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Research Article

Antioxidant Activity and Phytochemicals of Locally Consumed Plant Foods from Baguio City, Philippines

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Abstract

In the Philippines, Baguio City – known as the "City of Pines" – holds the country's major source of temperate climate vegetables. With increased dietary awareness, the consumption of plant foods rich in antioxidants has become relevant. Twenty-nine methanolic extracts from Baguio-produced plant foods were evaluated for antioxidant potential using DPPH, ferric reduction antioxidant power (FRAP), metal chelation, superoxide anion, nitric oxide, hydroxyl radical scavenging activities, MTT reduction, and phytochemical tests. *Fagopyrum tataricum* leaves, *Vaccinium myrtoides* fruit, and *Morus alba* fruit showed the most effective DPP radical, concentration-dependent reducing power, but low metal chelating activity. *Solanum tuberosum* tuber (22.86±63.26%) showed effective concentration-dependent chelating activity at 125 µg/mL. *Citrus aurantium* fruit (26.77±9.24%) and *Raphanus raphanistrum* root (41.13±0.11%) demonstrated an effective scavenging activity against superoxide anions at 45.5 µg/mL. Significant nitric oxide scavenging activity was observed in some fruits. *Brassica oleracea* Cab leaves (54.36 ± 2.38%) showed the highest inhibitory activity against hydroxyl radicals at 166.7 µg/mL. Phytochemical analyses showed that most plant samples revealed the presence of glycosides, terpenes/terpenoids, and steroids/phytosterols, while few contained phenolic and tannin components. These phytochemicals may explain the dual behavior as an antioxidant or a prooxidant observed. Thus, determining food antioxidant component types and their concentration is necessary to maximize the potential to scavenge oxidants.

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INTRODUCTION

Reactive Oxygen Species (ROS) are normal oxidant by-products of aerobic metabolism[1]. These reactive intermediates, which include superoxide anion (O_2•), the hydroxyl radical (OH•), and the singlet oxygen, are derived from the incomplete one-electron reduction of molecular oxygen[2]. Prolonged exposure to high ROS concentrations may lead to non-specific damage to proteins, lipids, and nucleic acids, often inducing irreversible functional alterations or complete destruction[3]. Antioxidants have gained importance for years due to their ability to neutralize the pathological effects of increased oxidative concentrations[4,5]. Though our bodies are equipped with innate antioxidant machinery, such as antioxidant enzymes and vitamins, these may not be enough to protect against the detrimental effects of excess free radicals. Consumption of foods rich in phytochemicals with strong antioxidant properties may help prevent and repair cellular damage to our bodies[5].

Natural antioxidants, particularly in fruits and vegetables, have gained increasing interest among consumers and the scientific community. Fruit and vegetable juices are rich sources of numerous phytochemicals, polyphenols, carotenoids, fiber, vitamins, and minerals[6,7]. Complex mixtures of these phytochemicals present in fruits and vegetables provide additive and synergistic effects on health promotion[8]. Thus, dietary intake of this food as a source of antioxidants is recommended.

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In the Philippines, Baguio City – known as the "City of Pines" – supplies the Philippines' daily requirements for highland vegetables[9]. Due to the temperate climate and wide land area, Baguio provided a conducive environment to cultivate quality fruits, vegetables, and other agricultural products. The Philippine Department of Agriculture stated that Baguio and neighboring provinces in Cordillera supply 80% of the highland vegetable requirement in major markets of Metro Manila and other lowland provinces[10]. Knowing the possible beneficial effects of plant foods cultivated from the country's primary agricultural source of prime vegetables, fruits, and crops is essential. Currently, limited studies are conducted on Baguio's commonly consumed plant foods. Thus, the study aims to determine the phytochemical constituents of some Baguio-derived vegetables and evaluate their antioxidant activities *in vitro*.

MATERIALS AND METHODS

Materials

Twenty-six plant samples were collected from local markets of Baguio (shown in **Table I**). Edible plant parts commonly consumed by locals were utilized in the study. All samples gathered were authenticated by the Institute of Biology Herbarium - University of the Philippines, Diliman. 1,1-diphenyl-2-picrylhydrazyl (DPPH), nitro blue tetrazolium (NBT), phenazine methosulfate (PMS), sodium nitroprusside (SNP), sulfanilamide, naphthyl ethylenediamine dihydrochloride (NED), potassium ferricyanide [$K_3Fe(CN)_6$], quercetin, butylated hydroxytoluene (BHT), ethylene diaminetetraacetic acid (EDTA), ascorbic acid, and reduced nicotinamide adenine dinucleotide (NADH) were purchased from Sigma-Aldrich Co. St. Louis, Germany. All other chemicals used were of analytical grade.

Table I. List of plant foods used with sample shortened names and parts used

Plant sample	English name/local name	Parts used	Specimen No.
Beta vulgaris L.	Sugar beets/redbeet	Root	NPL-032
Daucus carota subsp. *Sativus* (Hoffm.) Arcang.	Carrots/karot	Root	NPL-033
Lactuca sativa L. (Iceberg)	Iceberg lettuce/letsugas iceberg	Leaves	NPL-034
Lactuca sativa L. (Romaine)	Romaine lettuce/letsugas iceberg	Leaves	NPL-035
Lactuca sativa L. (Green Ice)	Green ice lettuce/letsugas green ice	Leaves	NPL-036
Lactuca sativa L. (Deep Red)	Deep red lettuce/pulang letsugas	Leaves	NPL-037
Brassica oleracea L. (cabbage)	Cabbage/repolyo	Leaves	NPL-038
Brassica oleracea L. (red cabbage)	Red cabbage/pulang repolyo	Leaves	NPL-039
Brassica oleracea L. (broccoli)	Broccoli/brokoli	Flower buds	NPL-040
Brassica oleracea L. (cauliflower)	Cauliflower/koliplor	Flower buds	NPL-041
Brassica rapa L. (pechay baguio)	Chinese cabbage/petchay Baguio	Leaves	NPL-042
Brassica rapa L. (flowering pechay)	Chinese cabbage/petchay Baguio	Flower	NPL-043
Nasturtium officinale R.Br	Watercress/tonghoy	Leaves	NPL-044
Raphanus raphanistrum subsp. *sativus* (L.) Domin	Red radish /pulang labanos	Fruit	NPL-045
Sechium edule (Jacq.) Sw.	Chayotte/sayote	Fruit	NPL-046
Morus alba L.	Mulberry/moras	Fruit	NPL-049
Fagopyrum tataricum (L.) Gaertn.	Buckwheat/malabato	Leaves	NPL-050
Fragaria x ananassa (Duchesne ex Weston) Duchesne ex Rozier	Strawberry/presa	Fruit	NPL-051
Citrus x aurantium L.	Sweet orange/Sagada oranges	Fruit	NPL-052
Solanum melongena L.	Eggplant/talong	Fruit	NPL-053
Capsicum annuum L.	Bell pepper	Fruit	NPL-054
Solanum lycopersicum L.	Tomato/kamatis	Fruit	NPL-055
Solanum tuberosum L.	Potato/patatas	Tuber	NPL-057
Cucurbita maxima Duschesne	Squash/kalabasa	Fruit	NPL-058
Solanum nigrum L.	Deadly nightshade/lubi-lubi or amti	Leaves	NPL-059
Vaccinium myrtoides	Blueberry/ayusip	Fruit	NPL-060

Methods

Sample preparation and extraction

All collected leaves, fruits, and roots were washed with distilled water, chopped, and cut into smaller pieces. Samples were dried through air-drying and lyophilization. Air-drying was employed on all leaf samples. On the other hand, samples with high water content were freeze-dried using Martin Christ Freeze Dryer Beta 2-8 LSC. All dried samples were kept at 4°C in sealed containers until ready for extraction. The dried samples were extracted with methanol at room temperature for 24 hours. The extract was then separated from the residue by filtration. The residue was re-extracted twice. The methanol

extract was concentrated using a rotary evaporator (Buchi Rotavapor R-200) at 40°C. Extracts were kept in tightly sealed bottles at 4°C until use.

Phytochemical screening

The secondary metabolites were determined in each plant sample using various tests[11,12]. The presence of reducing sugars in all plant samples was detected using Molisch, Fehling's, and Benedicts tests; proteins using Ninhydrin and Biuret tests; alkaloids using Mayer's, Wagner's, Hager's, and Dragendorff's tests; glycosides using Modified Borntranger's and Keller Killiani tests; steroids using Liebermann-Burchard test; terpenes and terpenoids using Salkowski's test; quinones using sulfuric acid test; anthraquinones using hydrochloric acid test; flavonoids using alkaline reagent and Shinoda tests; polyphenols using ferric chloride test; tannins using ferric chloride and gelatin tests; and saponins using froth test.

Antioxidant assays

DPPH scavenging activity: As much as 10 µL of standard and test compounds at different concentrations were loaded into a 96-well microplate. Afterward, 140 µL of 6.85×10^{-5} M DPPH was added to each well. The microplate was incubated for 30 minutes at room temperature in the dark. The absorbance was measured at 517 nm[13].

Ferric reduction antioxidant power (FRAP) assay: As much as 70 µL of standard and test compounds at different concentrations were mixed with 176.5 µL of 0.2 M sodium phosphate buffer (pH=7.4) and 176.5 µL of 1% [$K_3Fe(CN)_6$]. The mixture was incubated at 50°C for 20 minutes. After incubation, the reaction mixtures were acidified with 176.5 µL of 10% trichloroacetic acid and were centrifuged at 650x for 10 minutes. An aliquot of 273 µL of the supernatant was added to 273 µL of deionized water. Finally, 55 µL of 0.1% $FeCl_3$ was added to this solution. The absorbance was measured at 700 nm[14].

