Journal of Research in Pharmacy

Research Article

www.jrespharm.com

Analysis of anti-aging activity of Chinese perfume (*Aglaia odorata*) and Indian camphorweed (*Pluchea indica*) leaves using *Saccharomyces cerevisiae* model system

Lovy PERDANI[1], Nudia Mufidah AZASI [1], Fajar SOFYANTORO [1], Rudy Agung NUGROHO [2], Nor Ismaliza Mohd Ismail[3], Woro Anindito Sri TUNJUNG [1*]

1 Departement of Tropical Biology, Faculty of Biology, Universitas Gadjah Mada, Yogyakarta 55281, Indonesia.
2 Department of Biology, Faculty of Mathematics and Natural Sciences, University of Mulawarman, East Kalimantan 75242, Indonesia.
3 Department of Biological Science, Faculty of Science, Universiti Tunku Abdul Rahman, Malaysia.
* Corresponding Author. E-mail: wanindito@ugm.ac.id (W.A.S.T.); Tel. +62 (274) 580839.
Lovy Perdani and Nudia Mufidah Azasi are equal first authors.

Received: 30 December 2023 / Revised: 14 March 2024 / Accepted: 16 March 2024

ABSTRACT: This study examined the anti-aging effect of Chinese perfume (*Aglaia odorata*) and Indian camphorweed (*Pluchea indica*) leaf extracts on *Saccharomyces cerevisiae* as a model system. Investigation of the antioxidant activity and bioactive compounds using GC–MS and qualitative anti-aging spot tests were performed to determine the anti-aging effects. In addition, a quantitative anti-aging test was conducted using high-throughput chronological lifespan analysis. The results showed that the antioxidant enzyme activities of SOD, APX, and CAT in Chinese perfume leaves were 393.96 units/min/g FW, 215 µmoles H_2O_2/min/g FW, and 5.6 µmoles H_2O_2 decomposed/min/g FW, respectively; the values in Indian camphorweed leaves were 717.57 units/min/g FW, 48 µmoles H_2O_2/min/g FW, and 12.33 µmole H_2O_2 decomposed/min/g FW, respectively. The antioxidant activity of Chinese perfume and Indian camphorweed was 577.2 µg/mL and 348.86 µg/mL. The antioxidant bioactive compounds of Chinese perfume extract included n-hexadecanoic acid, β turmerone, and 2-propenoic acid, 3-phenyl-, methyl ester (methyl cinnamate) and those from Indian camphorweed included n-hexadecanoic acid and neophytadiene. Treatment with both extracts prolonged the life of yeast after 15 days of incubation. In addition, H_2O_2 stress conditions, the yeasts showed better growth with the addition of both leaf extracts. This study revealed that the extracts of Chinese perfume and Indian camphorweed leaves demonstrate promising potential as ingredients for anti-aging cosmetics.

KEYWORDS: anti-aging; antioxidant; Chinese perfume; Indian camphorweed; *S. cerevisiae*.

1. INTRODUCTION

Aging is the gradual reduction in physiological functions caused by progressive damage of various cellular components and machineries [1- 3]. Cellular aging due to oxidative stress might be initiated by the accumulation of reactive oxygen species (ROS) [4]. The impact of cellular aging is mainly apparent on the skin, such as wrinkles and pigmentation [5, 6]. Therefore, skin-aging prevention has become an important concern in recent years thereby promoting intensive research in anti-aging skincare. Cosmetics for skin care are encouraged to adhere to the cruelty-free concept, which advocates cosmetics that do not involve animals, both in the ingredients and the testing method. In addition, the general public has become highly selective in choosing anti-aging skincare that is free of animal components. Therefore, alternative ingredients for anti-aging skincare have garnered attention, particularly bioactive substances derived from plants [7-9]. Natural ingredients from plants show antioxidant activities in detoxifying ROS in the form of O_2-, $OH-$, and H_2O_2 [10, 11]. Furthermore, antioxidants can eliminate free radicals through enzymatic or nonenzymatic reactions [12]. Some of the enzymes with antioxidant activities include superoxide dismutase (SOD), ascorbate peroxidase (APX), and catalase (CAT) [13]. Meanwhile, vitamins C, B3, and E, polyphenols, flavonoids, and phenolics are phytochemical compounds with nonenzymatic antioxidant properties [14, 15].

Indonesian natural ingredients, like Indian camphorweed (*Pluchea indica*) and Chinese perfume (*Aglaia odorata*) leaves, have been found to possess antioxidants and potential anti-aging effects. Indian camphorweed contains antioxidant compounds from the phenolic class, such as caffeoylquinic acid derivatives [16]. Meanwhile, the Chinese perfume secretes various compounds with antioxidant activity,

How to cite this article: Perdani L, Azasi NM, Sofyantoro F, Nugroho AR, Ismail NIM, Tunjung WAS. Analysis of anti-aging activity of Chinese perfume (Aglaia odorata) and Indian camphorweed (Pluchea indica) leaves using Saccharomyces cerevisiae model system. J Res Pharm. 2025; 29(1): 396-406.

https://dx.doi.org/10.29228/jrp.2022.00
ISSN: 2630-6344

including hesperitin-7,3′-O-dimethylether, 5α-dammar-20-ene3ß, 24,25-triol, odorine, odorinol, triterpenes, and aglain that are useful as anti-inflammatory and anticancer agents [17, 18] and rocaglamide, rocaglaol, and flavagline that exhibit neuroprotective properties [19].

Cosmetic testing methods without involving experimental animals are also urgently required. SIR2, an essential gene in the regulatory mechanisms of aging, and the target of rapamycin (TOR), which is essential in nutrient sensing in mammals, are conserved in budding yeast *Saccharomyces cerevisiae* [20]. A growing body of research demonstrated that the life span of yeast can be extended by calorie restriction (CR) [21]. Therefore, *S. cerevisiae* has been widely used as a model system for studying anti-aging [22-24]. This study aimed to determine the phytochemical content and antioxidant ability of Chinese perfume and Indian camphorweed leaf extracts. The anti-aging activity of the extracts was also tested using budding yeast through spot test and high-throughput rapid chronological lifespan (HTRCL) test.

2. RESULTS

The Chinese perfume and Indian camphorweed are plants that commonly grow in home gardens and are widely utilized by the community as food or dyes (Figure 1)

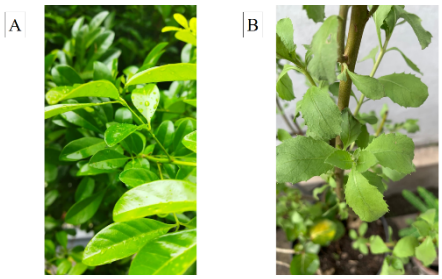

Figure 1. Plant sample. (A) Chinese perfume and (B) Indian camphorweed

Both leaf extracts displayed enzymatic antioxidant activity, with SOD exhibiting the highest value (Figure 2).

