Biological Activities of Quinoa Seeds Extract and their Effects on Antioxidants of Cancer Cells and Ultrastructure of *Candida tropicalis*

Sulaiman A. Alsalamah ,[a,]* Mohammed Ibrahim Alghonaim ,[a] Amani Alhejely , [b] Amal Naif Alshammari ,[b] and Mohammed A. Alfattah ,[c]

Over the current decade, drugs based on natural sources have attracted much consideration. Quinoa seeds extract (QSE) was analysed by gas chromatography-mass spectrometry which reflected the presence of 23 compounds. QSE exhibited anticancer effect against prostate (PC-3) and ovarian (SKOV3) cancer cell lines with IC_{50} 65.21 ± 0.24 µg/mL and 81.45 ± 0.79 µg/mL, respectively. Apoptosis of cancer cells was confirmed by flow cytometric analysis. Oxidative markers including catalase, glutathione, and superoxide dismutase decreased in specimens treated by QSE, while malondialdehyde increased in treated cancer cells. Growth of different yeasts was inhibited by QSE with different inhibition zones of 12±0.33, 13±1.5, and 21±0.5 mm. The minimum inhibitory concentration was 250, 125, and 31.2 µg/mL using *Candida glubruim, C. albicans,* and *C. tropicalis*, respectively. Transmission electron microscopy reflected ultrastructure changes in treated *C. tropicalis* by QSE, including cell wall rupture, collapse of cytoplasm, and shrinking of cytoplasmic membrane. It was concluded that QSE could suppress the proliferation of SKOV3 cells *in vitro* and induce their apoptosis. Moreover, the inhibition of tested yeasts might be mediated by ultrastructural changes.

DOI: 10.15376/biores.20.2.3612-3627

Keywords: Quinoa; Superoxide dismutase; Yeasts; Catalase; Cancer; Inhibition

Contact information: a: Department of Biology, College of Science, Imam Mohammad Ibn Saud Islamic University, Riyadh 11623, Saudi Arabia; b: Biology Department, AlDarb University College, Jazan University, Saudi Arabia; c: Department of Biology, College of Science, Jazan University, P.O. Box. 114, Jazan 45142, Kingdom of Saudi Arabia;

**Corresponding author: SAAlsalamah@imamu.edu.sa*

INTRODUCTION

Quinoa (*Chenopodium quinoa*), a species from the Chenopodiaceae family, is recognized as a pseudo-cereal originating from South America and has lately been familiarized to Europe, Asia, North America, and Africa. It serves as a natural source of food for humans due to its high nutritional value (Hernandez-Ledesma 2019). The *Chenopodium* genus is globally distributed, encompassing over 200 species, with seed colors including white to grey, red, and black. Quinoa is particularly valued as a nutritious food source, especially in developing nations. The seeds are rich with minerals and vitamins, as well as various bioactive compounds, including phenolics, carotenoids, and

flavonoids, which exhibit several biological properties (Vega-Gálvez *et al*. 2010). These metabolites are associated with a range of biological utilizations, including antimicrobial, anti-inflammatory, antioxidant, and anti-carcinogenic influences (Rahimi and Bagheri 2020). Some constituents of quinoa include phytosterols, betalains, phytoecdysteroids, saponins, polysaccharides, and phenolic compounds according to the review paper by Agarwal *et al*. (2023) and have antimicrobial, anticancer, and antiacetylcholisterenase properties. Khan and Javaid (2020a) mentioned that in addition to the quinoa seeds, the whole plant contains a variety of bioactive compounds that play an important role in the regulation of diabetics, in the prevention of inflammation, cancer suppression, management of cardiovascular, and obesity, besides other health issues.

The antifungal properties of quinoa saponins have been noted for their capability to bind with membranes steroids, which disrupts the membrane's integrity. In a previous study, quinoa saponins such as hederagenin and oleanolic acid glycosides suppressed *Candida albicans* growth (Woldemichael and Wink 2001). According to Bhaduri (2016), the extract of quinoa seeds inhibited some bacteria, namely *Enterococcus faecalis*, *P. aeruginosa,* and *Staphylococcus epidermidis.* However Park *et al*. (2017) did not record antibacterial properties of quinoa seed extracts (QSE) against *Listeria monocytogenes*, *Escherichia coli*, *Listeria monocytogenes*, *Staphylococcus aureus*, *Campylobacter jejuni*, *Salmonella typhimurium*, and *Bacillus cereus.* A gas chromatography-mass spectrometric (GC-MS) investigation of quinoa stems exhibited the occurrence of some composites which reflected antifungal, antibacterial, and antioxidant functional (Khan and Javaid 2019). Also *via* GC-MS analysis, several compounds were detected in quinoa leaves which repressed the growth of *Macrophomina phaseolina* (Khan and Javaid 2020b).

One of the most fatal diseases with a high occurrence in recent decades is cancer, which is a term used to describe about 100 different forms of malignant tumors with varying pathological and etiological characteristics (Al-Rajhi *et al*. 2022; Alghonaim *et al.* 2023). The current study concentrated on two cancer types: ovarian and prostate cancer. Recent research indicates that ovarian cancer is the most lethal gynecologic cancer, with less than half of patients surviving for more than five years following diagnosis (Li *et al*. 2024). Ovarian cancer is most often detected after menopause; however it can affect women at any age (Baker 2024). Regarding the other kind of cancer, 15% of all malignancies in males are prostate cancers, making it the second most frequent kind of male cancer (Almeeri *et al*. 2024). James *et al*. (2024) reviewed several scientific papers and concluded that prostate cancer cases will reach to 2.9 million infections in 2040, while in 2020 the number of cases was 1.4 million. Quinoa leaves extract showed anticancer activity against prostate cancer cell proliferation (Gawlik-Dziki *et al*. 2013). Human breast cancer (MCF-7) was inhibited by quinoa seeds because of the presence of several phenolic acids in their extract (Liu *et al*. 2020). Allami *et al*. (2022) indicated that QSE possess anticancer potential against hepatocarcinoma cell line (HepG2). The anticancer properties of quinoa seeds were linked to the existence of polyphenolic compounds, betalain saponin, flavonoids, and carotenoids, as reported previously (Pellegrini *et al*. 2017). Also, Hu *et al*. (2017) found that polysaccharide, phytoecdysteroids, and bioactive peptides of quinoa served as anticancer agents. Numerous cervical carcinoma cell lines in human namely C4-I, HTB-34, and HTB-35, were suppressed by quinoa extract (Pasko *et al*. 2019). As mentioned in the present introduction, QSE has been shown to possess anticancer and antimicrobial activities. The novelty of the present investigation lies in its focus on the

mechanisms of anticancer and antiyeast activities. This study planned to estimate the bio-function of QSE against pathogenic yeasts and two kinds of cancer including prostate cells and ovarian cells with action mechanisms.

