-protons at δ 2.23 and, 2.01 ppm for compound 15f.

Furthermore, the 13C NMR spectra of compounds 15bd, revealed the absence of spectral lines at δC 176.05 and 176.00 ppm corresponding to the thiocarbonyl group in the starting materials 13ab and the presence of new peaks at δC 36.22, 35.49, and 36.14 ppm attributed to the new methylene groups. The carbonyl and methyl groups of the acetamide moieties in compounds 15df were observed at δC 166.99, 167.11, 18.35, 20.55, and 13.82, respectively. In addition, the mass spectra (EI) of compounds 15bd, displayed the anticipated molecular ion peaks.

### Biological evaluation

**Effects of the synthesised 3H-quinazolin-4-one derivatives on cell viability of human colorectal cancer cell lines HT-29 and SW620**

As CRC starts with initial benign stages advanced to late stage leading to metastasis. Therefore, two human CRC cell lines which belong to two different stages namely, HT-29 which is derived from adenocarcinoma CRC and SW620 which is derived from metastatic site were selected for in vitro evaluation of the cytotoxicity (30 μg/ml) of twenty-one compounds incorporating the 3H-quinazolin-4-one scaffold.

Cell viability was monitored using the MTT assay and the results are presented in Supplementary Figure 1. Compared to the negative control, and the positive control (5-FU), the synthesised 3H-quinazolin-4-one derivatives displayed varied degrees of cytotoxicity against the examined colorectal cell lines. Eight out of all the examined compounds showed significant decrease in cell viability. In one hand, compound 15c inhibited only HT-29 cell line (47.5% viability) whereas compound 5b inhibited only SW620 cell line (46.6% viability). On the other hand, six compounds namely, 8a, 8f, 8j, 15a, 15b, and 15d, were potently capable of inhibiting cell viability of both human CRC cell lines. Compound 15d was the most active in this set reducing the cell viabilities of HT-29 and SW620 cells lines to 38% and, 36.7%, compared to 5-FU which demonstrated cell viabilities of 65.9 and 42.7%, respectively. Hence, compound 15d was selected for further mechanistic studies. The results indicated that compound 15d inhibited cell viability in a dose-dependent manner. The IC50 for 15d was ~20 μg/ml for HT-29 and SW620 cells (Supplementary Figures 2 and 3). These results were again confirmed using the xCELLigence RTCA system, which measures the cytotoxic effect of inhibitors in real time at different time points and 15d was found to inhibit the cell proliferation in human CRC HT-29 and SW620 cell lines in dose- and time-dependent manner (Supplementary Figures 4 and 5).

**Evaluation of anti-apoptotic protein expression by compound 15d**

SW620 cells were treated with various concentrations of 15d for 24 h. Subsequently, cell lysates were immunoblotted with the indicated antibodies in order to investigate the mechanism via which this compound inhibited cell viability of human CRC cells. Results shown in Supplementary Figure 6 indicated that 15d inhibited the anti-apoptotic proteins, Bcl2 and BclXL. These findings demonstrate that compound 15d inhibited the cell viability of human CRC cells by down regulating the expression of Bcl2 and BclXL and triggering the apoptotic pathway.

**In vitro evaluation of antiphospholipase A2 (PLA2) and antiproteases activities of the synthesised 3H-quinazolin-4-one derivatives**

As inflammation is associated with several types of cancers via influencing growth, apoptosis, and proliferation of cancer and stromal cells, the synthesised 3H-quinazolin-4-one derivatives were further screened to evaluate their antiphospholipases activities against proinflammatory enzymes implicated in cancer namely, hGLA, hGV, and X10. In addition, the inhibitory activity of these compounds towards the allergen and inflammatory PLA2 from honey bee venom (Apis mellifera, AmPLA2) and proinflammatory, haemolytic, myotoxic and neurotoxic Cobra (Naja mosambique...
mosambique) venom PLA2 (NmPLA2) were evaluated by determining their IC_{50} values. Results (Supplementary Table 1) revealed that six compounds, namely, 5a, 8c, 8d, 8j, 15a, and 15d displayed the most promising potency in inhibiting the catalytic activity of the studied hG-Ia, with IC_{50} values ranging from 5.75 ± 0.106 to 8.60 ± 0.56 µg/ml compared to that recorded with oleanolic acid which was used as a standard drug (5.25 ± 0.35 µg/ml). Among these compounds, 8d exhibited the lowest IC_{50} value (5.75 ± 0.106 µg/ml).