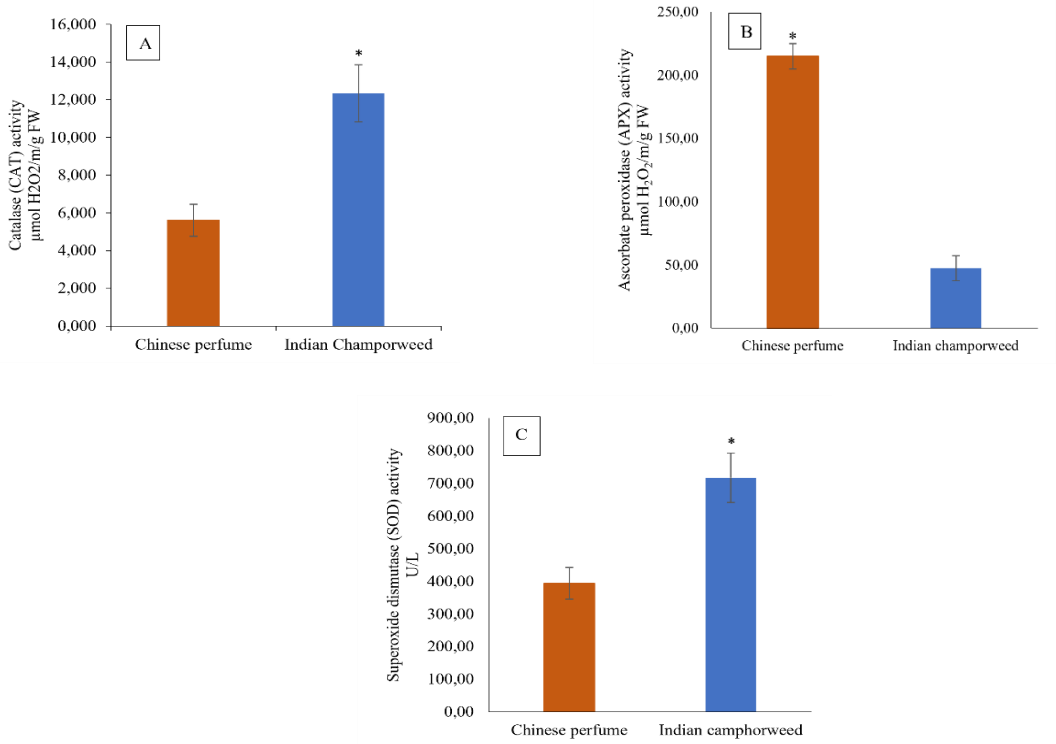

Figure 2. Enzymatic activity of Chinese perfume and Indian camphorweed. (A) Catalase, (B) Ascorbate peroxidase, and (C) Superoxide dismutase

The crude ethanol extract of Chinese perfume and crude ethyl acetate extract of Indian camphorweed leaves were selected for DPPH antioxidant tests and compared with ethanol and ethyl acetate solvents, which are commonly used in the manufacturing of cosmetic products. Indian camphorweed showed higher antioxidant activity than Chinese perfume, but both were less effective than the positive control (Table 1).

Table 1. Antioxidant activity of Chinese perfume and Indian camphorweed leaves

Extracts	**IC_{50} Value (µg/mL)**
Ethanol extract of Chinese perfume	$577.2^{a} \pm 2.60$
Ethyl acetate extract of Indian camphorweed	$348.86^{b} \pm 2.45$
Ascorbic acid (control)	$10.016^{c} \pm 0.167$

Note: $P < 0.05$, different words indicate significant differences through Duncan's tests at the 95% confidence level.

Profile analysis was also carried out to determine compounds with antioxidant activities (Table 2)

Table 2. Profile of bioactive compounds in Chinese perfume and Indian camphorweed

Extract	Compounds	Peak area (%)	Class	Bioactivity
Chinese perfume	Methyl palmitate	3.21	Fatty acid	antioxidant, anti-inflammatory [27]
	n-Hexadecanoic acid	1.77		antioxidant [28]
	2-Methyl-6-(4-methylenecyclohex-2-en-1-yl)hept-2-en-4-one or β-Turmerone	1.52	Sesquiterpenoid	antioxidant, anti-inflammatory [29]
	Turmerone	0.39		antioxidant, pro-proliferation [30]
	3,7,11,15-Tetramethyl-2-hexadecen-1-ol (phytol)	1.06	Terpenoid	anti-inflammatory, antioxidant [31]
	2-Propenoic acid, 3-phenyl-, methyl ester (methyl cinnamate)	0.43	Carboxylic acid	antioxidant, skin integrity protector [32]
Indian camphorweed	n-Hexadecanoic acid	36.01	Fatty acid	antioxidant [28]
	Neophytadiene	3.3	Sesquiterpenoid	antioxidant, anti-inflammatory [33]

The antioxidant activities of Chinese perfume and Indian camphorweed leaves might be attributed to their bioactive compounds. A total of 34 and 24 compounds were detected in Chinese perfume and Indian camphorweed extracts, respectively. Table 2 shows the compounds with antioxidant and anti-inflammatory activities and both extracts found n-Hexadecanoic, which are fatty acids is commonly used to produce cosmetics and soaps [34].

The viability of yeast cells incubated for 15 days in a mixture of medium and extract was observed to determine the anti-aging potential of Chinese perfume and Indian camphorweed leaves. Figure 3 shows the growth of yeast cells on the medium without oxidative stress. The growth of the negative control gradually decreased from day 1 to 15. The cells treated with CR (Calorie Restriction) exhibit better cell growth compared with the negative control, indicating that the CR group served as a good positive control. The Chinese perfume extract consistently promoted and maintained cell growth on day 1 to 15 compared with the positive control (CR), indicating that the Chinese perfume extract prolongs the life of yeast. On day 1 to 15, Indian camphorweed promoted cell growth relative to that in the control. All concentrations of this extract exhibited the same effect on yeast growth. Overall, both extracts promoted growth consistently across concentrations and extended yeast lifespan.