EXPERIMENTAL

Quinoa Seeds Extract Preparation and Its Characterization *via* GC-MS

The seeds of quinoa (*Chenopodium quinoa*) were sourced from the Agriculture Research Center, Jazan, Saudi Arabia. For the preparation of the QSE, 50 g of quinoa seeds (finely ground) were blended with 300 mL of methanol. The resulting mixtures were then allowed to sit in a shaking incubator for 45 min at 150 rpm and 25 °C (room temperature) prior to filtration. The clear extract was gathered and subsequently evaporated at 70 °C utilizing rotary evaporator to obtain 5 g dry weight extract. The GC-MS (Agilent 7890A, Agilent Technologies, Santa Clara, CA, USA) was utilized to characterize the obtained extract from quinoa seeds. The employed carrier gas was helium (flow proportion was 1 mL/min). The temperature of inlet, MSD ion source, filter mass, interface GC-MSD were 270, 170, 150, and 280 °C, respectively. The temperature of the column was programed serially at 60 °C (held for 2 min), 240 °C/min, and 300 °C/min. Compound identification was conducted utilizing the NIST MS data library.

Antitumor Activity of QSE with Malondialdehyde and Antioxidants Detection

The anticancer potential of QSE was examined using the MTT test on human prosterate (PC-3) and ovarian (SK-OV-3) cancer cells (American Type Culture Collection, Rockville, Maryland, United States). The cells were cultivated with the extract for 48 h at 37 °C with 5% CO_2 in a humidified incubator after being seeded at a density of 1×10^5 cells per well. About 10 µL of MTT reagent were applied to each well. Following a 4-h incubation period at 37 °C, the medium was extracted. Dimethyl sulfoxide (DMSO) was used to dissolve the formazan crystal. A microplate reader was employed to measure the absorbance at 570 nm. The inhibition of cells was recorded from the Eq. 1:

$$\text{Inhibition (\%)} = 1 - \frac{\text{Treated cells absorbance by the extract}}{\text{Untreated cells absorbance}} \times 100 \tag{1}$$

Glutathione malondialdehyde (MDA), Superoxide dismutase, and Catalase were determined according to Tsikas (2017), Zhao *et al*. (2019), and Kumar *et al*. (2012), respectively.

Cell Cycle and Apoptosis Analysis

For cell cycle analysis, the PC-3 and SK-OV-3 cells treated by 100 µg/mL of QSE for 48 h were harvested and then fixed through dipping in ice-cold 70% ethanol for 12 h at 4 °C. The pellets of cells were obtained *via* centrifugation (1000 rpm) and then resuspended in phosphate buffered saline (PBS), a commonly used buffer in cell biology that maintains a stable pH. Propidium iodide (PI) was used to staining the tested cells and analyzed using a flow cytometer (CytoFLEX, CA, USA). For analysis of cell apoptosis, apoptosis-mediated PC-3 and SK-OV-3cells death was detected by FITC-labeled Annexin V/PI. The

resuspended PC-3 and SK-OV-3cells in PBS were mixed with Annexin V and PI for 15 min in dark. The apoptosis of tested cells were assessed using the flow cytometer.

Yeast Inhibition Evaluation Using QSE

The well-plate agar diffusion method was used with slight modifications, to evaluate QSE anti-yeast efficacy against *Candida glabrata* (66032), *Candida albicans* (ATCC 10221), and *Candida tropicalis* (66029) in accordance with Almehayawi *et al*. (2024). The studied yeasts were placed in petri dishes after being standardized (according to the 0.5 McFarland scale) and sown in sterile Sabouraud dextrose agar (SDA) medium. Four wells (6 mm radius) were cut from the solidified SDA medium *via* sterile cork borer. The tested QSE (100 µL of 100 µg/mL) was injected into the wells using an automated microlitre pipette. Nystatin, an antifungal, served as a standard control, and DMSO was served as an un-effective control. The cultivated plates were then refrigerated at 4 °C for 1 h. After that, it was kept for 2 days at 35 °C in an incubator. The imaged clear zones were documented using a calibrated ruler (Al-Rajhi *et al*. 2023).

Detection of Minimum Inhibitory Concentration of QSE

The minimum inhibitory concentration (MIC) of QSE against the investigated yeasts were examined. A dilution equal to 0.5 McFarland was made for every type of yeast. The QSE was diluted to a dose of 1.0 mg/mL. RPMI 1640 broth (100 µL) was poured in the well of 96-well microtiter plate, then 100 µL of serial dilutions of QSE dose (3.9 to 500 µg/mL) was mixed with RPMI 1640 broth. The wells were inoculated with 100 µL (0.5 McFarland) of the studied yeast suspensions whereas wells devoid of yeast cell suspensions functioned as a negative control. After that, the plate was incubated at 30 °C for one day. MIC was the lowest extract concentration that resulted in a 50% drop in growth when compared to the controls. (Alsalamah *et al*. 2023).

Ultrastructure Investigation of *C. tropicalis* by Transmission Electron Microscopy (TEM)

C. tropicalis was the most sensitive to QSE compared to other tested yeasts. Therefore, it was selected for further study *via* TEM investigation. *Candida tropicalis* treated by a sub-dose of extract MIC (20 and 30 µg/mL) was initially cultured for one day before being viewed under a microscope. The cultures were then ready for TEM examination. The treated *C. tropicalis* was centrifuged at each step of the procedure: the fixation and dehydration stages took 5 min at 1500 rpm, and the infiltration stage took 10 min at 3000 rpm. After being received, the pellets were fixed for 30 min at 25 °C, employing 2% glutaraldehyde that had been dissolved in 0.05 M sodium phosphate. Using 1% solution of OsO_4, *C. tropicalis* cells were post-fixed with for 2 h at 5 °C, next being washed with sodium phosphate. After that, sample of *C. tropicalis* was desiccated for 2 h in ethanol. After 3 h of infiltration into each of the resin/ethanol sequences (20/80, 40/60, 60/40, and 80/20), the samples were left in 100% Spurr resin for 12 h. After being "sandwiched" in 100% Spurr resin and sprayed with a Teflon-like substance, the pellets were finally placed into coverslips to go through a 24-h polymerization process at 60 °C. After cooling, the coverslips were taken off and examined under a stereomicroscope to scrape off any resin fragments that contained pellets. The samples of *C. tropicalis* cells were then dried in an ethyl alcohol sequences (15%, 30%, 50%, 75%, and 100%) for 2 h

each. Next came 3 h of infiltration into the resin/ethyl alcohol sequences 20/80, 40/60, 60/40, and 80/20. The samples of *C. albicans* were incubated for 12 h at 100% Spurr resin. The pellets were ultimately put into coverslips to undergo a 24-h polymerization process at 60 °C after being "sandwiched" in 100% Spurr resin and sprayed with a Teflon-like material. Coverslips were removed once cooled and inspected under a stereomicroscope to eliminate any pellet-containing resin pieces. The pellets were cut *via* a Leica Ultracut R ultramicrotome, then located in resin blocks and examined by TEM (Hitachi H7500, running at 100 keV) (Abd El-Ghany and Tayel 2009).

Statistical Analysis

The analyses were performed as mean ± standard deviation (SD) and were estimated employing Microsoft Excel 365 and SPSS v.25.