The anti-PLA2 hGV data showed that three compounds; 5a, 8d, and 8j inhibited the enzyme with IC_{50} values ranging from 6.25 ± 0.78 to 9.60 ± 0.85 µg/ml compared to the value recorded with the standard drug (oleanolic acid, IC_{50}; 7.50 ± 0.71 µg/ml). Amongst them, compound 8j (IC_{50}; 6.25 ± 0.78 µg/ml), was being more potent than the reference drug.

The analysis of the inhibitory potency of the examined compounds against PLA2 H-GX showed that compounds; 5a, 5b, 5c, 8d, 8j, 10, 15a, and 15e inhibited the enzymatic activity with IC_{50} values ranging from 6.60 ± 0.85 to 9.50 ± 0.71 µg/ml. It worth to note that compounds 8d, 15a, and 15e exhibited lowered IC_{50} values than the reference drug (IC_{50}; 7.55 ± 0.64 µg/ml).

Amongst the tested 3H-quinazolin-4-one derivatives which exhibited inhibitory activity against NmPLA2 were compounds; 5a, 5b, 5c, 8d, 8e, 8f, 15a, and 15d with IC_{50} values ranging from 4.15 ± 0.50 to 8.50 ± 2.12 µg/ml compared to oleanolic acid (IC_{50}; 4.90 ± 0.42 µg/ml). Interestingly, compound 5b demonstrated the lowest IC_{50} which is also lower than that of the reference drug fusspot.

Finally, 13 compounds namely, 5a, 5b, 5c, 8b, 8c, 8d, 8e, 8f, 8i, 10, 15a, 15d, and 15e effectively suppressed AmPLA2 with IC_{50} values ranging from 4.20 ± 0.57 to 9.40 ± 0.85 µg/ml compared to the IC_{50} 4.20 ± 0.42 µg/ml value of oleanolic acid. Based on these results, AmPLA2 appears to be the maximally affected phospholipase by the synthesised compounds with compound 8f (IC_{50}; 4.20 ± 0.57 µg/ml) demonstrating inhibitory activity equivalent to that of the reference drug.

Similarly, the inhibitory potency of the selected 3H-quinazolin-4-one derivatives against five proteases namely, cathepsin-B, collagenase, thrombin, elastase, and trypsin was quantified by measuring and comparing the IC_{50} values produced by these compounds relative to the value produced by the protease inhibitor cocktail. The results of anti-proteases shown in Supplementary Table 2 indicated that compounds 8j and 15e were being the most active inhibitors against protease cathepsin-B with IC_{50} values of 1.40 ± 0.06 and 1.60 ± 0.07 µg/ml respectively compared to cocktail (IC_{50}; 0.175 ± 0.04 µg/ml).

Furthermore, compounds 8b, 8d, and 15e were found to be the most active in suppressing the collagenase activity with IC_{50} values ranging from 3.00 ± 0.01 to 4.50 ± 0.71 µg/ml compared to cocktail (IC_{50}; 0.15 ± 0.07 µg/ml) with compound 8d exhibiting the lowest IC_{50} value.

The highest anti-thrombin activity was demonstrated by compounds 5b, 5c, 8e, 10, and 15b, with IC_{50} values ranging from 0.90 ± 0.14 to 2.50 ± 0.71 µg/ml, with 5b demonstrating the lowest IC_{50} compared to cocktail (IC_{50}; 0.25 ± 0.07 µg/ml).

The highest anti-elastase activity was demonstrated by compounds 5b, 5c, 8e, 10, and 15b, with IC_{50} values ranging from 0.65 ± 0.02 µg/ml (compound 15b) to 1.75 ± 0.05 µg/ml (compound 5c) compared to that of cocktail (IC_{50}; 0.125 ± 0.04 µg/ml).