Journal of Research in Pharmacy
Research Article

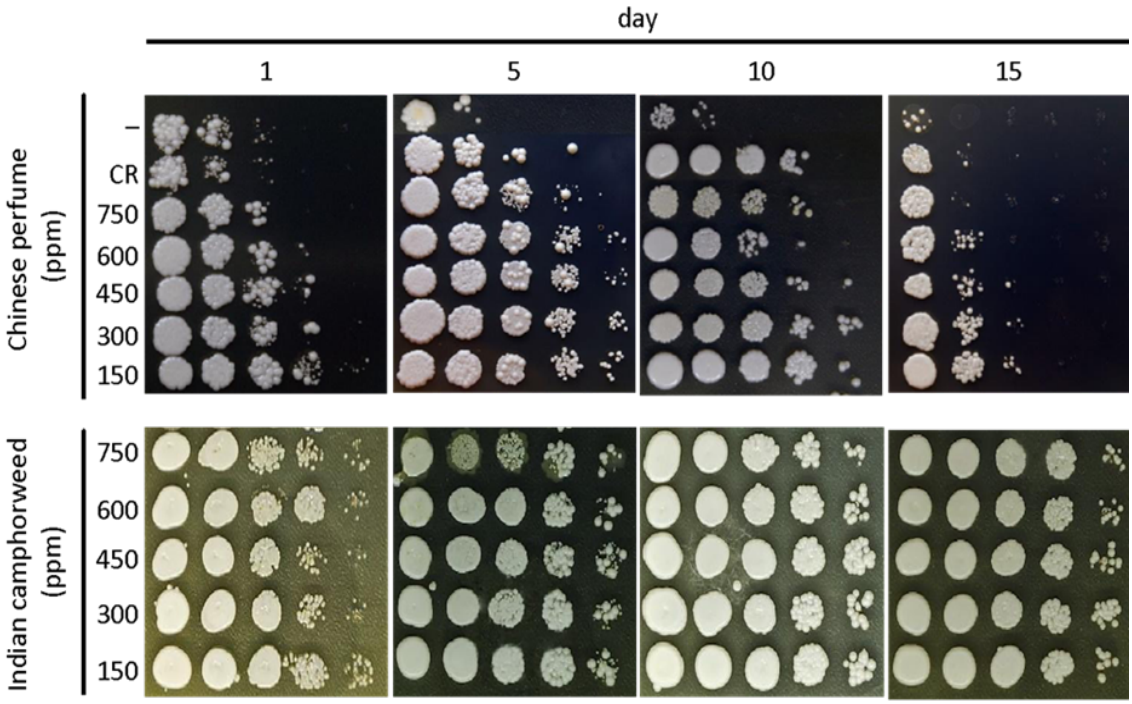

Figure 3. Growth of budding yeast supplemented with Chinese perfume and Indian camphorweed extracts. CR: calorie restriction.

In cell viability analysis, the negative control viability decreased gradually, while the CR group showed increased viability on the 5th and 10th days and a decrease on the 15th day. In general, the CR group demonstrated a higher viability than the negative control (Figure 4).

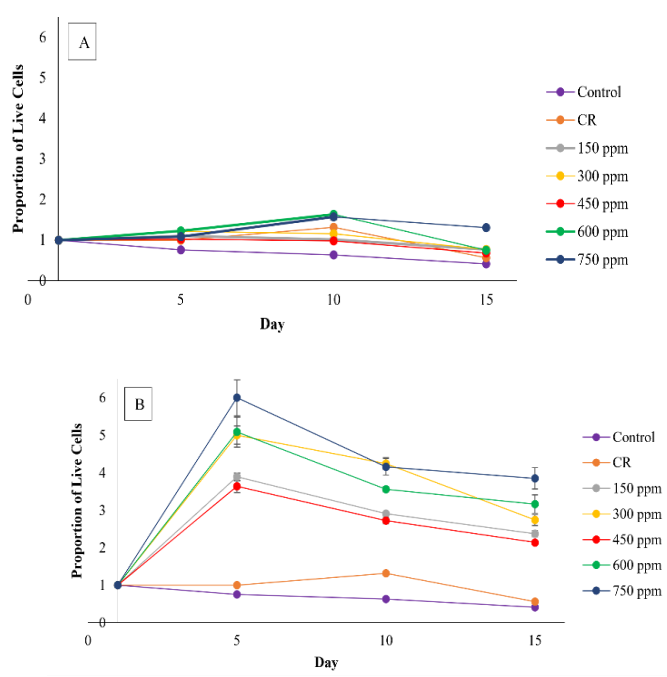

Figure 4. Cell viability after treatment with (A) ethanol extract of Chinese perfume and (B) ethyl acetate extract of Indian camphorweed leaves. Note: *P < 0.05, indicates significant differences through Duncan's tests at the 95% confidence level.

https://dx.doi.org/10.29228/jrp.2022.00
J Res Pharm 2025; 29(1): 396-406

As shown in Figure 4A, the Chinese perfume extract at concentrations of 600 and 750 ppm increased cell viability on days 5 and 10; however, the cell growth decreased on day 15. Although all variations in concentration decreased on day 15, yeast cell viability was still higher than that of the control and CR group. This finding indicated that the Chinese perfume extract can maintain cell viability better than the control treatment and CR.

Furthermore, the yeast treated with all extract concentrations showed that the cell viability increased on day 5 (Figure 4B) but decreased on days 10 and 15 indicating the onset of cell death. However, the decreased cell viability was significantly higher than the cell viability values on days 10 and 15 of the control and CR group. Until day 15, the Chinese perfume and Indian camphorweed extracts at a concentration of 750 ppm displayed the best cell viability-promoting activity, suggesting that this concentration should be adopted for the production of cosmetics.

Quantitative test with HTRCL assay and qualitative test with spot methods (without H_2O_2 stress) showed the same pattern. The Indian camphorweed extract had a better ability to maintain yeast cell viability than the Chinese perfume extract. Both extracts could maintain yeast viability significantly better than the control.

In terms of the viability of *S. cerevisiae* under H_2O_2 stress, the negative control showed no grow until the 15th day, indicating that H_2O_2 inhibits yeast growth. Meanwhile, the positive control CR grew on days 5 and 10 but not on day 15. The yeast treated with the Chinese perfume extract showed better growth compared with the control. In the presence of the Chinese perfume extract, the yeast grew optimally on day 5. On day 15, the yeast treated with the Chinese perfume extract showed better growth compared with the control. Meanwhile, treatment with the Indian camphorweed extract can maintain the yeast growth, which was better than the growth of the control on days 5, 10, and 15. In the medium containing 1 mM H_2O_2, the yeast supplemented with the Indian camphorweed extract showed better growth than that supplemented with the Chinese perfume extract. Meanwhile, both extracts could prolong yeast lifespan under 1-mM H_2O_2 stress (Figure 5A).