RESULTS and DISCUSSION

The GC-MS analysis of QSE revealed the presence of 23 compounds in different retention times, molecular weight, area%, and molecular formula (Table 1 and Fig. 1). Ethyl oleate, followed by ethyl-9,12-octadecadienoate, ethyl hexadecanoate, ethyl octadecanoate, and glyceryl monooleate, were detected with high area% as 24.3%, 13.4%, 7.33%, 7.19%, and 3.50%, respectively. Other compounds were detected at area % ranging from 0.25% to 2.47%. Leaves extract of quinoa was analysed *via* by GC-MS (Khan and Javaid 2022). Nine compounds were detected, from which 1,2-benzedicarboxylic acid, diisooctyl ester, and stigmasterol exhibited fungicidal effects against *M. phaseolina.* Carranza-Concha *et al*. (2021) mentioned that the chemical constituents of QSE and their levels of biological activities can differ among varieties. Some of the identified in QSE such as n-hexadecanoic acid demonstrated effect on human colon cancer cells IC_{50} quantity of 36.04 µg/ml (Bharath *et al.* 2021). Also flavone 4'-OH,5-OH,7-Di-O-glucoside reflected antioxidant and anticancer properties (Khan *et al.* 2021). n-Hexadecanoic acid and ethyl oleate according to study by Saravanakumar *et al.* (2018) have been employed as antimicrobial and antioxidant agents.

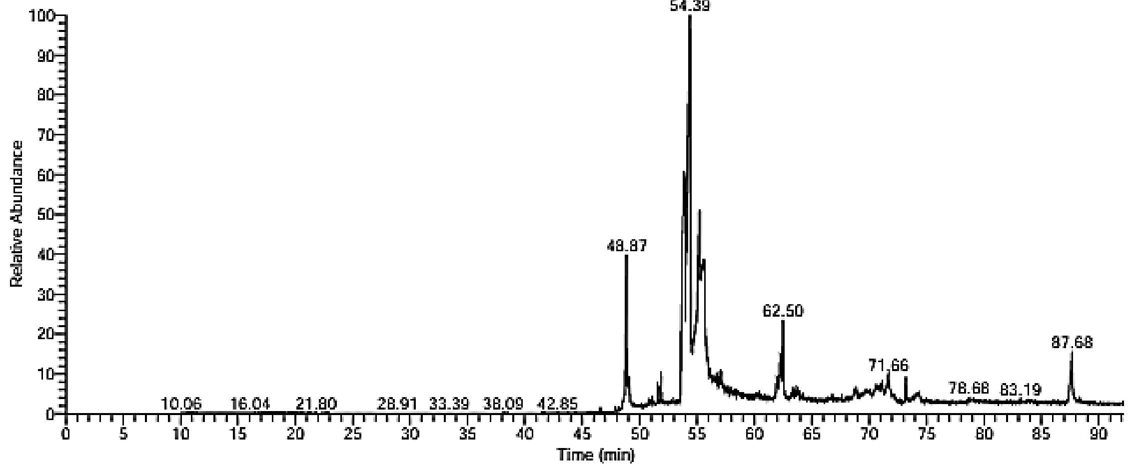

Fig. 1. GC-MS chromatograms of QSE

The cells of PC-3 and SK-OV-3 were affected by the QSE, but PC-3 was more affected than SK-OV-3 at all studied doses. For instance, up to a dose of 250 µg/mL QSE, the toxicity level reached to 96.3% for PC-3, while it was 21.4% for SK-OV-3 (Fig. 2). Moreover, the IC_{50} quantities of QSE were 65.21 ± 0.24 and 81.45 ± 0.79 µg/mL for PC-3 and SK-OV-3, respectively. The QSE was tested on normal Vero cells (ATCC: CCL-81) but gave high IC_{50} 213.52 ± 2.33 µg/mL (data not tabulated). The influence of QSE was noticed on the morphological profile of tested cancer cells, as illustrated in Fig. 3. The change that occured in PC-3 cell shape was highly influenced by quinoa extract compared to their effect on SK-OV-3 cells, particularly at high doses of the extract.

Table 1. Detected Compounds in QSE *via* GC-MS Analysis

*RT (min)	Area (%)	Compound	Formula	**MW (g/mol)
46.56	0.25	Methyl hexadecanoate	$C_{17}H_{34}O_2$	270
48.51	0.20	Octadec-9-enoic acid	$C_{18}H_{34}O_2$	282
48.86	7.33	Ehtyl hexadecanoate	$C_{18}H_{36}O_2$	284
49.12	1.32	n-Hexadecanoic acid	$C_{16}H_{32}O_2$	256
50.81	0.29	(9E,12Z)-octadeca-9,12-dienoic acid	$C_{18}H_{32}O_2$	280
51.58	1.20	9,12-Octadecadienoic acid, methyl ester, (E,E)	$C_{19}H_{34}O_2$	294
51.86	1.51	Methyl octadec-9-enoate	$C_{19}H36O_2$	296
53.80	13.43	Ethyl-9,12-octadecadienoate	$C_{20}H_{36}O_2$	308
54.39	24.29	Ethyl oleate	$C_{20}H_{38}O_2$	310
54.59	1.63	9,12-Octadecadienoyl chloride, (Z,Z)	$C_{18}H_{31}ClO$	298
55.22	7.19	Ethyl octadecanoate	$C_{20}H_{40}O_2$	312
62.26	2.25	Linoleoyl chloride	$C_{18}H_{31}ClO$	298
62.51	3.50	Glyceryl monooleate	$C_{21}H_{40}O_4$	356
63.35	0.47	(Z,Z)-1,3-Dioctadecenoyl glycerol	$C_{39}H_{72}O_5$	610
63.80	0.46	(9Z)-9-Hexadecenoic acid 2-oxiranylmethyl ester	$C_{19}H_{34}O_3$	310
67.62	0.25	(Z,Z)-1,3-Dioctadecenoyl Glycerol	$C_{39}H_{72}O_5$	620
68.68	0.33	Linolein, 2-mono	$C_{21}H_{38}O_4$	354
70.52	0.27	Tricyclo[20.8.0.0(7,16)]triacontane, 1(22),7(16)-diepoxy	$C_{30}H_{52}O_2$	444
73.21	1.21	Supraene	$C_{30}H_{50}$	410
74.33	0.36	1,2,3-propanetriyl tris[(E)-9-octadecenoate	$C_{57}H_{104}O_6$	884
78.68	0.25	Flavone 4'-OH,5-OH,7-Di-O-glucoside	$C_{27}H_{30}O_{15}$	594
87 .67	2.47	(9E)-9-Hexadecenyl (9E)-9-hexadecenoate	$C_{32}H_{60}O_2$	476
88 .31	0.31	2-[12-(oxiran-2-yl)dodecyl]oxirane	$C_{16}H_{30}O_2$	254