Metal chelating activity: In a 96-well microplate, different concentrations of the 20 µL methanol extracts were loaded, and 100 µL of 0.2 mmol/L $FeCl_2$ was added to each well. Afterward, 40 µL of 5 mmol/L ferrozine was added. The reaction mixture was incubated at room temperature for 10 minutes. The absorbance was measured at 562 nm[15].

Superoxide scavenging activity: As much as 10 µL of standard and test compounds at different concentrations were loaded into a 96-well microplate. Then, 100 µL 468 µM NADH, 100 µL 156 µM NBT, and 50 µL 60 µM PMS were added into each well. Five-minute incubation was done at room temperature. The absorbance was measured at 560 nm[16].

Nitric oxide scavenging assay: Sodium nitroprusside (10 mM, 2 mL) in phosphate buffer saline was incubated with test compounds in different concentrations at room temperature for 150 minutes. After 30 minutes, 0.5 mL of the incubated solution was added with 1 mL of Griess reagent (0.33% sulfanilamide in 20% glacial acetic acid, 0.5 mL, and 0.1% NED, 1 mL) and was incubated for 30 minutes at room temperature. The absorbance was measured at 546 nm[14].

MTT assay: Stock solutions of test compounds and extracts were prepared in DMSO (250-1000 µg/mL). The MTT (1 mg/mL) was dissolved in water. An aliquot of 190 µL of MTT solution in water and 10 µL of test compounds or extracts in DMSO were vortexed in a capped glass vial (2 mL) for 1 minute. As much as 200 µL DMSO was added, and the solution was vortexed again. The reaction mixture was then incubated at 37°C for six hours, 200 µL of the reaction mixture was pipetted to a 96-well cell culture plate, and the absorbance was measured at 570 nm[17].

Hydroxyl radical scavenging assay: The reaction mixture in a final volume of 1.0 mL contained 100 µL of 2-deoxy 2-ribose (28 mM in 20 mM KH_2PO_4 buffer, pH 7.4), 500 µL of the extract at various concentrations in buffer, 200 µL of 1.04 mM EDTA and 200 µM $FeCl_3$ (1 : 1, v/v), 100 µL of 1.0 mM hydrogen peroxide (H_2O_2), and 100 µL of 1.0 mM ascorbic acid. Test samples were kept at 37°C for an hour. The free radical damage imposed on the substrate, deoxyribose, was measured using the thiobarbituric acid test. As much as 1 mL of 1% thiobarbituric acid (TBA) and 1 mL of 2.8% trichloroacetic acid (TCA) was added to the test samples and incubated at 100°C for 20 minutes. After cooling, the absorbance was measured at 532 nm against a blank containing deoxyribose and buffer[18].

Data analysis

Results are expressed as mean ± SD. The statistical analysis was performed using one-way ANOVA. The differences were considered statistically significant at $p < 0.05$.

RESULTS AND DISCUSSION

DPPH scavenging activity

One mechanism by which antioxidants inhibit oxidation is by quenching reactive species through hydrogen or electron donation[19]. The DPPH assay is one of the most popular and frequently employed methods among antioxidant assays. DPPH is a stable free radical with a deep purple color and a strong absorption around 517 nm[20]. Increased concentration of antioxidants may result in a lighter solution[21].

Methanol extracts of *F. tataricum*, *L. sativa* GI, *V. myrtoides*, and *M. alba* have exhibited good concentration-dependent inhibitory activity against DPP radicals. *Fagopyrum tataricum* showed the most effective DPP radical inhibition (74.53±1.59%) at 66.67 µg/mL. Relatively good inhibitions were also observed in *L. sativa* GI (69.86±1.59%), *V. myrtoides* (66.10±4.43%), and *M. alba* (63.25±0.05%) at the same concentration. In addition, all these plant samples had demonstrated >50% scavenging even at 33.33 µg/mL dose. Similar findings have been observed in other studies. *Fagopyrum tataricum* exhibited significant antioxidant activity with IC_{50} of 159.51±1.29 µg/mL[22]. *Vaccinium myrtoides* fruit exhibited the highest antioxidant activity as indicated by its 92.35±0.69% DPPH radical scavenging activity among Baguio fruit and fruit wines[9]. Moreover, ethanolic leaf extracts of *V. myrtoides* (20.85 µg/mL) from Ifugao showed higher DPP inhibition than ascorbic acid (21.56 µg/mL)[23]. Significant increase in scavenging activity was observed in *M. alba* with 3.48%, 8.28%, 16.63%, and 25.84% inhibitions between 100-1000 µg/mL[24].

Different DPP inhibitory activities were observed between *L. sativa* and *B. oleracea* sample varieties. The four varieties of *L. sativa* exhibited DPPH inhibition at 66.67 µg/mL in increasing order: *L. sativa* RL (10.79±2.74%), *L. sativa* I (17.99±2.36%), *L. sativa* DR (33.18±5.56%), and *L. sativa* GI (69.86±1.59%), respectively. Similar findings showed that red and darker green types of lettuce possess higher antioxidant activity than the green type of lettuce. Red coral lettuce possessed the lowest EC_{50} value, followed by green coral, iceberg, butterhead, and romaine with 303.56±11.3, 775.55±43.7, 3991.67±174.7, 4230.13±401.5, and 4485.41±784.4 µg/mL, respectively[25]. In addition, red varieties of lettuce were significantly higher than those of green lettuce[26]. Likewise, four varieties of *B. oleracea* showed different activities at the highest concentration. *B. oleracea* RCab was revealed to be the most active extract, and *B. oleracea* Cab (5.96±8.82%) was the least. Methanolic extracts of *B. oleracea* varieties exhibited varying DPP radical inhibitions in the order: red cabbage > green cabbage > broccoli > cauliflower[27].

Some plant samples showed moderate scavenging activities. Moderate scavenging activities of extracts were observed in the following plant samples in increasing order: *B. oleracea* RCab, *F. anannasa*, *L. sativa* DR, *B. vulgaris*, and *S. nigrum*, with inhibitions of 29.99±3.38%, 32.92±2.06%, 33.18±5.56%, 34.28±1.67% and 47.54±0.93% at 66.67 µg/mL, respectively. Methanol leaf extract of *S. nigrum* significantly inhibited DPP radicals in a concentration-dependent manner with IC_{50} of 165 µg/mL[28]. In contrast, low scavenging activities (DPPH inhibition <25%) were demonstrated by other extracts, even at the highest concentration. No DPPH inhibition was observed for *C. aurantium*. The overall results are presented in **Figure 1**.

FRAP assay

The reducing capacity of a compound may serve as a significant indicator of its potential antioxidant activity. In this assay, antioxidant capacity measures the reduction of the ferric ion (Fe^{3+}) to the ferrous ion (Fe^{2+}) by donor electrons in the sample[29]. The activity is monitored by measuring the formation of Perls' Prussian blue complex at 700 nm[30]. Methanol extracts *of F. tataricum*, *L. sativa* GI, *V. myrtoides*, and *M. alba* have exhibited the highest concentration-dependent reducing ability among Baguio plant foods. *Fagopyrum tataricum* showed the most effective iron reduction (72.44±1.99%) at 38.2 µg/mL. Comparable reductions to that of *F. tataricum* were also observed in *L. sativa* GI (71.60±1.00%), *V. myrtoides* (71.80±1.80%), and *M. alba* (71.77±1.94%). As mentioned earlier, the plant possessed reducing abilities based on other studies. Maximum activity was exhibited by methanol extract of *F. tataricum*, greater than the gallic acid standard at 200 µg/mL[31]. Wild Blueberries (*Vaccinium* sp.) extract of some wild and cultivated Blueberries from Romania showed iron reduction, with Wild Type 1 (73.71±3.2 µM Fe^{2+}/g) being the most potent[32]. Mulberry variety (S-1708; *Morus* sp.) exhibited reducing activity of 4107.22 ± 97.6 µM/Fe(II) mg and 3540.60 µM/Fe(II) mg in methanol and ethanol solvents, respectively[33].