As shown in Figure 5B, 3-mM H_2O_2 oxidative stress inhibited cell growth in the negative control. Meanwhile, cell growth in the CR group could be observed on day 10. These results indicated that the yeast treated with CR required a long adaptation time under high H_2O_2 stress (3 mM). In addition, CR helped maintain yeast growth under 1-mM H_2O_2 stress. The yeast supplemented with the Chinese perfume extract grew optimally on day 5. However, on day 10, growth was only observed for the yeast treated with the Chinese perfume extract at a concentration of 750 ppm. These data suggested that CR and 750 ppm Chinese perfume extract had the same potential to maintain yeast growth under 3-mM H_2O_2 stress. Meanwhile, the yeast treated with the Indian camphorweed extract grew optimally on day 5 but showed a decrease in growth on day 10 and 15. The Indian camphorweed extract prolonged the life of the yeast compared with the control and CR groups and performed better than the Chinese perfume extract in prolonging the life span and maintaining the growth of yeast under 3-mM H_2O_2 stress.

3. DISCUSSION

This study determined the anti-aging activity of two extracts using budding yeast as a model in an attempt to minimize the use of animal models in anti-aging skincare development. Budding yeast *S. cerevisiae* is a model system commonly used in studying various biological mechanisms of eukaryotic cells [35-37]. Yeast has served as the main model system for molecular and systems biology owing to the various experimental approaches available for altering its cell components [38, 39]. In anti-aging research, yeast has been employed as a prime model system. It demonstrates an outstanding ability to enter a stationary phase and cease to divide upon starvation, such as in nutrient-limited batch cultures, thus prolonging its age in the absence of nutrients. Yeast might live for a few days to several weeks during the postmitotic period depending on the culture conditions and strain. Large-scale aging studies, which commonly use aging model system and can last between 20 days and 3 years, are feasible to be performed using yeast in a relatively short time [40].

The addition of *Hibiscus sabdariffa* crown extract successfully prolonged the life span of *S. cerevisiae* [21]. Several phytochemical compounds and other substances, such as carnitine [41], hesperidin [42], *Melannurca campana* fruit extract [43], and Syzygium aromaticum extract [44], are also known to prevent aging and other factors affecting the life span of yeast cells [45].

In this study, CR was used as a positive control. CR increases the activity of metabolic pathways, including the modulation of mitochondrial activity and reduction of oxidative damage [46]. The effect of CR on the aging mechanisms is related to the presence of nutrient signaling-induced cascade reactions, such as insulin/insulin-like growth factor-1 signaling, TOR pathway, adenosine monophosphate-activated protein

kinase signaling pathway, and sirtuin [47]. CR, with the limitation of glucose supply, is also related to the glycation theory of aging [48]. Glucose limitation decreases TOR/Sch 9 and Ras-protein kinase A signals and increases SIRT1 deacetylation [49], which in turn affects histones, decreases P53 gene activity, and inhibits inflammation through the NFkB signaling pathway. As a result, cell division and growth are halted, resulting in extended cell-life span [50].

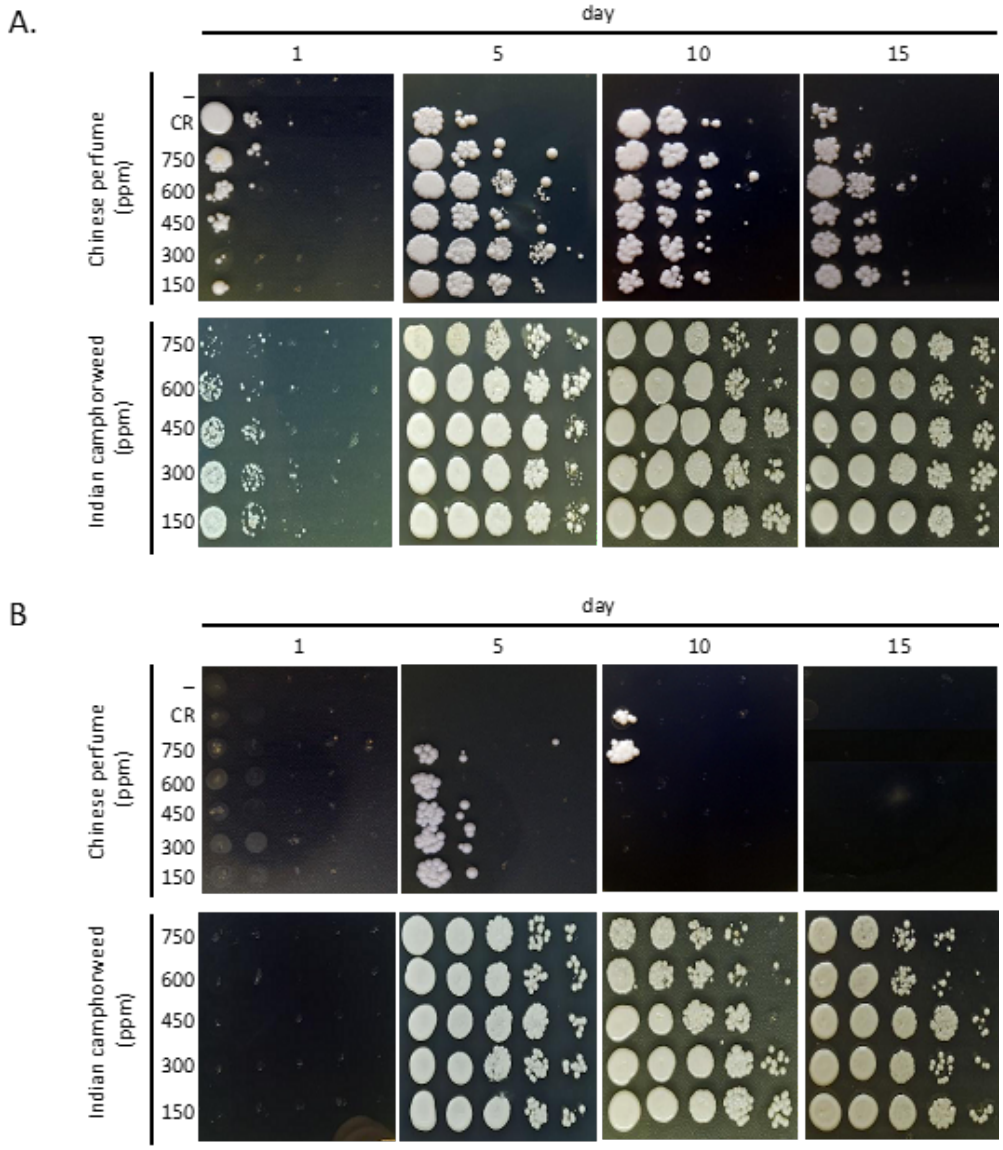

Figure 5. Effect of Chinese perfume and Indian camphorweed on cells cultured in medium containing (A) 1-mM H_2O_2 and (B) 3-mM H_2O_2 (B).