*RT: Retention time, **MW: Molecular weight

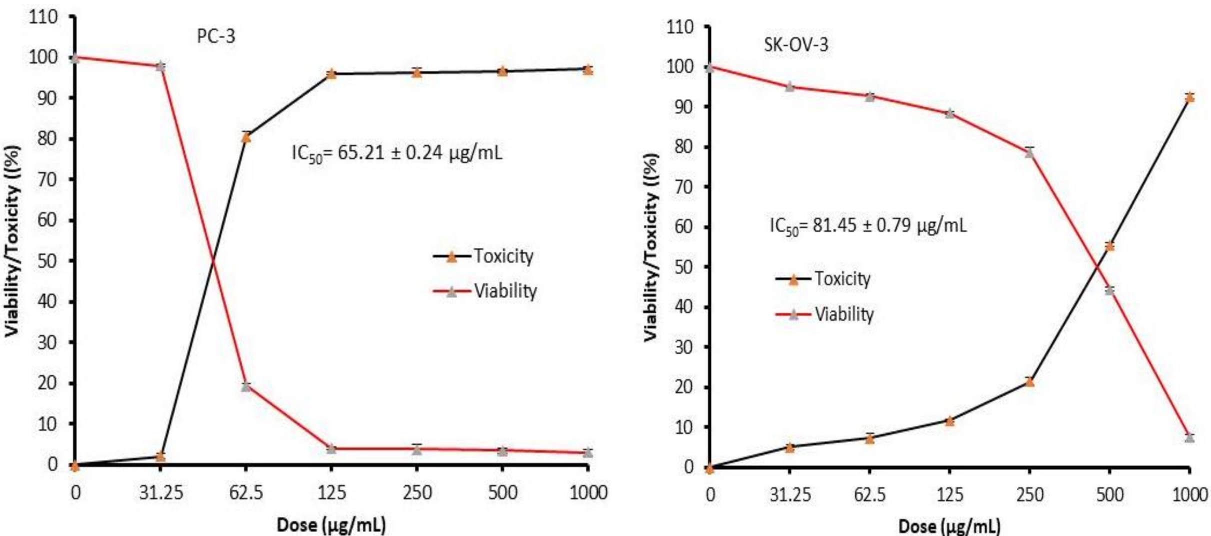

Fig. 2. Toxicity of quinoa seeds extract against PC-3 and SK-OV-3 cancer cell lines

The cells appeared to be circular, and led to shrinkage of cells, besides aggregation due to the effect of the QSE, particularly at high doses. These results indicated that QSE may perform a vital effect in the chemoprevention of tumor. According to Shen *et al.* (2022), in a dose-dependent manner, seed oil of black quinoa displayed anti-propagation influence on HCT 116 cells *via* the stimulation of apoptosis. In a previous study, polysaccharide composed of glucose and galacturonic acid separated from *C. quinoa* seeds exhibited multiple biological functions including immune-regulatory, antioxidant, and anticancer (human liver cancer and human breast cancer) effects *in vitro* (Hu *et al*. 2017). Mollaei *et al*. (2021) observed that lung cancer cells apoptosis was induced by exposure to QSE, and apoptosis was accompanied by increasing the *BAX*/*BCL2* ratio. The anticancer potential of quinoa seeds may be attributed to the presence of some constituents such as 1H-indole-3-carboxaldehyde and benzaldehyde, 4-hydroxy- as mentioned previously (Khan and Javaid 2020a). Excellent IC_{50} value (14.6 µg/mL) was recorded using QSE against HepG2 (Mohamed *et al.* 2019). The powder of quinoa seeds was attractive (IC_{50} was 14.6 µg/mL) against hepatocarcinoma cell line of HepG2 (Allami *et al*. 2022). Additional, quantification of QSE-stimulated apoptosis of PC-3 and SK-OV-3 cells was conducted by flow cytometric assessment (Figs. 4 and 5). Cellular DNA content in cancer cells was analysed after staining by propidium iodide, the analysis showed four phases G0/G1/S/G2-M, which reflect that it probably can be used to determine cell cycle arrest, which is correlated to the quantity of DNA in all phases separately. The outcomes of cycle analysis explained that the PC-3 and SK-OV-3 cells presented an increase in proliferation of cells, but QSE treatment exhibited a decline in cell development, indicating a progress of apoptosis. The results of Mollaei *et al*. (2021) indicated that quinoa may possess fatal properties on the MCF-7 through apoptotic mechanism. A similar remark concerning cell cycle arrest at various stages was recognized by El Makawy *et al*. (2024); they showed that quinoa extract efficaciously arrested the cycle of cancer cells at the G0/G1. According to Shang *et al*. (2024), saponins of quinoa (40 µg/mL) decreased the HT-29 cells viability, where the cell cycle illustrated that the cell number proportion in the G0/G1 phase

multiplied by 23.0%, besides the apoptosis percentage being raised by 22.6%. As mentioned in Table 2, the oxidative markers were influenced in treated cells by quinoa extract. Catalase, glutathione, and superoxide dismutase (SOD) declined in treated cells, while MDA increased (16.9±0.80 and 20.13±1.05 µmol/mg protein in PC-3 and SKOV-3, respectively) in treated cells. The present findings were similar with a recent investigation that used the cinnamon plant and other cancer cells (breast and human fetal lung fibroblast) (Selim *et al.* 2024).

Table 2. Malondialdehyde and Antioxidants in PC-3 and SK-OV-3 Cancer Cell Lines Treated by Quinoa Seeds Extract

Cell Type		MDA (µmol/mg protein)	Catalase (U/mg protein)	Glutathione Reduced (mmole/mg protein)	SOD (U/mg protein)
PC-3	Control	7.23±0.31	23.50±0.87	28.43±0.68	25.43±0.61
	Treated	16.9±0.80	13.97±1.60	12.53±1.27	11.83±1.62
SKOV-3	Control	9.10±0.46	30.67±1.46	21.50±0.82	17.30±0.60
	Treated	20.13±1.05	19.03±2.02	15.77±0.31	7.77±0.25