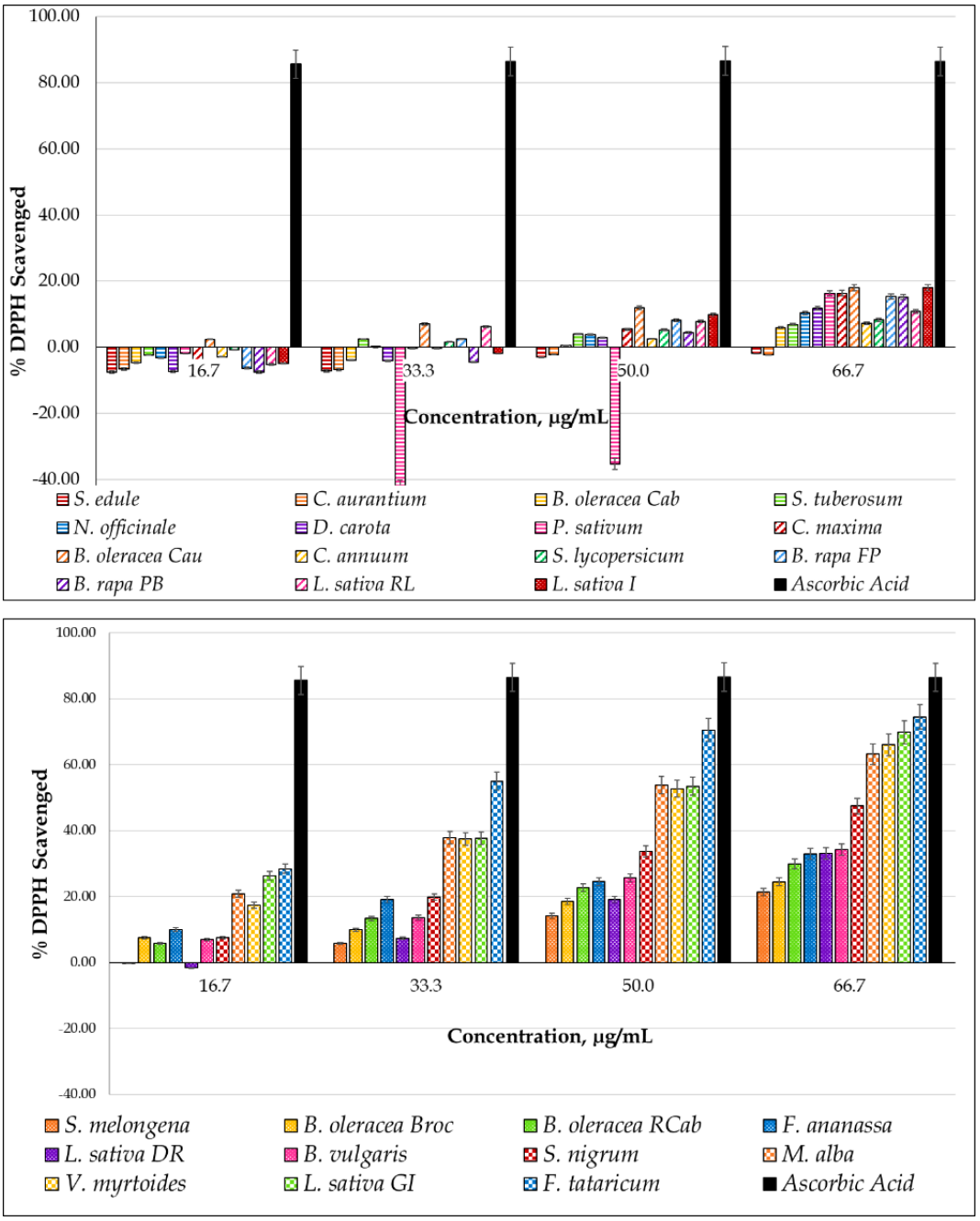

Figure 1. DPPH scavenging assay of Baguio plant foods.

Interestingly, other plant samples showed high reducing abilities. Relatively high reducing power of extracts was observed in the following plant samples in increasing order: *B. oleracea* RCab, *B. vulgaris*, *L. sativa* DR, and *B. rapa* FP, with an inhibition of 71.92±3.46%, 72.74±3.41%, 74.32±0.33% and 74.65±2.83% at 50.9 µg/mL, respectively. In contrast, low-reducing activities (iron reduction <25%) were demonstrated by other extracts, even at the highest concentration. Moreover, no iron reduction was observed for *C. maxima*. Reducing power between sample varieties of *L. sativa* was assessed. Varieties of *L. sativa* exhibited varying iron reduction at 50.9 µg/mL in increasing order: *L. sativa* I (37.06±8.80%), *L. sativa* RL (41.84±2.38%), *L. sativa* DR. (74.32±0.33%) and *L. sativa* GI (76.46±2.21%), respectively. Strong reducing capacity exhibited by plant samples may indicate greater antioxidant activity[34]. These results infer that dark-colored lettuces have higher FRAP values than the typical green varieties[35]. The overall results are presented in **Figure 2**.

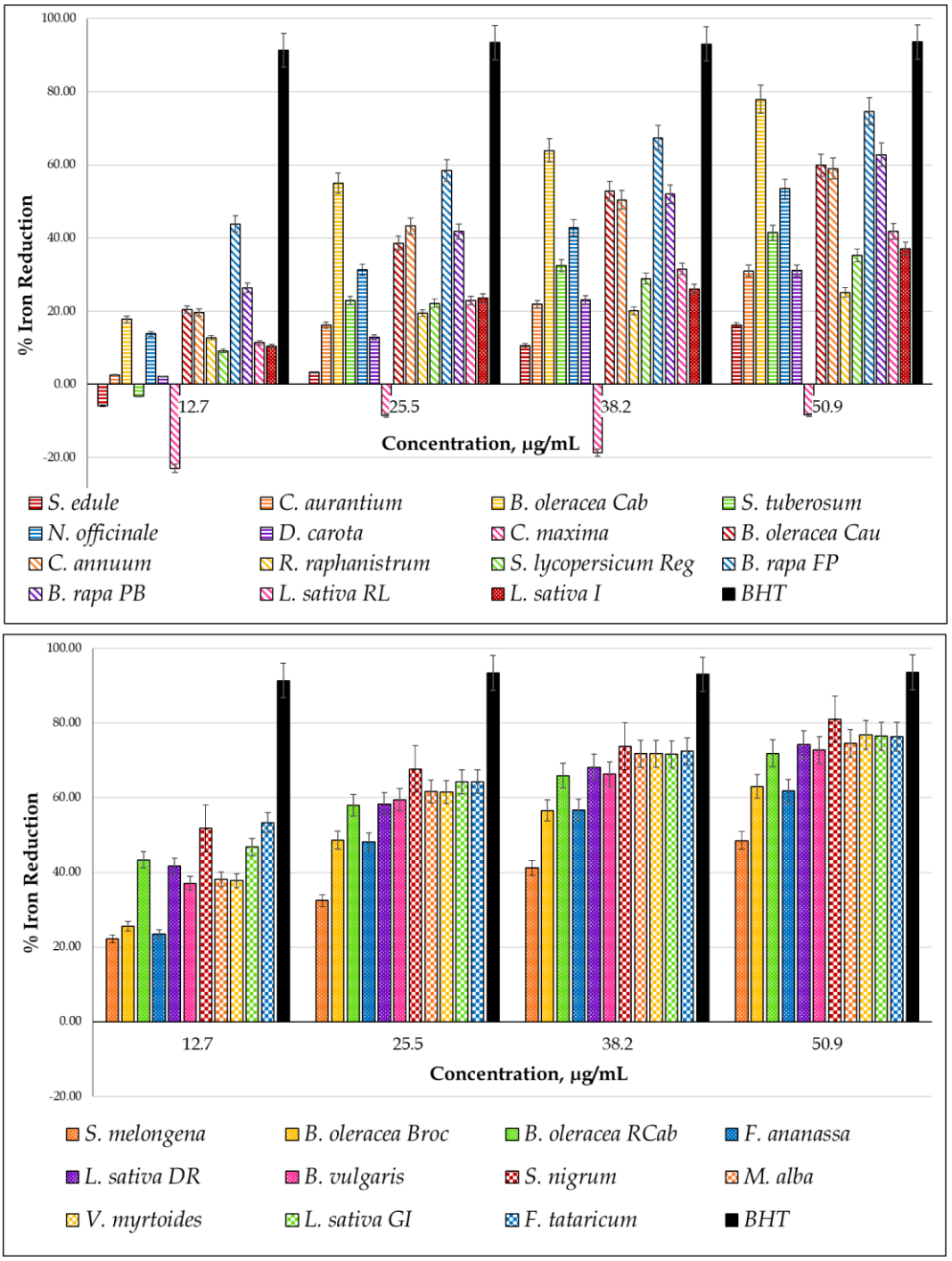

Figure 2. Reducing Power of Baguio plant foods.

Metal chelating activity

Metals, such as Fe and Cu, and ultra-trace elements, Co and Ni, act as cofactors that assist enzymes in catalyzing biochemical reactions efficiently[36]. Transition metals become toxic at elevated tissue concentrations. Excess transition metals can initiate hydroxyl radical production through the Fenton reaction ($H_2O_2 + Fe^{2+} \rightarrow Fe^{3+} + OH^- + OH\bullet$)[37]. This process hastens the rate of lipid peroxidation by the continuous generation of peroxy radicals (LOO•) to form lipid hydroperoxides (LOOH) – the main primary products of lipid peroxidation[38]. Chelation therapy is the preferred medical treatment for reducing the toxic effects of metals[39]. The use of metal chelators can improve the symptoms of metal overload. Synthetic chelators have posed severe side effects; hence, using natural plant foods with chelating ability has been getting more attention[40].

In metal chelation, a decrease in the absorbance of the red-violet Fe^{2+}/ferrozine complex is monitored[41]. Low metal chelating activity was observed from Baguio plant foods. Most plant samples were <20%, even at the highest concentration. *S.*

tuberosum showed the highest effective concentration-dependent chelating activity with inhibitions 6.30±3.82%, 16.76±3.82%, and 22.86±63.26% at 62.5, 93.8, and 125 µg/mL, respectively. However, lower chelation was observed in Baguio-grown *S. tuberosum* compared with other studies. Benguet varieties, Igorota (EC_{50}= 11.0±3.2 µg/mL) and Ganza (EC_{50}= 14.7±3.2 µg/mL) exhibited effective chelating activity[42]. Purple-colored potatoes had a higher chelating effect than white and yellow potato varieties from Korea[43]. Conversely, no iron chelation was observed for *D. carota* and *C. annuum*. The overall results are presented in **Figure 3**.