The negative control experienced aging due to the respiratory threshold factor. When yeast is grown in normal glucose medium, the glucose level gradually decreases over time and makes the yeast unable to remodel its normal metabolism, resulting in a short life span [51]. Meanwhile, the negative control supplemented with H_2O_2 could not grow due to the produced ROS acting as oxidative stress.

Spot-test results showed that Chinese perfume and Indian camphorweed induce anti-aging activity in yeast in the absence or presence of H_2O_2. H_2O_2 was added to increase the level of intracellular ROS, which causes oxidative stress and accelerates aging [52]. The yeast supplemented with the Indian camphorweed extract grew optimally in the presence of 3 mM H_2O_2, indicating that this treatment exhibited better anti-aging activity than the Chinese perfume extract. However, our preliminary study showed that yeast cells could not grow in H_2O_2 at concentrations higher than 3 mM.

Bioactive compounds with antioxidant properties might act as a radical scavenger [53]. Kavitake et al. [54] carried out the antioxidant analysis of galactan exopolysaccharide (EPS) using the DPPH method and found that the supplementation of antioxidants in the form of EPS with IC_{50} of 450 µg/mL could extend the life of yeast under oxidative stress of 1-mM H_2O_2. In the present work using the same method, Chinese perfume and Indian camphorweed extracts showed IC_{50} values of 577.2 and 348.86 µg/mL, respectively. The Chinese perfume and Indian camphorweed crude extracts were able to maintain the cell growth and prolong the life of yeast under H_2O_2 stress. These results indicated that both crude extracts deliver anti-aging activity better than EPS, which is a purified compound.

Indian camphorweed and Chinese perfume contain enzymatic and nonenzymatic antioxidants. In this study, both extracts exhibited higher SOD activity than CAT and APX activities because SOD is the first line of defense against O_2- dismutation [25]. SOD promotes the initial stages of ROS in singlet oxygen form and free radicals that are expelled sequentially with the help of APX and CAT [12]. Meanwhile, CAT and APX show differences in converting H_2O_2 into water molecules [13].

In addition to the enzymatic antioxidants, the nonenzymatic antioxidant found in both extracts was n-hexadecanoic acid, which belongs to the group of fatty acid compounds and exhibits antioxidant and anti-inflammatory activities [55]. Fatty acids could protect the skin from stress-induced aging [56]. Therefore, Chinese perfume and Indian camphorweed extracts have the potential as natural anti-aging which can be formulated as promising ingredients in anti-aging cosmetics.

4. CONCLUSION

The ethanol extract of Chinese perfume and the ethyl acetate extract of Indian camphorweed leaves prolong the lifespan of budding yeast in the presence or absence of H_2O_2 oxidative stress. The leaf extracts contain bioactive compounds with antioxidant properties that might be useful as ingredients of anti-aging cosmetics.

5. MATERIALS AND METHODS

5.1 Plant Materials

Chinese perfume and Indian camphorweed leaves were obtained from the Center for Research and Development of Medicinal Plants and Traditional Medicines, Tawangmangu, Central Java, Indonesia

5.2 Leaf extraction

To evaluate the antioxidant enzyme activities such as SOD, CAT, and APX, fresh leaves samples were mixed with 0.1 M potassium phosphate buffer (pH 7.0) containing 1-mM Na-EDTA and 1% polyvinyl pyrrolidone to obtain extracts. The fresh leaf extracts were centrifuged at 5,000 rpm and 17°C for 30 min to obtain leaf supernatants.

For the antioxidant activity test, bioactive compounds analysis, spot test, and HTRCL test, leaf powder (100 g) was macerated using ethyl acetate (Indian camphorweed) and ethanol (Chinese perfume) solvents with a ratio of 1:2. The samples were immersed in the respective solvent for 2 days, followed by two rounds of additional maceration. The filtrate was evaporated at room temperature, and the extract was stored in dark bottles at 4°C.

5.3 Superoxide dismutase activity assay

The SOD activity was measured as previously described [25] with modifications. Reducing buffer solution (1 mL) containing Tris HCl (pH 8,2), 1-mM Na-EDTA, ddH_2O (1 mL), and pyrogallol solution (10 µL) were added to 8 µL of leaf supernatant. The absorbance was repeatedly scanned at a wavelength of 325 nm at intervals of 1–3 min using a GENESYS 10UV scanning spectrophotometer. Enzyme activity was recorded at a 1–3 min interval, which is suitable for monitoring the absorbance change to calculate the reaction rate of antioxidant enzymes [26].

5.4 Catalase activity assay

CAT activity was measured as previously described [25] with modifications. Leaf supernatant (200 µL) was mixed with 1 mL of 50 mM sodium phosphate buffer (pH 7) and 1 mL of 30% H_2O_2. Absorbance was immediately measured at a wavelength of 240 nm with time interval of 1–3 min.

5.5 Ascorbate peroxidase activity assay

The APX activity was measured as previously described [25] with modifications. Each leaf supernatant (100 µL) was mixed with 0.4 mL of a mixture of 0.1-mM Na-EDTA and 0.05-mM sodium phosphate buffer (pH 7), 0.4 mL of 0.05-mM ascorbic acid solution, 0.4 mL of ddH_2O, and 0.8 mL of 3% H_2O_2. Absorbance was monitored at a wavelength of 290 nm every 1 min for 3 min.

5.6 Antioxidant activity test

The antioxidant activity of leaf extracts was tested using the DPPH method. The extracts were dissolved in pro-analytical methanol at concentrations of 1000, 500, 250, 125, 62.5, and 31.25 g/mL. Each extract was added with 0.1 mM DPPH at 1:2 ratio. The mixture was incubated at room temperature and in the dark for 30 min. After incubation, absorbance was measured using a UV–vis spectrophotometer (Genesys) at a wavelength of 517 nm. Ascorbic acid was used as a control with concentrations of 2, 4, 6, 8, and 10 g/mL.

5.7 Bioactive compound analysis

The bioactive compounds of the leaf extracts were analyzed using GC–MS (AGILENT 7890A and MS 5977B) at 50°C–325°C. GC column DB-5MS (30 m × 250 µm × 0.25 µm) and helium was used as the mobile phase. Compounds were identified by comparing the sample MS spectra with the NIST17 database.

5.8 Spot test

S. cerevisiae (FNCC 3012) was cultured in liquid YPD medium for 24 h. The initial OD600 was calculated at 0.1. Yeast was also cultured in a medium containing 2% glucose and extracts (150, 300, 450, 600, and 750 ppm) dissolved in DMSO. As a positive control, yeast was cultured in 0.5% glucose medium (Calorie Restriction; CR). Each culture was incubated in an incubator shaker at 120 rpm and 30°C. Spot tests were carried out on days 1, 5, 10, and 15 after extract treatment to examine the effect of oxidative stress. All spot experiments were performed at least three times. Growth was observed after 3 days of incubation at 30°C in solid medium without or with H_2O_2 (1 and 3 mM).