Finally, the lowest IC_{50} values ranging from 0.50 ± 0.00 to 2.25 ± 0.04 µg/ml against trypsin were demonstrated by compounds 5b, 5c, 8e, 10, and 15b, with compound 15b displaying the lowest IC_{50} compared to that of the reference drug (IC_{50}; 0.215 ± 0.04 µg/ml).

In vitro evaluation of inhibitory activities of 3H-quinazolin-4-one derivatives against enzymes implicated in metabolic syndrome

Considering an interactive relationship between diabetes and cancers, the in vitro inhibitory potential of the prepared 3H-quinazolin-4-one derivative against α-amylase, α-glucosidase, and xanthine oxidase (enzymes related to metabolic syndrome) was investigated.

The IC_{50} values exhibited by the chemical compounds against α-amylase activity are shown in Supplementary Table 3, which indicated that compounds 8d, 8h, 8j, 15a, 15b, 15e, and 15f, were more potent in suppressing the enzyme with IC_{50} values ranging from 94.00 ± 2.83 µg/ml (compound 15b) to 121.00 ± 9.90 µg/ml (compound 15e) than quercetin the reference drug (IC_{50}; 123.0 ± 2.83 µg/ml).

In addition, compounds 8g (IC_{50}; 3.25 ± 0.35 µg/ml), 8h (IC_{50}; 3.05 ± 0.21 µg/ml), and 8i (IC_{50}; 3.45 ± 0.64 µg/ml) were more potent in inhibiting α-glucosidase activity than quercetin (IC_{50}; 3.80 ± 0.28 µg/ml) (Supplementary Table 4).

Although none of the tested compounds was more effective than allopurinol (reference drug) in inhibiting xanthine oxidase (XO) activity (Supplementary Table 5) (IC_{50}; 0.65 ± 0.07 µg/ml), compound 8f (IC_{50}; 3.00 ± 1.41 µg/ml) was the most active among the tested compounds.

Conclusions

A series of 25 compounds incorporating the 3H-quinazolin-4-one scaffold were synthesised, 20 of which were new and fully characterised. Twenty-one compounds were screened for their cytotoxicity on human CRC cell lines HT-29 and SW620 using the MTT assay. Six compounds namely, 8a, 8f, 8j, 15a, 15b, and 15d potently reduced viability of both cell lines, with 15d the most active in this set displaying residual viability 38%, 36.7% against HT-29 and SW620 cells lines, respectively. Further mechanistic studies using 15d revealed that this compound inhibited the cell proliferation of HT-29 and SW620 cell lines in a dose- and time-dependent manner with IC_{50} values ~20 µg/ml. Evaluation of apoptotic protein expression by compound 15d revealed that it reduced the viability of the used human CRC cells by down regulating the expression of Bcl2 and Bclxl.

Based on these results, 15d could be considered as an attractive candidate for further investigations as a potential anticancer agent. Furthermore, the prepared compounds were screened for their inhibitory activities against certain phospholipases including, hG-Ia, hG-V, hG-X, NmPLA2, and AmPLA2, and five proteases namely, cathepsin-B, collagenase, thrombin, elastase, and trypsin, in addition to three enzymes involved in metabolic syndrome namely, α-amylase, α-glucosidase, and xanthine oxidase. Although none of the tested compounds showed good antiprotease activity, six compounds 8j, 8d/15a/15e, 5b, and 8f demonstrated higher antiphospholipases potential against proinflammatory isoforms hGV, hG-X, NmPLA2, and AmPLA2 than oleanolic acid, which was used as reference drug.

Therefore, these compounds would be of interest as preclinical candidates in trials for anticancer and anti-inflammatory drugs.

All the tested compounds were inactive against xanthine oxidase, whereas compounds 8d, 8h, 8j, 15a, 15b, 15e, and 15f elicited higher α-amylase inhibition than the reference drug quercetin. Furthermore, compounds 8g, 8h, and 8i were more...
potent in inhibiting α-glucosidase activity than the reference drug allopurinol. Consequently, these compounds can be considered as potential targets that can be further investigated for developing novel anti-diabetes mellitus (DM) drugs.

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Disclosure statement

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