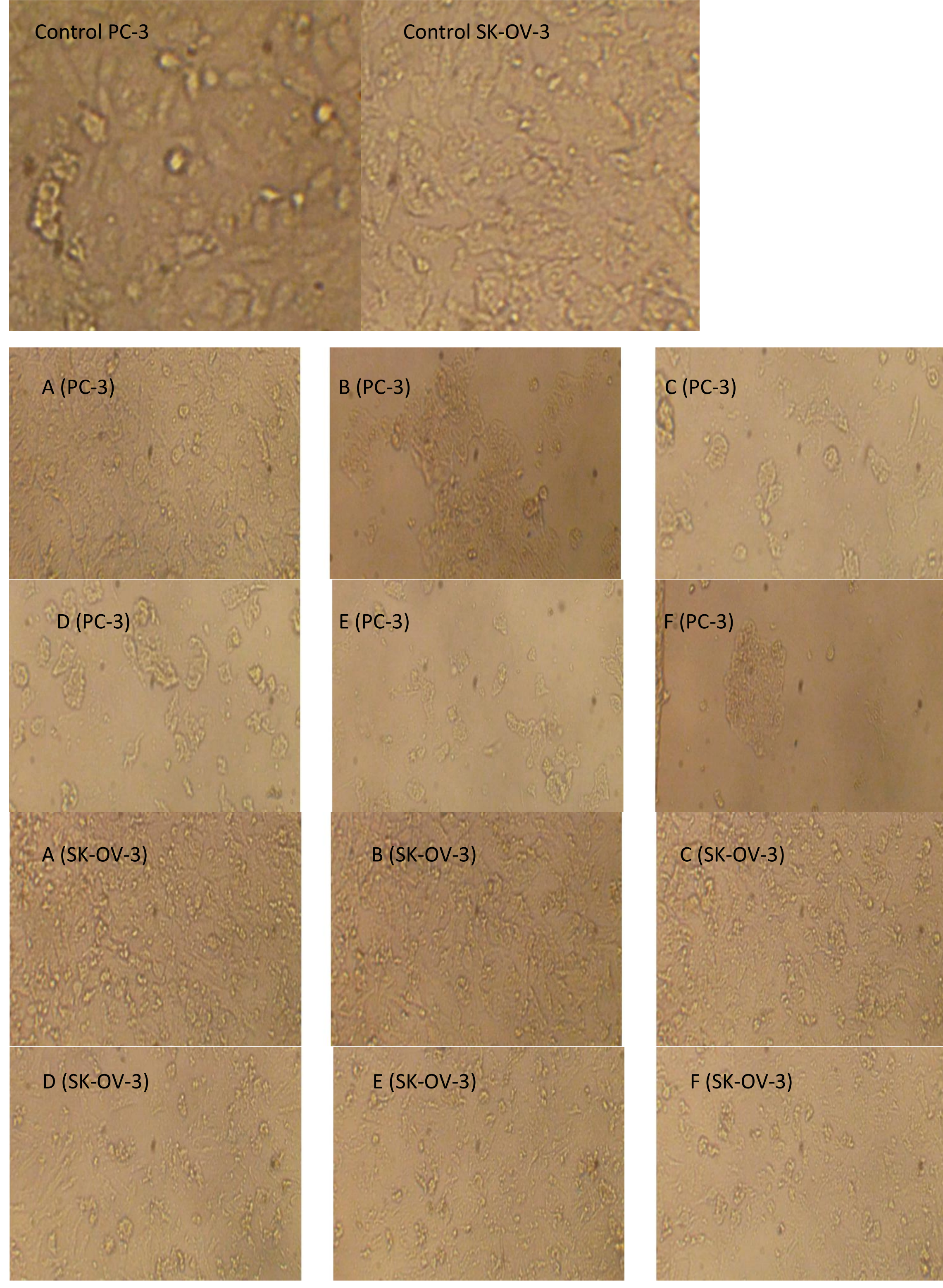

Fig. 3. Morphological changes in treated PC-3 and SK-OV-3 cancer cell lines treated by different doses of quinoa seeds extract. A, 31.25; B, 62.5; C,125; D, 250; E, 500; and F, 1000 µg/mL

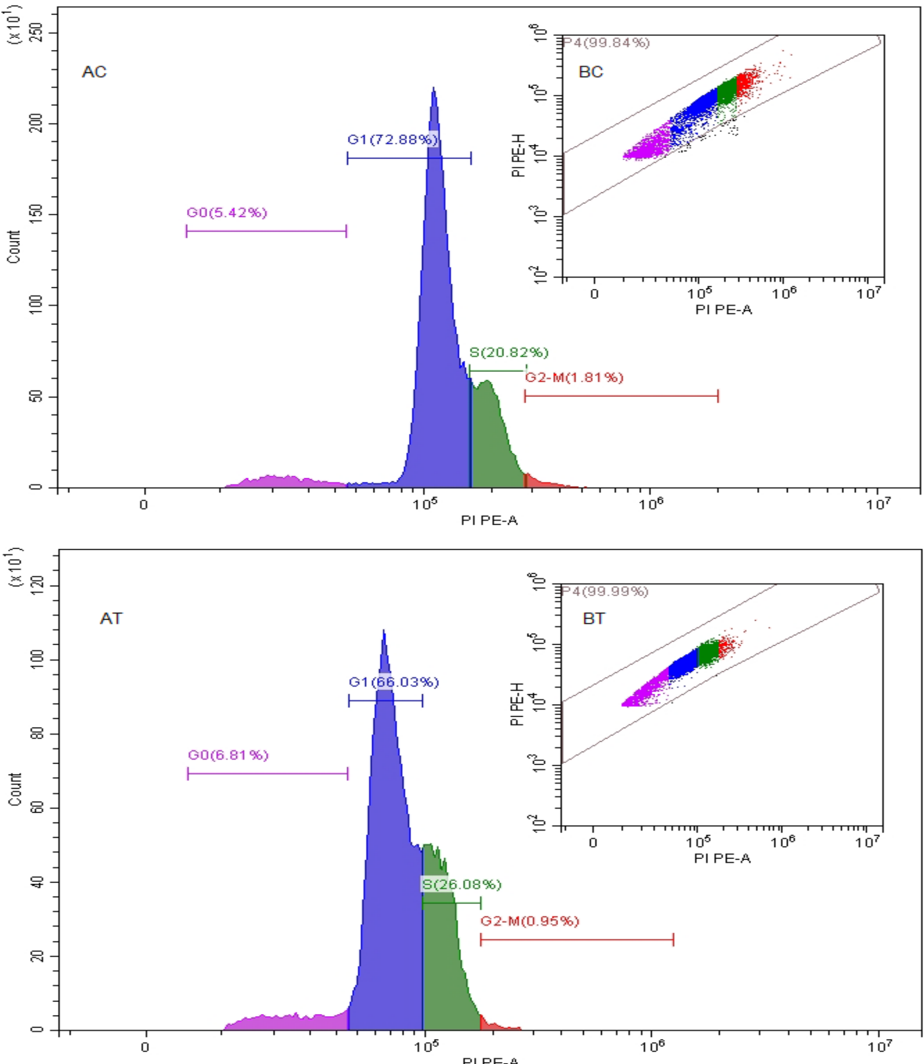

Fig. 4. Flow cytometric assess of PC-3 (AC) and apoptosis rate (BC) (control), Flow cytometric assess of PC-3 (AT) treated and apoptosis rate BT (treated)

The recorded results indicated that QSE inhibited the tested yeasts but less than the effect of the standard drug (Table 3 and Fig. 6). *Candida tropicalis* was the most susceptible (inhibition zone 21±0.5 mm), followed by *C. albicans* (inhibition zone 13±1.5 mm), and *C. glubruim* (inhibition zone 12±0.33 mm) with MIC values of 31.25, 125, and 250 µg/mL, respectively. *Candida tropicalis* was examined *via* TEM to show the effect of quinoa extract on their ultrastructure; remarkable changes were watched in the treated cells including cell wall, collapse of cytoplasm, and shrinking of cytoplasmic membrane at 20 µg/mL (Fig. 7). At 30 µg/mL, damage with rupture in cell wall was observed besides appearance of irregular cytoplasm. These changes were compared to the untreated cell (control), which was observed in identical form. Antimicrobial activities of crude polysaccharide extracts were tested against various bacteria and yeasts. The extracts inhibited bacteria but not inhibited *Cryptococcus neoformans* and *C. albicans* (Zhu *et al*. 2024). Sen *et al*. (2024) documented the antifungal and anticancer characteristics of quinoa-derived peptides and consequently suggested their possible use in drug industry.