5.9 High Throughput Rapid Cronological Lifespan test

HTRCL test was performed using the MTT method. This test aimed to determine the viability of yeast cells after 0, 5, 10, and 15 days of extract incubation quantitevely. In brief, 50 µL of culture was transferred to a 96-well microplate, followed by the addition of 50 µL of RCL solution (4% glucose, 1 mg/mL MTT, and 0.2 mM phytomenadione. The cultures were incubated for 30 min at 30°C in a gyratory shaker, added with 100 µL of solubilization solution (0.2% triton X and 20-mM HCl in 100% isopropanol, and incubated for 30 min. Absorbance was measured using an ELISA reader at a wavelength of 595 nm. Cell viability was calculated by the following formula:

Proportion of cell viability on day n = (A595 on day-n)/(A595 on day-0)

5.10 Data analysis

Spot density was analyzed qualitatively to determine the anti-aging activity of the extracts against yeast. The proportion of cell viability was analyzed quantitatively using Microsoft Excel and SPSS version 22 (SPSS, Inc. USA). HTRCL and antioxidant enzyme analysis used one-way ANOVA (95% confidence), followed by Duncan test ($P < 0.05$) for significant differences.

Acknowledgements: We acknowledge Prof. Dr. Yuli Widiyastuti from the Research Center For Pharmaceutical Ingredient and Traditional Medicine, Research and Innovation Agency, Indonesia for providing leaf samples.

Author contributions: Concept – W.A.S.T.; Design – W.A.S.T, L.P., N.M.A.; Supervision – W.A.S.T.; Resources – W.A.S.T.; Materials – L.P., N.M.A.; Data Collection and/or Processing – L.P., N.M.A.; Analysis and/or Interpretation – L.P., N.M.A, F.S., R.A.N., W.A.S.T.; Literature Search – L.P., N.M.A.; Writing – L.P., N.M.A., F.S., R.A.N.; Critical Reviews – L.P., N.M.A, F.S., R.A.N., N.I.M.I., W.A.S.T.

Conflict of interest statement: All authors reported no potential conflict of interest

REFERENCES

[1] Batubara I, Astuti RI, Prastya ME, Ilmiawati A, Maeda M, Suzuki M, Hamamoto A, Takemori H. The antiaging effect of active fractions and ent-11α-hydroxy-15-oxo-kaur-16-en-19-oic acid isolated from *Adenostemma lavenia* (L.) O. Kuntze at the cellular level. Antioxidants. 2020; 9(8): 719. http://dx.doi.org/10.3390/antiox9080719.

[2] Micheli L, Bertini L, Bonato A, Villanova N, Caruso C, Caruso M, Bernini R, Tirone F. Role of hydroxytyrosol and oleuropein in the prevention of aging and related disorders: Focus on neurodegeneration, skeletal muscle dysfunction and gut microbiota. Nutrients. 2023; 15(7): 1767. http://dx.doi.org/10.3390/nu15071767.

[3] Sharma V, Mehdi MM. Oxidative stress, inflammation and hormesis: The role of dietary and lifestyle modifications on aging. Neurochem Int. 2023; 164: 105490. http://dx.doi.org/10.1016/j.neuint.2023.105490.

[4] Papaccio F, D'Arino A, Caputo S, Bellei B. Focus on the contribution of oxidative stress in skin aging. Antioxidants. 2022; 11(6): 1121. http://dx.doi.org/10.3390/antiox11061121.

[5] Falholt Elvebakken H, Bruntse AB, Vedel C, Kjærulff S. Topical *Lactiplantibacillus plantarum* LB244R® ointment alleviates skin aging: An exploratory trial. J Cosmet Dermatol. 2023; 22(6): 1911-1918. http://dx.doi.org/10.1111/jocd.15657.

[6] Masaki H. Role of antioxidants in the skin: Anti-aging effects. J Dermatol Sci. 2010; 58(2): 85-90. http://dx.doi.org/10.1016/j.jdermsci.2010.03.003.

[7] Bharadvaja N, Gautam S, Singh H. Natural polyphenols: A promising bioactive compounds for skin care and cosmetics. Mol Biol Rep. 2023; 50(2): 1817-1828. http://dx.doi.org/10.1007/s11033-022-08156-9.

[8] Cruz AM, Gonçalves MC, Marques MS, Veiga F, Paiva-Santos AC, Pires PC. In vitro models for anti-aging efficacy assessment: A critical update in dermocosmetic research. Cosmetics. 2023; 10(2): 66. http://dx.doi.org/10.3390/cosmetics10020066.

[9] Poomanee W, Yaowiwat N, Pattarachaidaecharuch T, Leelapornpisid P. Optimized multiherbal combination and in vivo anti-skin aging potential: A randomized double blind placebo controlled study. Sci Rep. 2023; 13(1): 5633. http://dx.doi.org/10.1038/s41598-023-32738-7.

[10] Davalli P, Mitic T, Caporali A, Lauriola A, D'Arca D. ROS, cell senescence, and novel molecular mechanisms in aging and age-related diseases. Oxid MedCell Longev. 2016; 2016: 3565127. http://dx.doi.org/10.1155/2016/3565127.

[11] Nogueira V, Hay N. Molecular pathways: reactive oxygen species homeostasis in cancer cells and implications for cancer therapy. Clin Cancer Res. 2013; 19(16): 4309-4314. http://dx.doi.org/10.1155/2016/3565127.

[12] Stephenie S, Chang YP, Gnanasekaran A, Esa NM, Gnanaraj C. An insight on superoxide dismutase (SOD) from plants for mammalian health enhancement. J Funct Foods. 2020; 68: 103917. http://dx.doi.org/10.1016/j.jff.2020.103917.

[13] Rajput VD, Harish, Singh RK, Verma KK, Sharma L, Quiroz-Figueroa FR, Meena M, Gour VS, Minkina T, Sushkova S, Mandzhieva S. Recent developments in enzymatic antioxidant defence mechanism in plants with special reference to abiotic stress. Biology. 2021; 10(4): 267. http://dx.doi.org/10.3390/biology10040267.

[14] Ganceviciene R, Liakou AI, Theodoridis A, Makrantonaki E, Zouboulis CC. Skin anti-aging strategies. Dermatoendocrinol. 2012; 4(3): 308-319. http://dx.doi.org/10.4161/derm.22804.