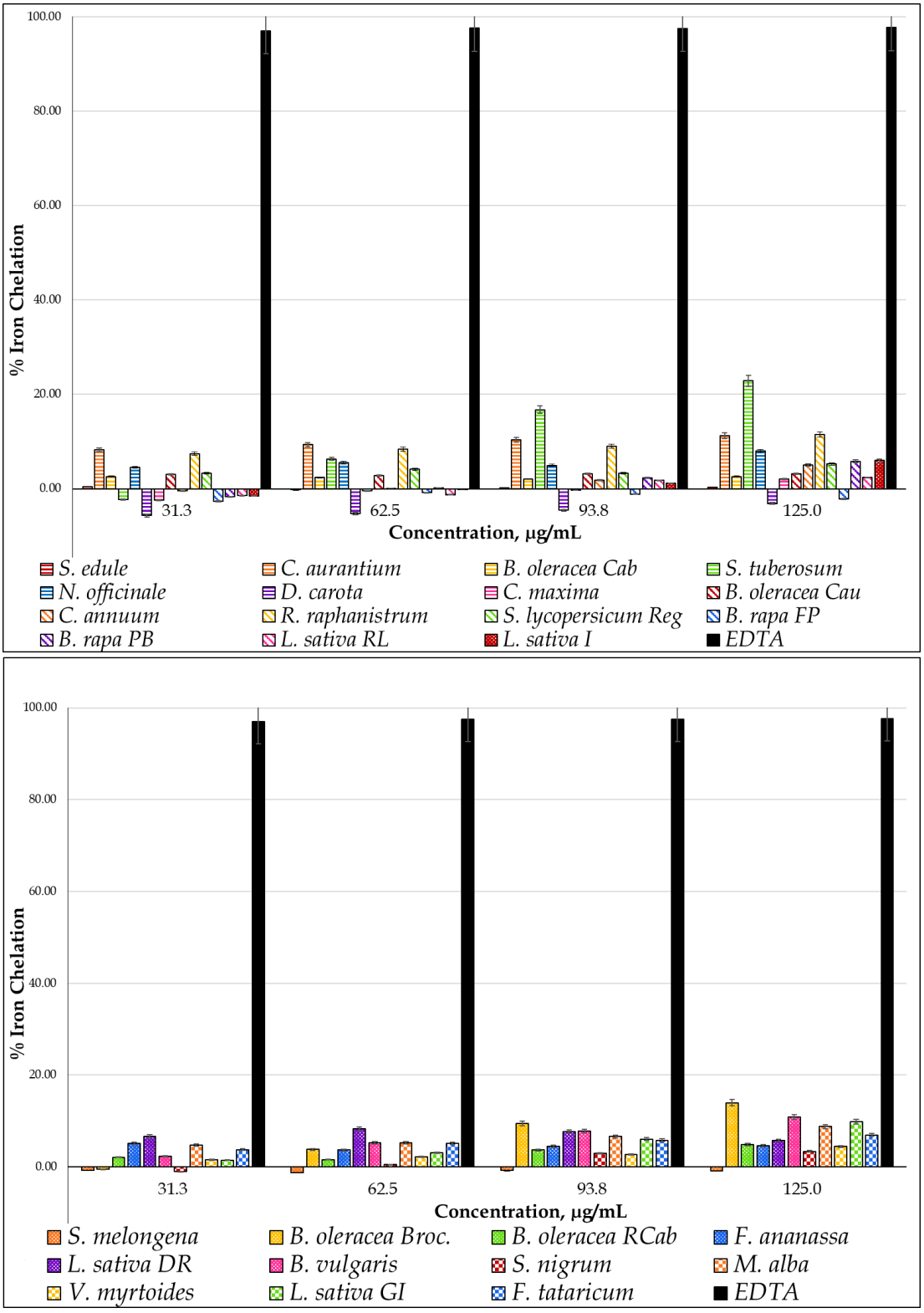

Figure 3. Metal chelating activity of Baguio plant foods.

Superoxide scavenging activity

Superoxide ($O_2^{\bullet-}$) is a free radical with a short biological lifespan produced by the one-electron reduction of molecular oxygen[44]. Superoxide anion initiates free radical formation of other reactive oxygen species in living systems[45]. It can also react with nitric oxide and form peroxynitrite[46]. Thus, knowing the right food which will provide good superoxide scavenging properties may help lower the risk of many degenerative diseases. The overall results are presented in **Figure 4**.

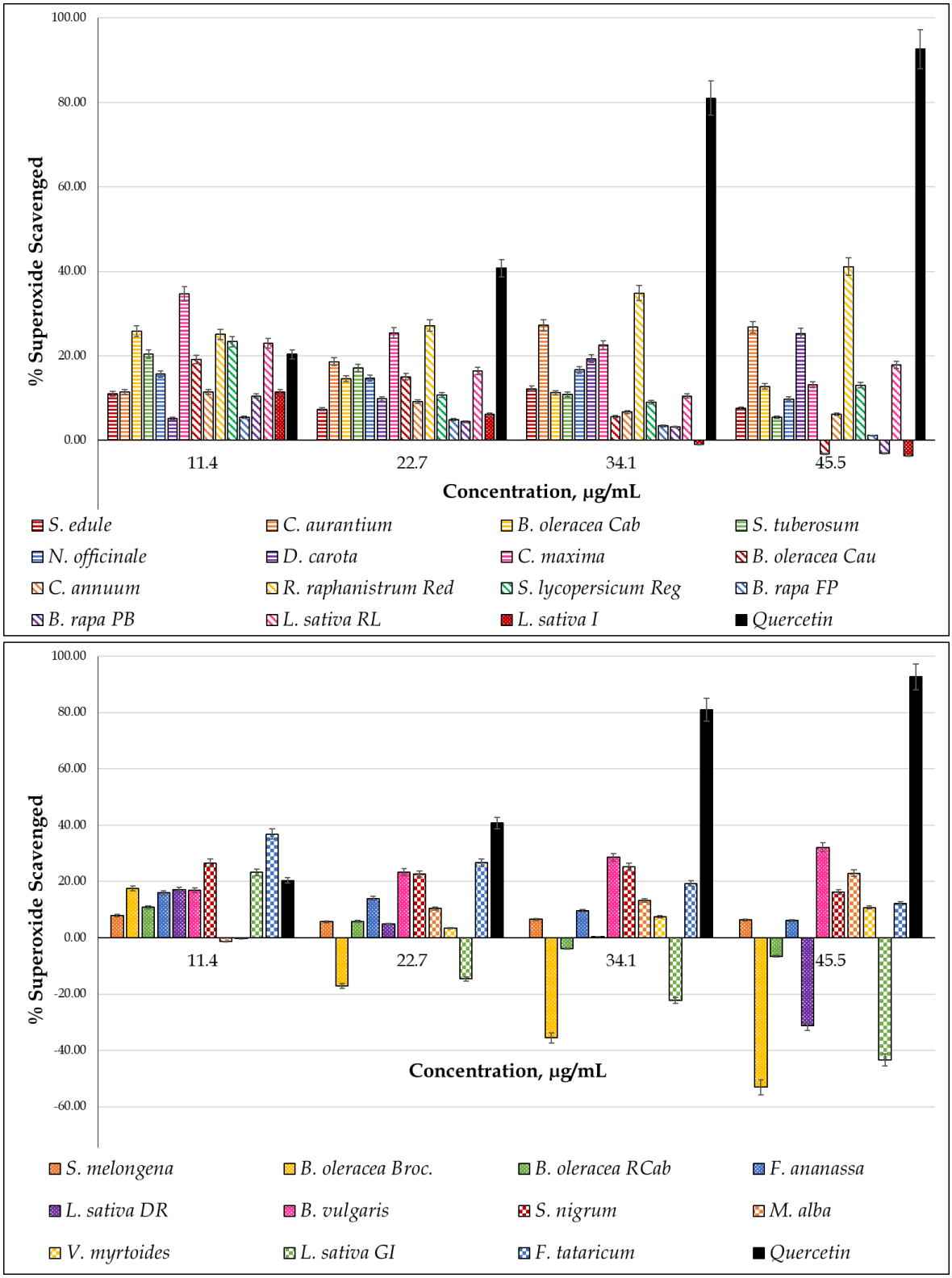

Figure 4. Superoxide scavenging activity of Baguio plant foods.

In this assay, a decrease in absorbance at 560 nm indicates the scavenging of superoxide radicals[47]. Methanol extracts of Baguio plant foods showed inhibitions of superoxide radicals. Some extracts showed the highest superoxide radical scavenging activity at the lowest concentration. Greater than 20% superoxide scavenging activity was observed at 11.4 µg/mL dose in the following plant samples in increasing order: *L. sativa* RL (22.94±2.51%), *L. sativa* GI (23.20±8.44%), *S. lycopersicum* Reg (23.35±2.70%), *B. oleracea* Cab (25.87±0.47%), *S. nigrum* (26.57±3.98%), *C. maxima* (34.61±2.21%), and *F. tataricum* (36.81±1.70%). *Citrus aurantium* and *R. raphanistrum* demonstrated an effective scavenging activity against superoxide anions. However, it was observed that as the dose of some extracts increases, their scavenging ability decreases. *Fagopyrum tataricum* showed a significant change in activity from the lowest concentration with 36.81±1.70% (at 11.4 µg/mL) superoxide scavenging capacity to a 12.15±0.46% (at 45.5 µg/mL). The same pattern of activity was demonstrated by *L. sativa* GI (23.20 to -43.41%), *S. lycopersicum* Reg (23.35 to 13.03%), *B. oleracea* Cab (25.87 to 12.73%), *S. nigrum* (26.57 to 16.26%) and *C. maxima* (34.61 to 13.15%). Similar findings were reported in some Quezon Province plant food extracts that exhibited a decrease in superoxide scavenging activity and stimulation of superoxide radical production as the dose was increased.5 *Ficus odorata*, an endemic medicinal plant in the Philippines, has shown a concentration-dependent stimulation of $O_2^{\bullet -}$[48]. With these reported results demonstrated the dual action, as an antioxidant and as a prooxidant, of some plant foods studied. Therefore, natural antioxidants have been shown to act as prooxidants under certain conditions[5].