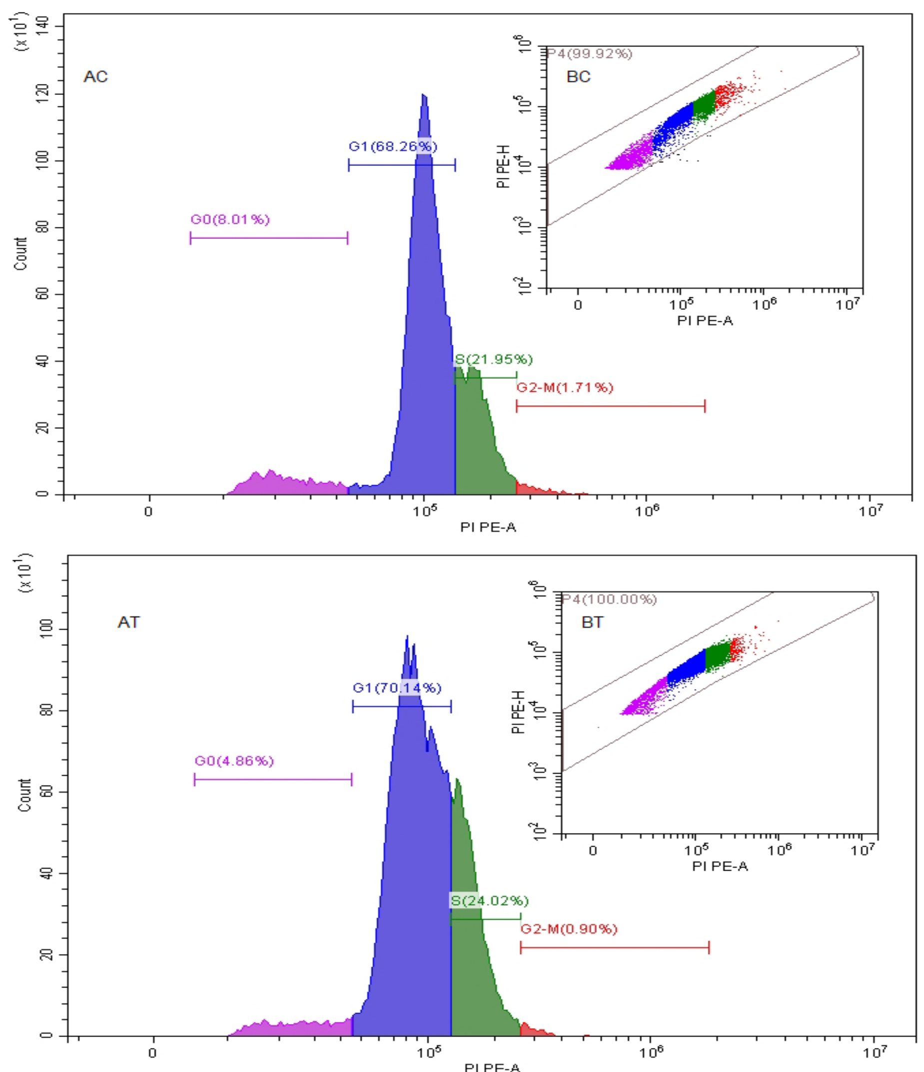

Fig. 5. Flow cytometric assess of SK-OV-3 (AC) and apoptosis rate (BC) (control), Flow cytometric assess of SK-OV-3 (AT) treated and apoptosis rate BT (treated)

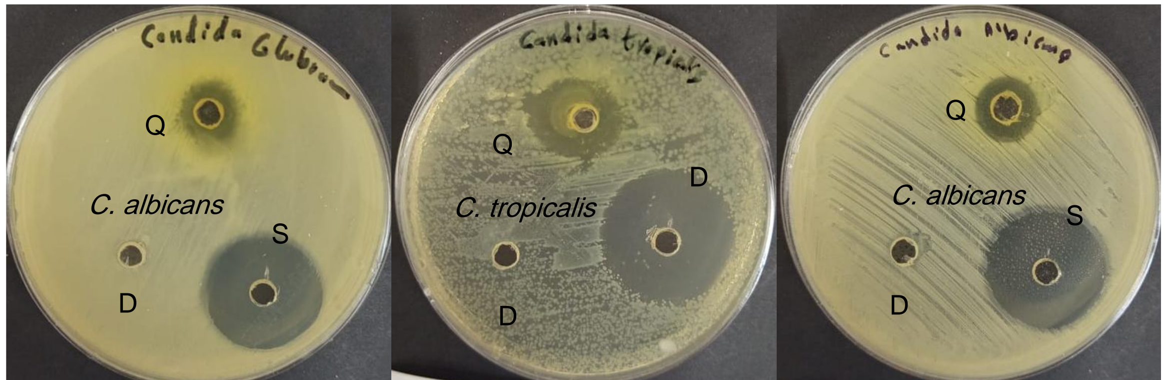

Fig. 6. Inhibition of different species of yeasts by quinoa extract (Q), fluconazole (S), and DMSO (D)

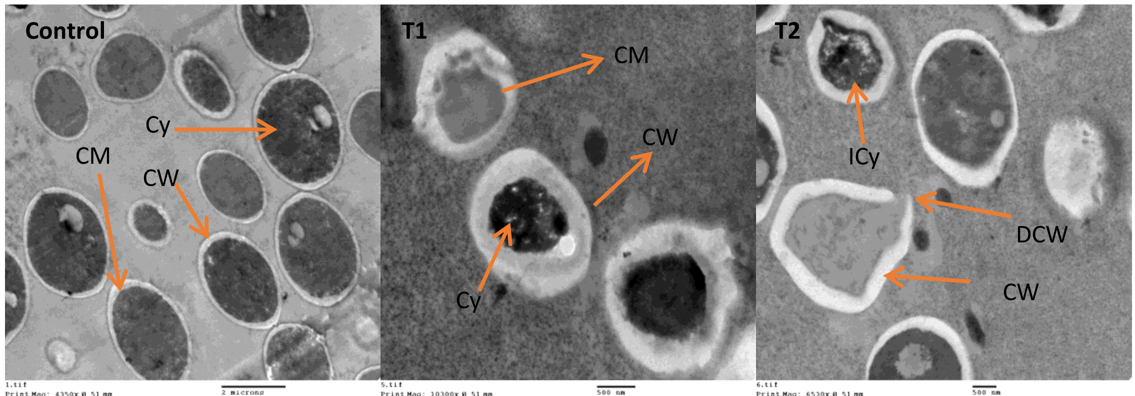

Fig. 7. Ultrastructure of *C. tropicalis* at two different doses of quinoa seeds extract 20 µg/mL (T1) and 30 µg/mL (T2). (CW, cell wall; CM, cell membrane; Cy, cytoplasm; ICy, irregular cytoplasm; DCY, damage cell wall)

Table 3. Inhibition of Different Yeasts of Quinoa Seeds Extract with MIC Values

Tested Yeast	Inhibition Zone (mm)			MIC (µg/mL	
	Extract	Standard	DMSO	Extract	Standard
C. albicans	13±1.5	28±0.5	0.0	125	3.9
C. tropicalis	21±0.5	30±0.33	0.0	250	7.8
C. glubruim	12±0.33	27±0.66	0.0	31.25	15.62

CONCLUSIONS

1. By means of gas chromatograpy-mass spectrometry (GC-MS), numerous compounds were detected in quinoa seed extract (QSE); moreover, the ethyl oleate represented the main detected compound with the highest area %
2. The results showed that the PC-3 and SK-OV-3 cells were sensitive to quinoa seeds extract.
3. The pathogenic yeasts namely *Candita tropicalis*, *C. albicans*, and *C. glubruim* were inhibited by QSE with different levels of inhibitions.
4. Transmission electron micrscopy (TEM) investigation showed changes in the ultrastructure of *C. tropicalis* that had been exposed to different doses of QSE.

FUNDING

The authors wish to appreciate the Deanship of Scientific Research at Imam Mohammad Ibn Saud Islamic University (IMSIU) for the support and funding the current study (Grant number IMSIU-DDRSP2501).