[15] Noridayu AR, Hii YF, Faridah A, Khozirah S, Lajis N. Antioxidant and antiacetylcholinesterase activities of *Pluchea indica* Less. Int Food Res J. 2011; 18(3): 925-929.

[16] Vongsak B, Kongkiatpaiboon S, Jaisamut S, Konsap K. Comparison of active constituents, antioxidant capacity, and α-glucosidase inhibition in *Pluchea indica* leaf extracts at different maturity stages. Food Biosci. 2018; 25: 68-73. http://dx.doi.org/10.1016/j.fbio.2018.08.006.

[17] Efdi M, Pardede A, Hara H, Syafrizayanti S, Ariesanty D, Ninomiya M, Koketsu M. Chemical constituents of *Aglaia odorata* leaves and their anti-inflammatory effects. Nat Prod Commun. 2017; 12(11): 1717-1720.

[18] Wang DX, Yang SM. Chemical constituents from the leaves of *Aglaia odorata*. Z Naturforsch C J Biosci. 2013; 68(3-4): 82-86. http://dx.doi.org/10.1515/znc-2013-3-402.

[19] Wang JK, Guo Q, Zhang XW, Wang LC, Liu Q, Tu PF, Jiang Y, Zeng KW. *Aglaia odorata* Lour. extract inhibit ischemic neuronal injury potentially via suppressing p53/Puma-mediated mitochondrial apoptosis pathway. J Ethnopharmacol. 2020; 248: 112336. http://dx.doi.org/10.1016/j.jep.2019.112336.

[20] Sudiyani Y, Eka Prastya M, Maryana R, Triwahyuni E, Muryanto. The Budding Yeast *Saccharomyces cerevisiae* as a Valuable Model Organism for Investigating Anti-Aging Compounds [Internet]. Saccharomyces. IntechOpen; 2021. Available from: http://dx.doi.org/10.5772/intechopen.96662.

[21] Sarima AR, Meryandini A. Modulation of aging in yeast *Saccharomyces cerevisiae* by roselle petal extract (*Hibiscus sabdariffa* L.). Am J Biochem Biotechnol. 2019; 15(1): 23-32. http://dx.doi.org/10.3844/ajbbsp.2019.23.32.

[22] Lin Y, Sun Y, Weng Y, Matsuura A, Xiang L, Qi J. Parishin from *Gastrodia elata* extends the lifespan of yeast via regulation of Sir2/Uth1/TOR signaling pathway. Oxid Med Cell Longev. 2016;2016:4074690. http://dx.doi.org/10.1155/2016/4074690.

[23] Mercado-Sáenz S, López-Díaz B, Burgos-Molina AM, Sendra-Portero F, González-Vidal A, Ruiz-Gómez MJ. Exposure of *S. cerevisiae* to pulsed magnetic field during chronological aging could induce genomic DNA damage. Int J Environ Health Res. 2022; 32(8): 1756-1767. http://dx.doi.org/10.1080/09603123.2021.1910212.

[24] Mukherjee M, Jana CK, Das N. Oxidation of biological molecules with age and induced oxidative stress in different growth phases of *Saccharomyces cerevisiae*. Antonie Van Leeuwenhoek. 2023; 116(4): 353-365. http://dx.doi.org/10.1007/s10482-022-01807-8.