Nitric oxide scavenging activity

Nitric oxide (NO) is an important cell signaling molecule. At lower concentrations, NO aids in angiogenesis[49]. Nitric oxide plays vital roles in humans, which include dilating blood vessels, raising blood supply and lowering blood pressure, regulating platelet aggregation, signaling molecules between neurons, and killing bacteria[50,51]. However, NO also possesses a dual role. As a free radical, nitric oxide readily reacts with other radical species and the metal centers of metalloproteins[52]. Moreover, when nitric oxide is near superoxide, peroxynitrite ($ONOO^-$) may spontaneously form[44]. In this assay, the Griess reagent can estimate nitric oxide formed[14]. Nitric oxide scavengers compete with oxygen, producing reduced nitric oxide. Most of the Baguio plant foods exhibited high nitric oxide scavenging ability. Greater than 50% superoxide scavenging activity was observed in *S. lycopersicum* Reg (75.43±0.71%), *B. vulgaris* (65.21±0.37%), *C. aurantium* (64.10±0.57%), *S. melongena* (62.20±0.84%), *V. myrtoides* (57.69±1.47%), *R. raphanistrum* (56.70±2.64%), *L. sativa* GI (56.02±1.01%), *S. tuberosum* (53.77±3.43%), *M. alba* (51.96±0.60%), *C. annuum* (50.84±0.88%), at 16.7 µg/mL dose. Observed activities were comparable to gallic acid (56.93±6.35%) at the same concentration. However, some of the Baguio extracts were seen to behave as prooxidants as the dose was increased to 66.7 µg/mL.

Lactuca sativa GI (Green Ice Lettuce) exhibited a significant change in NO scavenging ability from 56.02±1.00% (at 16.7 µg/mL) to -87.33±2.50% (at 66.7 µg/mL). The same pattern of activity was demonstrated by *B. oleracea* Broc (35.74 to -45.58%), *B. rapa* FP (11.73 to -27.58%), *S. nigrum* (29.51 to -69.25%), *L. sativa* RL (33.67 to -57.57%), *N. officinale* (47.09 to -47.27%), and *S. edule* (18.96 to -24.39%). The overall results are presented in **Figure 5**.

MTT assay

MTT was developed as an antioxidant assay utilizing the redox reaction to screen natural product extracts or purified compounds[17]. Methanol extracts of *S. tuberosum*, *B. oleracea* Cab, *B. vulgaris*, *S. nigrum*, and *L. sativa* GI have exhibited the highest concentration-dependent reducing ability among Baguio plant foods. *Brassica oleracea* Cab showed the most effective MTT reduction (48.89±0.431%) at 66.7 µg/mL. Good reductions were also observed in *B. vulgaris* (45.79±1.35%), *L. sativa* GI (43.73±0.81%), *S. nigrum* (41.47±2.04%), and *S. tuberosum* (31.97±1.18%) at the same concentration. In addition, all these plant samples had extended their potency showing >20% scavenging even at 16.7 µg/mL. In contrast, low-reducing activities (iron reduction <25%) were demonstrated by other extracts, even at the highest concentration. Moreover, no MTT reduction was observed for *S. melongena*, *F. annanasa*, *M. alba*, *V. myrtoides*, and *F. tataricum*. The overall results are presented in **Figure 6**.

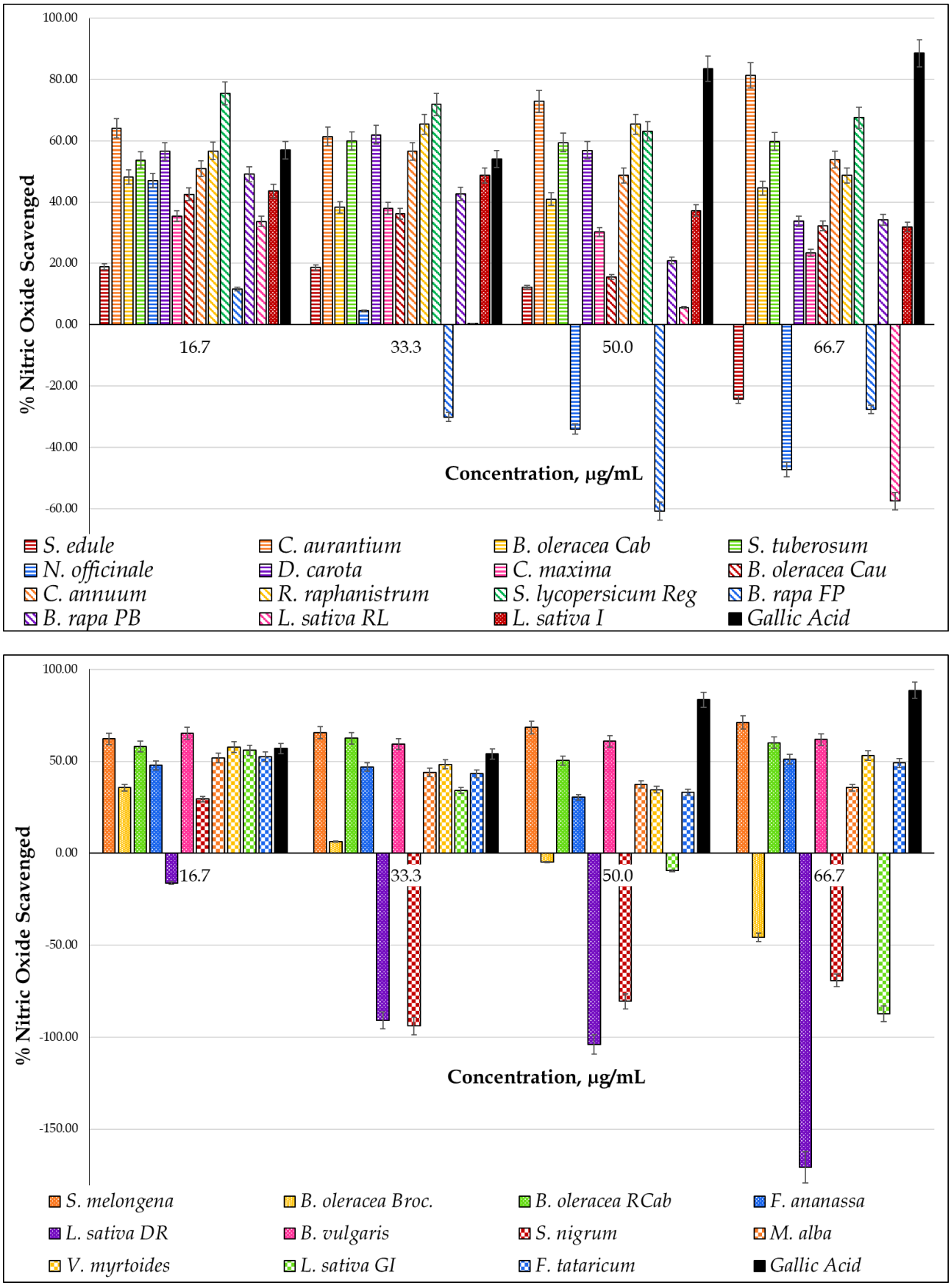

Figure 5. Nitric oxide scavenging activity of Baguio plant foods.