REFERENCES CITED

Abd El-Ghany, T. M., and Tayel, A. (2009). "Efficacy of certain agrochemicals application at field rates on soil fungi and their ultrastructure," *Res. J. Agric. Biol. Sci.* 5(2), 150-160. DOI:10.1016/j.btre.2020.e00496

Abdelghany, T. M., Hassan, M. M., El-Naggar, M. A., and Abd El-Mongy, M. (2020). "GC/MS analysis of *Juniperus procera* extract and its activity with silver nanoparticles against Aspergillus flavus growth and aflatoxins production," *Biotechnology Reports* 27, article e00496 . DOI:10.1016/j.btre.2020.e00496

Agarwal, A., Tripathi A. D., Kumar T., Sharma K. P., and Patel S. K. S. (2023). "Nutritional and functional new perspectives and potential health benefits of quinoa and chia seeds," *Antioxidants* 12(7), article 1413. DOI:1010.3390/antiox12071413

Alghonaim, M. I., Alsalamah, S. A., Alsolami, A., and Abdelghany, T. A. (2023). "Characterization and efficiency of *Ganoderma lucidum* biomass as an antimicrobial and anticancer agent," *BioResources* 18(4), 8037-8061. DOI: 10.15376/biores.18.4.8037-8061

Allami, R. H., Mohsin, R. H., and Al-lami, M. S. (2022). "Cytotoxicity of alcoholic extract of quinoa seed against some cancer cell lines," *Chinese Journal* of *Medical Genetics* 32(4), 525-532

Almeeri, M. N. E., Awies, M., and Constantinou, C. (2024). "Prostate cancer, pathophysiology and recent developments in management: A narrative review," *Current Oncology Reports* 1-9. DOI: 10.1007/s11912-024-01614-6

Almehayawi, M. S., Almuhayawi, M. S., El-Fadl, S. R. A., Nagshabandi, M. K., Tarabulsi, M. K., Selim, S., Alruwaili, Y. S., Mostafa, E. M., Al Jaouni, S. K., and Abdelghany, T. M. (2024). "Evaluating the anti-yeast, anti-diabetic, wound healing activities of *Moringa oleifera* extracted at different conditions of pressure via supercritical fluid extraction," *BioResources* 19(3), 5961-5977. DOI: 10.15376/biores.19.3.5961-5977

Al-Rajhi, A. M. H., Qanash, H., Bazaid, A. S., Binsaleh, N. K., and Abdelghany, T. M. (2023). "Pharmacological evaluation of *Acacia nilotica* flower extract against *Helicobacter pylori* and human hepatocellular carcinoma *in vitro* and *in silico*," *J. Funct. Biomater.* 14(4), article 237. DOI: 10.3390/jfb14040237

Al-Rajhi, A. M. H., Yahya, R., Abdelghany, T. M., Fareid, M. A., Mohamed, A. M., Amin, B. H., and Masrahi, A. S. (2022). "Anticancer, anticoagulant, antioxidant, and antimicrobial activities of *Thevetia peruviana* latex with molecular docking of antimicrobial and anticancer activities," *Molecules* 27(10), article 3165. DOI: 10.3390/molecules27103165

Alsalamah, S. A., Alghonaim, M. I., Jusstaniah, M., and Abdelghany, T. M. (2023). "Anti-yeasts, antioxidant and healing properties of henna pre-treated by moist heat and molecular docking of its major constituents, chlorogenic and ellagic acids, with *Candida albicans* and *Geotrichum candidum* proteins," *Life* 13(9), article 1839. DOI:10.3390/life13091839

Baker, T. (2024). "Early detection, symptoms, and treatment options for ovarian cancer," *International Journal of Advanced Engineering Technologies and Innovations* 10(2), 332-343.

Bhaduri, S. (2016). “An assessment of antioxidant and anti-proliferative activities of super grain quinoa,” *J. Food Process Technol*. 7, article 549. DOI: 10.4172/2157-7110.1000549.

Bharath, B., Perinbam, K., Devanesan, S., AlSalhi, M. S., and Saravanan, M. (2021). “Evaluation of the anticancer potential of Hexadecanoic acid from brown algae Turbinaria ornata on HT–29 colon cancer cells,” *Journal of Molecular Structure* 1235, article 130229. DOI: 10.1016/j.molstruc.2021.130229

Carranza-Concha, J., Chairez-Huerta, S. G., Contreras-Martínez, C. S., and García-Martínez, E. (2021). “Characterization of nutritional and antioxidant properties of quinoa seeds (*Chenopodium quinoa* Willd.),” *Revista Fitotecnia Mexicana* 44(3), 357-365. DOI:10.35196/rfm.2021.3.357

El makawy, A. I., Abdel-Aziem, S. H., and Mohammed, S. E. (2024). “Exploration of tumor growth regression of quinoa and chia oil nanocapsules via the control of PIK3CA and MYC expression, anti-inflammation and cell proliferation inhibition, and their hepatorenal safety in rat breast cancer model,” *Bull Natl Res Cent.* 48, article 7. DOI:10.1186/s42269-023-01161-3

Gawlik-Dziki, U, Swieca, M, Sulkowski, M, Dziki, D, Baraniak, B, and Czyz, J. (2013). “ Antioxidant and anticancer activities of *Chenopodium quinoa* leaves extracts - in vitro study,” *Food Chem Toxicol*. 57, 154-60. DOI:10.1016/j.fct.2013.03.023.

Gawlik-Dziki, U., Świeca, M., Sułkowski, M., Dziki, D., Baraniak, B., and Czyż, J. (2013). “Antioxidant and anticancer activities of *Chenopodium quinoa* leaves extracts–in vitro study,” *Food and Chemical Toxicology* 57, 154-160. DOI:10.1016/j.fct.2013.03.023

Hernandez-Ledesma, B. (2019). “Quinoa (*Chenopodium quinoa* Willd.) as source of bioactive compounds: A review,” *Bioact. Compd. Health Dis.* 2(3) 27-47. DOI:10.31989/bchd.v2i3.556

Hu, Y., Zhang, J., Zou, L., Fu, C., Li, P., and Zhao, G. (2017). “Chemical characterization, antioxidant, immune-regulating and anticancer activities of a novel bioactive polysaccharide from *Chenopodium quinoa* seeds,” *International Journal of Biological Macromolecules* 99, 622-629. DOI:10.1016/j.ijbiomac.2017.03.019

Kaur, I., and B. Tanvar. (2016). “Quinoa beverages: Formulation, processing and potential health benefits,” *Rom J. Diabetes Nutr. Metab. Dis*. 23(2), 215-225.

Khan, I. H., and A. Javaid. (2019). “Antifungal, antibacterial and antioxidant components of ethyl acetate extract of quinoa stem,” *Plant Protection* 3(03), 125-130.

Khan, I. H., and Javaid, A. (2020a). “Anticancer, antimicrobial and antioxidant compounds of *Quinoa inflorescence*,” *Adv. Life Sci*. 8(1), 68-72.

Khan, I. H., and Javaid, A. (2020b). “Antifungal activity and GC-MS analysis of n-butanol extract of quinoa (*Chenopodium quinoa* Willd.) leaves,” *Bangladesh Journal of Botany* 49(4), 1045-1051.