[25] Das S, Talukdar D, Sangha MK, Chaudhary DP, Borah N, Das A, Das S, Saikia SP. Antioxidant enzymes potential in leaves of oats and barley and phytochemistry of stress tolerance. J Pharmacogn Phytochem. 2017; 6(6): 694-703.
[26] Zhang QA, Wang X, Song Y, Fan XH, gArcíA MArtín JF. Optimization of pyrogallol autoxidation conditions and its application in evaluation of superoxide anion radical scavenging capacity for four antioxidants. J AOAC Int. 2016; 99(2): 504-511. http://dx.doi.org/10.5740/jaoacint.15-0223.
[27] Adnan M, Nazim Uddin Chy M, Mostafa Kamal AT, Azad MO, Paul A, Uddin SB, Barlow JW, Faruque MO, Park CH, Cho DH. Investigation of the biological activities and characterization of bioactive constituents of *Ophiorrhiza rugosa* var. prostrata (D.Don) & mondal leaves through in vivo, in vitro, and in silico approaches. Molecules. 2019; 24(7): 1367. http://dx.doi.org/10.3390/molecules24071367.
[28] Tayade AB, Dhar P, Kumar J, Sharma M, Chauhan RS, Chaurasia OP, Srivastava RB. Chemometric profile of root extracts of *Rhodiola imbricata* Edgew. with hyphenated gas chromatography mass spectrometric technique. PLoS One. 2013;8(1):e52797. http://dx.doi.org/10.1371/journal.pone.0052797.
[29] Hameed IH, Altameme HJ, Idan SA. *Artemisia annua*: Biochemical products analysis of methanolic aerial parts extract and anti-microbial capacity. Res J Pharm Biol Chem Sci. 2016; 7(2): 1843-1868.
[30] Saga Y, Hatakenaka Y, Matsumoto M, Yoshioka Y, Matsumura S, Zaima N, Konishi Y. Neuroprotective effects of aromatic turmerone on activity deprivation-induced apoptosis in cerebellar granule neurons. Neuroreport. 2020; 31(18): 1302-1307. http://dx.doi.org/10.1097/WNR.0000000000001551.
[31] Ismail GA, Gheda SF, Abo-shady AM, Abdel-karim OH. In vitro potential activity of some seaweeds as antioxidants and inhibitors of diabetic enzymes. Food Sci Technol. 2020; 40(3): 681-691. http://dx.doi.org/10.1590/fst.15619.
[32] Hseu YC, Korivi M, Lin FY, Li ML, Lin RW, Wu JJ, Yang HL. Trans -cinnamic acid attenuates UVA-induced photoaging through inhibition of AP-1 activation and induction of Nrf2-mediated antioxidant genes in human skin fibroblasts. J Dermatol Sci. 2018; 90(2): 123–134. http://dx.doi.org/10.1016/j.jdermsci.2018.01.004.
[33] Raman BV, Samuel LA, Saradhi MP, Rao BN, Krishna NV, Sudhakar M, Radhakrishnan TM. Antibacterial, antioxidant activity and GC-MS analysis of *Eupatorium odoratum*. Asian J Pharm Clin Res. 2012; 5(2): 99-106.
[34] Ogbeide OK, Eze OF, Akaeze DA, Akhigbe IU, Omoruyi U, Iyekowa O, Owolabi BJ. Physico-chemical properties, chemical composition, biodiesel production and antibacterial potential of *Terminalia catapa* seed oil. ChemSearch J. 2021; 12(2): 70-80.
[35] Holland CL, Weis MF, England CJ, Berry AM, Hall PD, Lewis LK. Deficiency in homologous recombination is associated with changes in cell cycling and morphology in *Saccharomyces cerevisiae*. Exp Cell Res. 2023; 430(1): 113701. http://dx.doi.org/10.1016/j.yexcr.2023.113701.
[36] Revel B, Catty P, Ravanel S, Bourguignon J, Alban C. High-affinity iron and calcium transport pathways are involved in U (VI) uptake in the budding yeast *Saccharomyces cerevisiae*. J Hazard Mater. 2022; 422: 126894. http://dx.doi.org/10.1016/j.jhazmat.2021.126894.
[37] Vanderwaeren L, Dok R, Voordeckers K, Nuyts S, Verstrepen KJ. *Saccharomyces cerevisiae* as a model system for eukaryotic cell biology, from cell cycle control to DNA damage response. Int J Mol Sci. 2022; 23(19): 11665. http://dx.doi.org/10.3390/ijms231911665.
[38] Duina AA, Miller ME, Keeney JB. Budding yeast for budding geneticists: A primer on the *Saccharomyces cerevisiae* model system. Genetics. 2014; 197(1): 33-48. http://dx.doi.org/10.1534/genetics.114.163188.
[39] Mohammadi S, Saberidokht B, Subramaniam S, Grama A. Scope and limitations of yeast as a model organism for studying human tissue-specific pathways. BMC Syst Biol. 2015; 9: 96. http://dx.doi.org/10.1186/s12918-015-0253-0
[40] Zimmermann A, Hofer S, Pendl T, Kainz K, Madeo F, Carmona-Gutierrez D. Yeast as a tool to identify anti-aging compounds. FEMS Yeast Res. 2018; 18(6): foy020. http://dx.doi.org/10.1093/femsyr/foy020.
[41] Kiruthika B, Padma PR. *Zea mays* leaf extracts protect *Saccharomyces cerevisiae* cell against oxidative stress-induced cell death. J Acute Med. 2013; 3(3): 83-92. http://dx.doi.org/10.1016/j.jacme.2013.06.005.
[42] Sun K, Xiang L, Ishihara S, Matsuura A, Sakagami Y, Qi J. Anti-aging effects of hesperidin on *Saccharomyces cerevisiae* via inhibition of reactive oxygen species and UTH1 gene expression. Biosci Biotechnol Biochem. 2012; 76(4): 640-645. http://dx.doi.org/10.1271/bbb.110535.
[43] Stirpe M, Palermo V, Bianchi MM, Silvestri R, Falcone C, Tenore G, Novellino E, Mazzoni C. Annurca apple (*M. pumila* Miller cv Annurca) extracts act against stress and ageing in *S. cerevisiae* yeast cells. BMC Complement Altern Med. 2017;17(1):200. http://dx.doi.org/10.1186/s12906-017-1666-7.
[44] Lesmana D, Andrianto D, Astuti RI. Antiaging properties of the ethanol fractions of clove (*Syzygium aromaticum* L.) bud and leaf at the cellular levels: Study in yeast *Schizo saccharomyces* pombe. Sci Pharm. 2021; 89(4): 45. http://dx.doi.org/10.3390/scipharm89040045.
[45] Belak ZR, Harkness T, Eskiw CH. A rapid, high-throughput method for determining chronological lifespan in budding yeast. J Biol Methods. 2018; 5(4):e106. http://dx.doi.org/10.14440%2Fjbm.2018.272.
[46] López-Lluch G, Navas P. Calorie restriction as an intervention in ageing. J Physiol. 2016; 594(8): 2043-2060. http://dx.doi.org/10.1113/JP270543.
[47] Lee SH, Min KJ. Caloric restriction and its mimetics. BMB Rep. 2013; 46(4): 181. http://dx.doi.org/10.5483%2FBMBRep.2013.46.4.033.
[48] Kim CS, Park S, Kim J. The role of glycation in the pathogenesis of aging and its prevention through herbal products and physical exercise. J Exerc Nutrition Biochem. 2017; 21(3): 55. http://dx.doi.org/10.20463%2Fjenb.2017.0027.

[49] Rahnasto-Rilla M, Tyni J, Huovinen M, Jarho E, Kulikowicz T, Ravichandran S, A. Bohr V, Ferrucci L, Lahtela-Kakkonen M, Moaddel R. Natural polyphenols as sirtuin 6 modulators. Sci Rep. 2018; 8(1): 4163. http://dx.doi.org/10.1038/s41598-018-22388-5.

[50] Fabrizio P, Longo VD. Chronological aging-induced apoptosis in yeast. Biochim Biophys Acta. 2008; 1783(7): 1280-1285. http://dx.doi.org/10.1016/j.bbamcr.2008.03.017.

[51] Ocampo A, Liu J, Schroeder EA, Shadel GS, Barrientos A. Mitochondrial respiratory thresholds regulate yeast chronological life span and its extension by caloric restriction. Cell Metab. 2012; 16(1) 55-67. http://dx.doi.org/10.1016/j.cmet.2012.05.013.

[52] Schieber M, Chandel NS. ROS function in redox signaling and oxidative stress. Curr Biol. 2014; 24(10): R453-R462. http://dx.doi.org/10.1016/j.cub.2014.03.034.

[53] Ighodaro OM, Akinloye OA. First line defence antioxidants-superoxide dismutase (SOD), catalase (CAT) and glutathione peroxidase (GPX): Their fundamental role in the entire antioxidant defence grid. Alexandria J Med. 2018; 54(4): 287-293. http://dx.doi.org/10.1016/j.ajme.2017.09.001.

[54] Kavitake D, Veerabhadrappa B, Sudharshan SJ, Kandasamy S, Devi PB, Dyavaiah M, Shetty PH. Oxidative stress alleviating potential of galactan exopolysaccharide from *Weissella confusa* KR780676 in yeast model system. Sci Rep. 2022; 12(1): 1089. http://dx.doi.org/10.1038/s41598-022-05190-2.

[55] Mazumder K, Nabila A, Aktar A, Farahnaky A. Bioactive variability and in vitro and in vivo antioxidant activity of unprocessed and processed flour of nine cultivars of *Australian lupin* species: a comprehensive substantiation. Antioxidants. 2020; 9(4): 282. http://dx.doi.org/10.3390/antiox9040282.

[56] Weimann E, Silva MB, Murata GM, Bortolon JR, Dermargos A, Curi R, Hatanaka E. Topical anti-inflammatory activity of palmitoleic acid improves wound healing. PLoS One. 2018; 13(10): e0205338. http://dx.doi.org/10.1371/journal.pone.0205338.