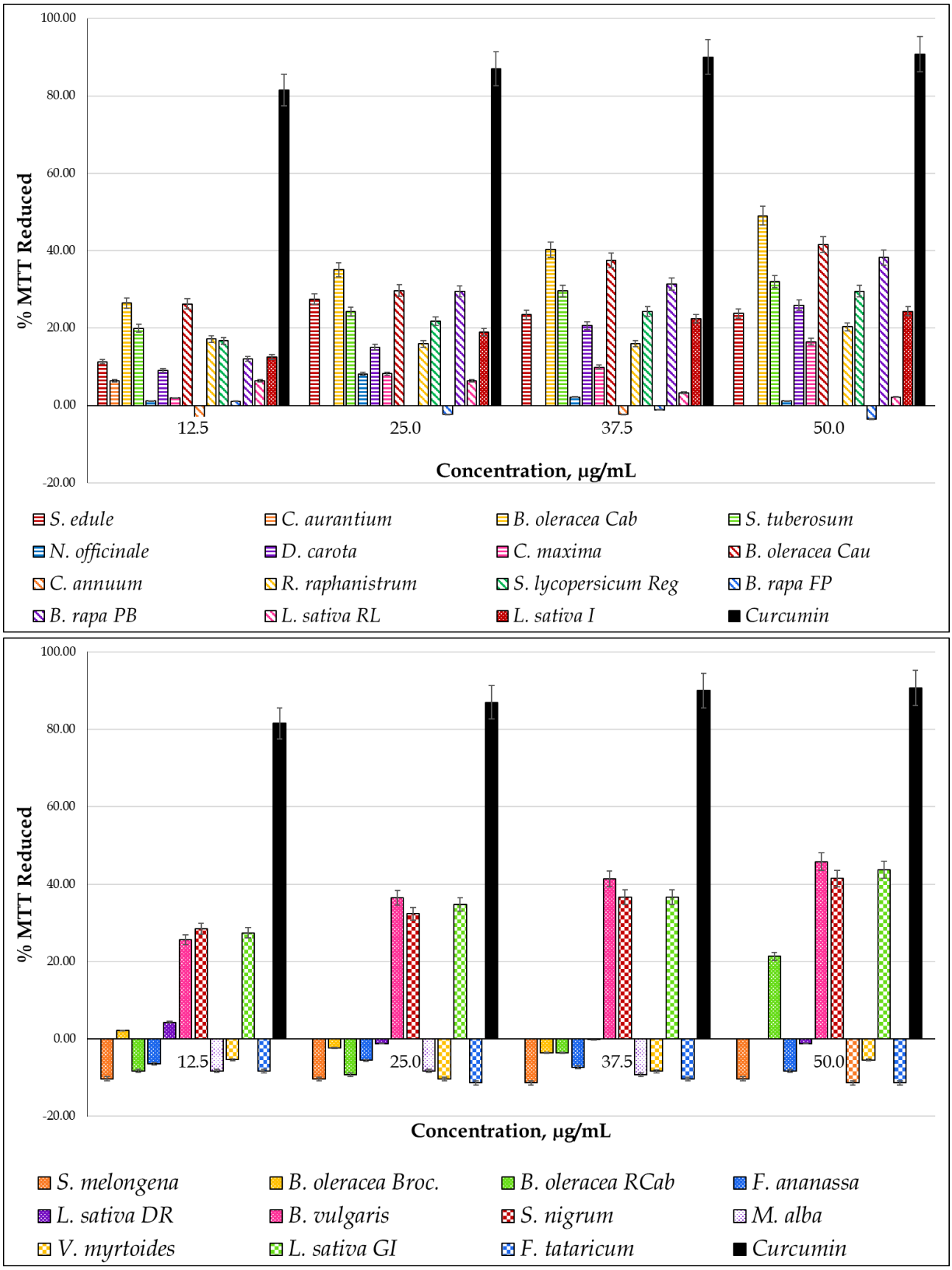

Figure 6. MTT reducing activity of Baguio plant foods.

Hydroxyl radical scavenging assay

Hydroxyl radicals are highly reactive and short-lived molecules. These molecules can react with lipids, polypeptides, proteins, and DNA, especially thiamine and guanosine bases[53]. The high reactivity of hydroxyl radicals may result in reduced disulfide bonds in fibrinogen, resulting in abnormal folding[54]. Therefore, it is vital to remove hydroxyl radicals.

Baguio plant foods showed scavenging ability against hydroxyl radicals. Among these plant foods, *B. oleracea* Cab showed the highest inhibitory activity against hydroxyl radicals at 166.7 µg/mL by 54.36±2.38%. Antioxidant activity and polyphenol content of *B. oleracea* varieties, it was revealed that methanolic extracts of *B. oleracea* varieties exhibited varying hydroxyl radical inhibitions in the order: red cabbage > green cabbage > broccoli > cauliflower[27]. Comparable scavenging to that of *B. oleracea* Cab was also observed in *C. maxima* (53.26±0.82%), *C. annuum* (48.38±2.14%), *L. sativa* RL (48.37±0.819%), and *L. sativa* GI (46.18±1.2%) at the same concentration. In addition, varieties of *L. sativa* exhibited different nitric oxide radical scavenging activities. The four varieties of *L. sativa* exhibited scavenging activity at 166.7 µg/mL in decreasing order: *L. sativa* RL > *L. sativa* GI > *L. sativa* I > *L. sativa* DR. These conformed with results using various Serbian lettuce varieties[55]. Among the three plant varieties, the Neva variety possessed the highest hydroxyl scavenging activity (IC_{50}=87.56±1.05 µg/mL), followed by Emerald, then Vera[54]. Other commonly consumed plant foods in Baguio exhibited ~30-40% scavenging activity at 166.7 µg/mL. The overall results are presented in **Figure 7**.

Phytochemical analysis

All Baguio plant samples contained reducing sugars and quinone compounds. Terpenes and terpenoids were found in all extracts except *B. rapa* FP, *N. officinale*, and *S. nigrum*. Only *L. sativa* Green GI, *L. sativa* DR, *B. oleracea* RCab, *F. tataricum*, and *V. myrtoides* revealed the presence of phenolic and tannin compounds. Alkaloids were found in *D. carota*, *L. sativa* DR, *B. oleracea* Cab, *B. oleracea* RCab, *R. raphanistrum*, *C. aurantium*, and *S. lycopersicum* Reg. A few plant samples contained flavonoid and saponin compounds. Among all samples tested, *N. officinale* possessed the least phytochemicals present. The overall results are presented in **Table II**.

Many phytochemicals support the body's innate antioxidant machinery. Phytochemicals: polyphenols, flavonoids, anthocyanins, and carotenoids are the major contributors to their antioxidant properties[56]. Polyphenols, which include flavonoids, stilbenes, lignans, and phenolic acids, are chemical substances characterized by aromatic rings with one or more hydroxyl groups. These compounds react with free radicals, resulting in the delocalization of the gained electron and stabilization of the aromatic nucleus through resonance. This, in turn, stops the free radical chain reaction[57]. Carotenoids, which exhibit a characteristic, symmetrical tetraterpene skeleton found in colored pigments of plant foods, are effective "radical-trapping antioxidants" and one of the most efficient singlet oxygen quenchers[58]. Other phytochemicals such as terpenes and terpenoids, alkaloids, and saponin compounds were also reported for antioxidant activities[59-61].

However, several studies reported that phenolic antioxidants can also act as prooxidants under certain conditions, like high concentrations of transition metal ions, alkali pH, and the presence of oxygen molecules[62-64]. Large molecular weight phenolics, such as hydrolysable and condensed tannins, have little or no prooxidant properties compared to simple phenol. Polyphenols with low oxidation potentials (Epa) exhibit antioxidant activity, while those with high Epa values act as prooxidants[5]. This characteristic could describe a dual action of phenolic compounds, where high-Epa polyphenols exist in some extracts that simultaneously exhibit antioxidant and prooxidant activities.

In summary, the study revealed that phytochemicals from these plant foods exhibited various degrees and types of antioxidant components and activities. For example, some plant foods, *F. tataricum*, *V. myrtoides*, and *M. alba*, possess higher or equal antioxidant activity than known standards. The various composition of phytochemicals in plant foods exerts different "strength" against oxidants. Reports have shown that exogenous antioxidants may show prooxidant activities, especially when administered at high doses. Despite these drawbacks, food-based secondary metabolites hold promising avenues for health benefits. Further work may be done to elucidate these results *in vivo* and identify compounds responsible for these activities. Moreover, continuous studies on phytochemical mechanisms and interactions may be done to establish the most significant impact of antioxidant systems on alleviating chronic diseases.

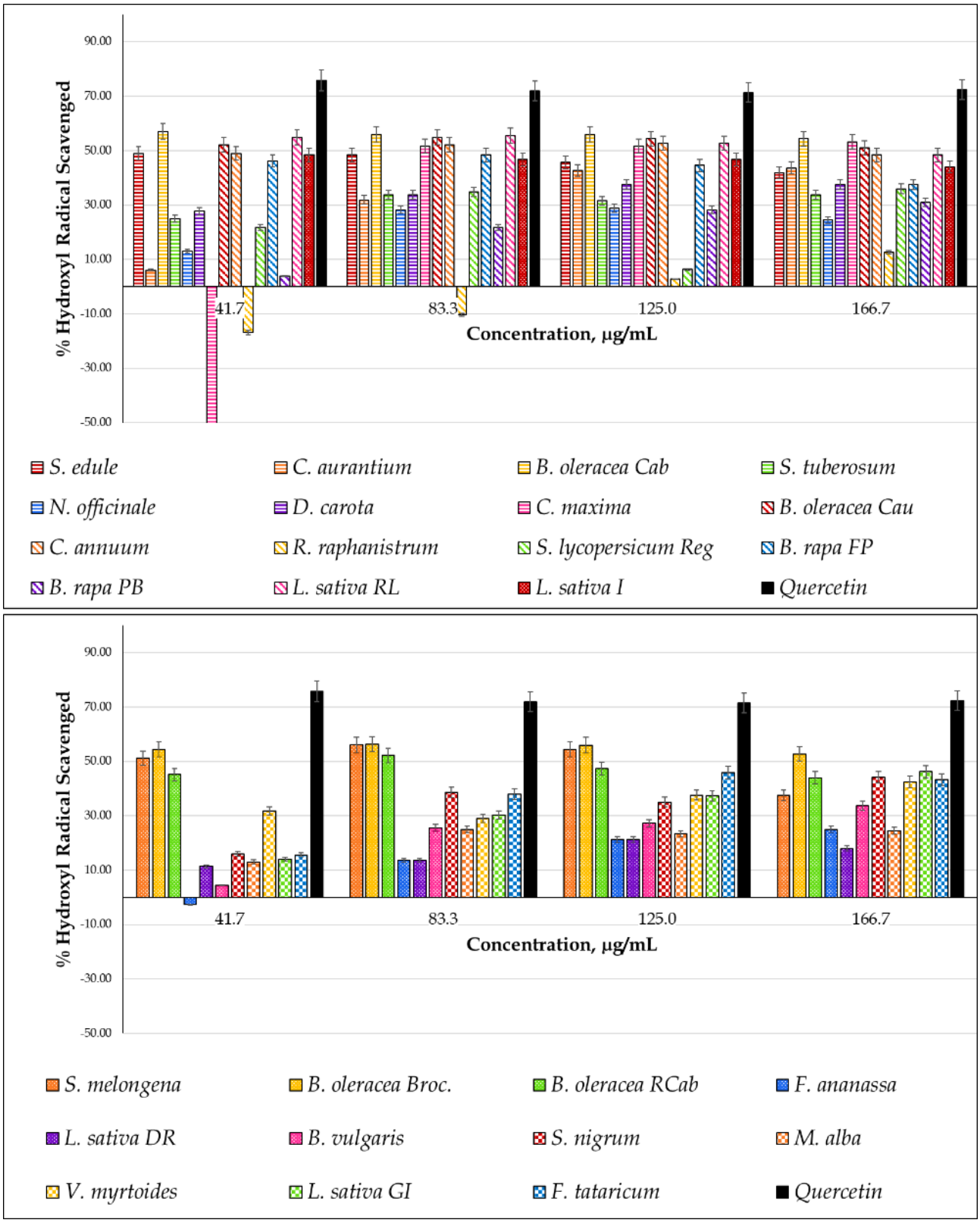

Figure 7. Hydroxyl radical scavenging activity of Baguio plant foods.