Khan, I. H., and Javaid, A. (2022). “Antifungal activity of n-butanol stem extract of quinoa against *Macrophomina phaseolina*,” *Pak. J. Bot.* 54(4), 1507-1510. DOI: 10.30848/PJB2022-4(7)

Khan, N., Ali, A., Qadir, A., Ali, A., Warsi, M. H., Tahir, A., and Ali, A. (2021). “GC-MS analysis and antioxidant activity of *Wrightia tinctoria* R. Br. leaf extract,” *J. AOAC Int*. 104, 1415-1419. DOI: 10.1093/jaoacint/qsab054

Kumar, A., Dutt, S., Bagler, G., Ahuja, P. S., and Kumar, S. (2012). "Engineering a thermo-stable superoxide dismutase functional at sub-zero to> 50 C, which also tolerates autoclaving," *Scientific reports* 2(1), 387. DOI:10.1038/srep00387

Li, X., Li, Z., Ma, H., Li, X., Zhai, H., Li, X., and Hao, Z. (2024). "Ovarian cancer: Diagnosis and treatment strategies," *Oncology Letters* 28(3), article 441. DOI: 10.3892/ol.2024.14574

Liu, M., Zhu, K., Yao, Y., Chen, Y., Guo, H., Ren, G., and Li, J. (2020). "Antioxidant, anti-inflammatory, and antitumor activities of phenolic compounds from white, red, and black *Chenopodium quinoa* seed," *Cereal Chemistry* 97(3), 703-713. DOI:10.1002/cche.10286

Mohamed, D. A., Fouda, K. A., and Mohamed, R. S. (2019). "In vitro anticancer activity of quinoa and safflower seeds and their preventive effects on non alcoholic fatty liver," *Pak. J. Biol. Sci*. 22(8), 383-392. DOI:10.3923/pjbs.2019.383.392

Mollaei, H., Karimi, F., Ghorbany, M., Hosseinzadeh, M. S., Moudi, M., and Mousavi-Kouhi, S. M. (2021). "Investigating cytotoxic effect and molecular mechanisms of quinoa seed extract against human lung cancer cell line," *Jentashapir Journal of Cellular and Molecular Biology* 12(4), article 121089. DOI: 10.5812/jjcmb.121089

Park, J. H., Lee, Y. J., Kim, Y. H., and Yoon, K. S. (2017). "Antioxidant and antimicrobial activities of quinoa (*Chenopodium quinoa* Willd.) seeds cultivated in Korea," *Prev. Nutr. Food Sci.* 22(3), 195-202. DOI: 10.3746/pnf.2017.22.3.195.

Pasko, P., Tyszka-Czochara, M., Namiesnik, J., Jastrzebski, Z., Leontowicz, H., Drzewiecki, J., Martinez-Ayala, A. L., Nemirovski, A., Barasch, D., and Gorinstein, S. (2019). "Cytotoxic, antioxidant and binding properties of polyphenols from the selected gluten free pseudo cereals and their byproducts: *In vitro* model," *J. Cereal Sci*. 87, 325-333. DOI:10.1016/j.jcs.2019.04.009

Pellegrini, M., Lucas-Gonzalez, R., Fernández-López, J., Ricci, A., Pérez Álvarez, J. A., Sterzo, C. L., and Viuda, M.. (2017). "Bioaccessibility of polyphenolic compounds of six quinoa seeds during in vitro gastrointestinal digestion," *J. Funct. Foods* 38(A), 77-88. DOI:10.1016/j.jff.2017.08.042

Rahimi, E., and Bagheri, M. (2020). "Chemical, antioxidant, total phenolic and flavonoid components and antimicrobial effects of different species of quinoa seeds," *Egyptian Journal of Veterinary Sciences* 51(1), 43-54. DOI:10.21608/ejvs.2019.17122.1098

Saravanakumar, K., Chelliah, R., Ramakrishnan, S. R., Kathiresan, K., Oh, D. H., and Wang, M. H. (2018). "Antibacterial, and antioxidant potentials of non-cytotoxic extract of *Trichoderma atroviride*," *Microbial Pathogenesis* 115, 338-342. DOI: 10.1016/j.micpath.2017.12.081

Selim, S., Alruwaili, Y. S., Ejaz, H., Abdalla, A. E., Almuhayawi, M. S., Nagshabandi, M. K., Tarabulsi, M. K., Al Jaouni, S. K., Bazuhair, M. A., and Abdelghany, T. M. (2024). "Estimation and action mechanisms of cinnamon bark *via* oxidative enzymes and ultrastructures as antimicrobial, anti-biofilm, antioxidant, anti-diabetic, and anticancer agents," *BioResources* 19(4), 7019-7041. DOI: 10.15376/biores.19.4.7019-7041

Sen, A., Sharma, G., Tomer, N., Shibu, B. S., and Moin, S. (2024). "Isolation, purification, and characterization of bioactive peptide from *Chenopodium quinoa* seeds: Therapeutic and functional insights," *Journal of Applied Pharmaceutical Research* 12(6), 184-191. DOI:10.69857/joapr.v12i6.835

Shang, H., Sun, J., Zheng, Z., Sun, S., and Yan, X. (2024). "Study on the effect of quinoa saponins on human colon cancer HT-29 Cells," *Food Sci Nutr.* 13(1), article e4669. DOI: 10.1002/fsn3.4669

Shen, Y., Zheng, L., Peng, Y., Zhu, X., Liu, F., Yang, X., and Li, H. (2022). "Physicochemical, antioxidant and anticancer characteristics of seed oil from three *Chenopodium quinoa* genotypes," *Molecules* 27(8), article 2453. DOI:10.3390/molecules27082453

Tsikas, D. (2017). "Assessment of lipid peroxidation by measuring malondialdehyde (MDA) and relatives in biological samples: Analytical and biological challenges," *Analytical Biochemistry* 524, 13-30. DOI:10.1016/j.ab.2016.10.021

Vega-Gálvez, A., Miranda, M., Vergara, J., Uribe, E., Puente, L., and Martínez, E. A. (2010). "Nutrition facts and functional potential of quinoa (*Chenopodium quinoa* willd.), an ancient Andean grain: A review," *J Sci Food Agric*. 90, 2541-2547. DOI:10.1002/jsfa.4158.

Woldemichael, G., and Wink, M. (2001). "Identification and biological activities of triterpenoid saponins from *Chenopodium quinoa*," *J. Agric. Food Chem*. 49(5), 2327-2332. DOI:10.1021/jf0013499

Zhao, M. X., Wen, J. L., Wang, L., Wang, X. P., and Chen, T. S. (2019). "Intracellular catalase activity instead of glutathione level dominates the resistance of cells to reactive oxygen species," *Cell Stress Chaperones* 24(3), 609-619. DOI:10.1007/s12192-019-00993-1.

Zhu, X., Yang, G., Shen, Y., Niu, L., Peng, Y., Chen, H., Li, H., and Yang, X. (2024). "Physicochemical properties and biological activities of quinoa polysaccharides," *Molecules* 29(7), article 1576. DOI: 10.3390/molecules29071576

Article submitted: January 21, 2025; Peer review completed: March 9, 2025; Revised version received March 13, 2025; Published: March 28, 2025.
DOI: 10.15376/biores.20.2.3612-3627