Table II. Phytochemical profile of methanolic extracts of Baguio plant foods

Plant Sample	Flavonoids	Coumarins	Reducing sugars	Proteins	Saponins	Glycosides	Alkaloids	Terpenes/ Terpenoids	Tannins	Phenolics	Steroids and phytosterol	Quinones	Anthraquinones
B. vulgaris	-	-	+	+	+	+	-	+	-	-	-	+	-
D. carota	-	+	+	+	+	+	+	+	-	-	+	+	+
L. sativa I	-	+	+	+	-	-	-	+	-	-	-	+	+
L. sativa RL	+	+	+	+	-	-	-	+	-	-	-	+	-
L. sativa GI	-	+	+	+	-	+	-	+	+	+	+	+	-
L. sativa DR	-	+	+	-	-	+	+	+	+	+	+	+	-
B. oleracea Cab	+	+	+	+	-	-	+	+	-	-	-	+	-
B. oleracea RCab	+	+	+	+	-	+	+	+	+	+	+	+	-
B. oleracea Broc	-	+	+	-	-	+	-	+	-	-	+	+	+
B. oleracea Cau	-	+	+	+	-	+	-	+	-	-	+	+	-
B. rapa PB	-	+	+	+	+	+	-	+	-	-	-	+	+
B. rapa FP	-	+	+	+	-	+	-	-	-	-	+	+	-
N. officinale	-	+	+	-	-	-	-	-	-	-	+	+	-
R. raphanistrum	+	+	+	+	-	+	+	+	-	-	+	+	+
S. edule	+	+	+	-	+	+	-	+	-	-	+	+	-
M. alba	+	+	+	-	-	+	-	+	-	-	+	+	+
F. tataricum	-	+	+	-	-	-	-	-	+	+	-	+	-
F. ananassa	+	+	+	+	-	+	-	+	-	-	+	+	+
C. aurantium	+	+	+	+	-	+	+	+	-	-	+	+	-
S. melongena	-	+	+	-	-	-	-	+	-	-	+	+	-
C. annuum	-	+	+	+	-	+	-	+	-	-	-	+	-
S. lycopersicum Reg	-	+	+	+	+	+	+	+	-	-	-	+	-
S. tuberosum	-	+	+	+	+	-	-	+	-	-	-	+	-
C. maxima	-	-	+	+	+	-	-	+	-	-	+	+	+
S. nigrum	-	+	+	+	+	-	-	-	-	-	-	+	-
V. myrtoides	+	+	+	-	-	+	-	+	+	+	+	+	+

CONCLUSION

In conclusion, the study revealed that Baguio plant foods contained various phytochemicals and showed promising antioxidant capacities. The findings of this study may provide information that consuming Baguio-cultivated plant foods are beneficial and may be applied in the management of various free radical-linked diseases.

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AUTHORS' CONTRIBUTION

PRB performed laboratory experiments and wrote the paper. **RCC** performed laboratory experiments; **GFY** supervised the flow, conceptualized, and advised ideas, and edited the manuscript.

DATA AVAILABILITY

None.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

REFERENCES

1. Ponnampalam EN, Kiani A, Santhiravel S, Holman BWB, Lauridsen C, Dunshea FR. The Importance of Dietary Antioxidants on Oxidative Stress, Meat and Milk Production, and Their Preservative Aspects in Farm Animals: Antioxidant Action, Animal Health, and Product Quality-Invited Review. Animals. 2022;12(23):3279. doi:10.3390/ani12233279

2. Vona R, Pallotta L, Cappelletti M, Severi C, Matarrese P. The Impact of Oxidative Stress in Human Pathology: Focus on Gastrointestinal Disorders. Antioxidants. 2021;10(2):201. doi:10.3390/antiox10020201

3. Papuc C, Goran GV, Predescu CN, Nicorescu V. Mechanisms of Oxidative Processes in Meat and Toxicity Induced by Postprandial Degradation Products: A Review. Compr Rev Food Sci Food Saf. 2017;16(1):96-123. doi:10.1111/1541-4337.12241

4. Parcheta M, Świsłocka R, Orzechowska S, Akimowicz M, Choińska R, Lewandowski W. Recent Developments in Effective Antioxidants: The Structure and Antioxidant Properties. Materials. 2021;14(8):1984. doi:10.3390/ma14081984

5. Yu GFB, Cabrera RCR, Bueno PRP, Sia IC. The Antioxidant Activity of Plant Foods from Quezon Province, Philippines. Acta Med Philipp. 2020;54(2):151-60. doi:10.47895/amp.v54i2.1531

6. Cajuday LA, Membreve DMS, Serrano, JE. Evaluation of the antioxidant and anticancer activities of Canarium ovatum (Burseraceae) pulp extracts. Int J Biosci. 2017;11(3):247-56. doi:10.12692/ijb/11.3.247-256

7. Ragasa CY, Torres OB, Gutierrez JMP, Kristiansen HPB, Shen CC. Triterpenes and Acylglycerols from Canarium ovatum. J Appl Pharm Sci. 2015;5(4):94-100. doi:10.7324/japs.2015.50416

8. Morales-Soto A, García-Salas P, Rodríguez-Pérez C, Jiménez-Sánchez C, Cádiz-Gurrea MdlL, Segura-Carretero A, et al. Antioxidant capacity of 44 cultivars of fruits and vegetables grown in Andalusia (Spain). Food Res Int. 2014;58:35–46. doi:10.1016/j.foodres.2014.01.050

9. Barcelo, R. Phytochemical Screening and Antioxidant Activity of Edible Wild Fruits in Benguet, Cordillera Administrative Region, Philippines. Electron J Bio. 2015;11(3):80-9.

10. Agoot, L. CAR contributes 1-M kilos veggies to PH food sustainability. Philippine News Agency. Available from: https://www.pna.gov.ph/articles/1136896

11. Prasad MP, Shekhar S, Amit B. Phytochemical Analysis and Antioxidant potential of Piper species and its Molecular Characterization by RAPD Markers. Int J Fundam Appl Sci. 2012;1(4):71-4.

12. Kuntal DAS, Dang R, Sivaraman G, Ellath RP. Phytochemical Screening for Various Secondary Metabolites, Antioxidant, and Anthelmintic Activity of Coscinium fenestratum Fruit Pulp: A New Biosource for Novel Drug Discovery. Turk J Pharm Sci. 2018;15(2):156-65. doi:10.4274/tjps.54376

13. Subhashini N, Thangathirupathi A, Lavanya N. Antioxidant Activity of Trigonella foenum graecum using various in vitro and ex vivo models. Int J Pharm Pharm Sci. 2011;3(2):96-102.

14. Bueno PRP, Buno CBM, Santos DL, Santiago LA. Antioxidant activity of Ficus pseudopalma Blanco and its cytotoxic effect on hepatocellular carcinoma and peripheral blood mononuclear cells. Curr Res Biol Pharma Sci. 2013;2(2):14-21.

15. Alam MN, Bristi NJ, Rafiquzzaman M. Review on in vivo and in vitro methods evaluation of antioxidant activity. Saudi Pharm J. 2013;21(2):143-52. doi:10.1016/j.jsps.2012.05.002

16. Hazra B, Biswas S, Mandal N. Antioxidant, and free radical scavenging activity of Spondias pinnata. BMC Complement Altern Med. 2008;8:63. doi:10.1186/1472-6882-8-63

17. Subhadradevi S, Asokkumar K, Umamaheswari M, Sivashanmugam A, Sankaranand R. In Vitro Antioxidant Activity of Vetiveria zizanioides Root Extract. Tanzan J Health Res. 2010;12(4):276-81.

18. Liu Y, Nair MG. An efficient and economical MTT assay for determining the antioxidant activity of plant natural product extracts and pure compounds. J Nat Prod. 2010;73(7):1193-5. doi:10.1021/np1000945

19. Cornago DF, Rumbaoa RG, Geronimo IM. Philippine Yam (Dioscorea spp.) Tubers Phenolic Content and Antioxidant Capacity. Philipp J Sci. 2011;140(2):145-52.

20. Akar Z, Küçük M, Doğan H. A new colorimetric DPPH Scavenging activity method with no need for a spectrophotometer applied on synthetic and natural antioxidants and medicinal herbs. J Enzyme Inhib Med Chem. 2017;32(1):640–7.doi:10.1080/14756366.2017.1284068

21. Adebiyi O, Olayemi FO, Ning-Hua T, Guang-Zhi Z. In vitro antioxidant activity, total phenolic and flavonoid contents of ethanol extract of stem and leaf of Grewia carpinifolia. Beni-Suef Univ J Basic Appl Sci. 2017;6(1):10-4. doi:10.1016/j.bjbas.2016.12.003

22. Wajid M, Uzair M, Chaudhary BA. Phytochemical Screening Antioxidant and Alpha-glucosidase Inhibitory Activities of Fagopyrum tataricum L. Extract. J Pharm Res Int. 2017;18(6):1-6. doi:10.9734/jpri/2017/36067

23. Galvez MAC. Evaluation of DPPH Free Radical Scavenging Activity and Phytochemical Screening of Selected Folkloric Medicinal Plants in Tinoc, Ifugao, Cordillera Administrative Region, Philippines. Int J Sci Res Publ. 2015;5(12):440-5.

24. Park E, Song JH, Kim GN, Kim HO. Anti-oxidant and Anti-obese Effects of Mulberry (Morus alba L.) Leaf Extract in 3T3-L1 Cells. Korean J Aes Cosmetol. 2015;13(1):19-26.

25. Gan YZ, Azrina A. Antioxidant properties of selected varieties of lettuce (Lactuca sativa L.) commercially available in Malaysia. Int Food Res J. 2016;23(6):2357-62.

26. Llorach R, Martínez-Sánchez A, Tomás-Barberán FA, Gil MI, Ferreres F. Characterisation of polyphenols and antioxidant properties of five lettuce varieties and escarole. Food Chem. 2008;108(3):1028-38. doi:10.1016/j.foodchem.2007.11.032

27. Upadhyay R, Sehwag S, Singh SP. Antioxidant Activity and Polyphenol Content of Brassica oleracea Varieties. Int J Veg Sci. 2016;22(4):353-63. doi:10.1080/19315260.2015.1048403

28. Maharana L, Kar DM, Pattnaik S, Sahu PK, Si SC. In vitro Antioxidant Activity of Aqueous Leaf Extract of Solanum nigrum L. Pharmacologyonline. 2010;3:333-45.

29. Youn JS, Kim Y-J, Na HJ, Jung HR, Song CK, Kang SY, Kim, JY. Antioxidant activity and contents of leaf extracts obtained from Dendropanax morbifera LEV are dependent on the collecting season and extraction conditions. Food Sci Biotechnol. 2019;28(1):201-7. doi:10.1007/s10068-018-0352-y

30. Chou ST, Chao WW, Chun YC. Antioxidative activity and safety of 50% ethanolic red bean extract (Phaseolus radiatus L. var. Aurea). J Food Sci. 2003;68(1):21-5. doi:10.1111/j.1365-2621.2003.tb14108.x

31. Mann S, Gupta D, Gupta R. Evaluation of nutritional and antioxidant potential of Indian Buckwheat grains. Indian J Tradit Knowl. 2012; 11(1):40-4.

32. Bunea A, Rugina OD, Pintea AM, Sconța Z, Bunea CI, Socaciu C. Comparative Polyphenolic Content and Antioxidant Activities of Some Wild and Cultivated Blueberries from Romania. Not Bot Horti Agrobot Cluj Napoca. 2011;39(2):70-6. doi:10.15835/nbha3926265

33. Ranjan B, Kumar R, Verma N, Mittal S, Pakrasi PL, Kumar RV. Evaluation of the Antidiabetic Properties of S-1708 Mulberry Variety. Pharmacogn Mag. 2017;13(Suppl 2):S280–8. doi:10.4103/pm.pm_490_16

34. Subramanian R, Subbramaniyan P, Raj V. Antioxidant activity of the stem bark of Shorea roxburghii and its silver reducing power. Springerplus. 2013;2(1):28. doi:10.1186/2193-1801-2-28

35. Llorach R, Tomás-Barberán FA, Ferreres F. Lettuce and chicory byproducts as a source of antioxidant phenolic extracts. J Agric Food Chem. 2004;52(16):5109-16. doi:10.1021/jf040055a

36. Gupta SP. Roles of metals in human health. MOJ Bioorg Org Chem. 2018;2(5):221-4. doi:10.15406/mojboc.2018.02.00085

37. Ferreira CA, Ni D, Rosenkrans ZT, Cai W. Scavenging of reactive oxygen and nitrogen species with nanomaterials. Nano Res. 2018;11(10):4955-84. doi:10.1007/s12274-018-2092-y

38. Shehta N, Kamel AE, Sobhy E, Ismail ME. Malondialdehyde and superoxide dismutase levels in patients with epilepsy: a case–control study. Egypt J Neurol Psychiatry Neurosurg, 2022;58:51. doi:10.1186/s41983-022-00479-5

39. Flora SJS, Pachauri V. Chelation in Metal Intoxication. Int J Environ Res Public Health. 2010;7(7):2745–88. doi:10.3390/ijerph7072745

40. Hatcher HC, Singh RN, Torti FM, Torti SV. Synthetic and natural iron chelators: therapeutic potential and clinical use. Future Med Chem. 2009;1(9):1643–70. doi:10.4155/fmc.09.121

41. Shubina VS, Shatalin YV. Antioxidant and iron-chelating properties of taxifolin and its condensation product with glyoxylic acid. J Food Sci Technol. 2017;54(6):1467-75. doi:10.1007/s13197-017-2573-0

42. Rumbaoa RG, Cornago DF, Geronimo I. Phenolic content and antioxidant capacity of Philippine potato (Solanum tuberosum) tubers. J Food Compos Anal. 2009;22(6):546-50. doi:10.1016/j.jfca.2008.11.004

43. Lee SH, Oh SH, Hwang IG, Kim HY, Woo KS, Woo, SH, et al. Antioxidant Contents and Antioxidant Activities of White and Colored Potatoes (Solanum tuberosum L.). Prev Nutr Food Sci. 2016;21(2):110–6. doi:10.3746/pnf.2016.21.2.110

44. Patel R, Rinker L, Peng J, Chilian WM. Reactive Oxygen Species: The Good and the Bad. In: Filip C, Albu E, editors. Reactive Oxygen Species (ROS) in Living Cells. London, UK: IntechOpen; 2017. doi:10.5772/intechopen.71547

45. Dayem AA, Hossain MK, Lee SB, Kim K, Saha SK, Yang GM, et al. The Role of Reactive Oxygen Species (ROS) in the Biological Activities of Metallic Nanoparticles. Int J Mol Sci. 2017;18(1):120. doi:10.3390/ijms18010120

46. Jha N, Ryu JJ, Choi EH, Kaushik NK. Generation and Role of Reactive Oxygen and Nitrogen Species Induced by Plasma, Lasers, Chemical Agents, and Other Systems in Dentistry. Oxid Med Cell Longev. 2017;2017:7542540. doi:10.1155/2017/7542540

47. Kaur P, Arora S. Superoxide anion radical scavenging activity of Cassia siamea and Cassia javanica. Med Chem Res. 2011;20:9–15. doi:10.1007/s00044-009-9274-9

48. Santiago LA, Mayor AB. Prooxidant Effect of the Crude Ethanolic Leaf Extract of Ficus odorata Blanco Merr. In Vitro: Its Medical Significance. Int J Biotechnol Bioeng. 2014;8(1):53-60.

49. Yang C, Hwang HH, Jeong S, Seo D, Jeong Y, Lee DY, et al. Inducing angiogenesis with the controlled release of nitric oxide from biodegradable and biocompatible copolymeric nanoparticles. Int J Nanomedicine, 2018;13:6517–30. doi:10.2147/IJN.S174989

50. Ahmad A, Dempsey SK, Daneva Z, Azam M, Li N, Li PL, et al. Role of Nitric Oxide in the Cardiovascular and Renal Systems. Int J Mol Sci. 2018;19(9):2605. doi:10.3390/ijms19092605

51. Yu B, Ichinose F, Bloch DB, Zapol WM. Inhaled nitric oxide. Br J Pharmacol. 2019;176(2):246–55. doi:10.1111/bph.14512

52. Radi R. Oxygen radicals, nitric oxide, and peroxynitrite: Redox pathways in molecular medicine. Proc Natl Acad Sci U S A. 2018;115(23):5839-48. doi:10.1073/pnas.1804932115

53. Lalhminghlui K, Jagetia GC. Evaluation of the free-radical scavenging and antioxidant activities of Chilauni, Schima wallichii Korth in vitro. Future Sci OA. 2018;4(2):FSO272. doi:10.4155/fsoa-2017-0086

54. Lipinski B, Pretorius E. Hydroxyl Radical-Modified Fibrinogen as a Marker of Thrombosis: The Role of Iron. Hematology. 2012;17(4):241-7. doi:10.1179/1607845412Y.0000000004

55. Zdravković JM, Aćamović-Djoković GS, Mladenović JD, Pavlović RM, Zdravković MS. Antioxidant capacity and contents of phenols, ascorbic acid, β-carotene and lycopene in lettuce. Hem Ind. 2014;68(2):193–8. doi:10.2298/hemind130222043z

56. Zhang YJ, Gan RY, Li S, Zhou Y, Li AN, Xu DP, et al. Antioxidant Phytochemicals for the Prevention and Treatment of Chronic Diseases. Molecules. 2015;20(12):21138-56. doi:10.3390/molecules201219753

57. Lee MT, Lin WC, Yu B, Lee, TT. Antioxidant capacity of phytochemicals and their potential effects on oxidative status in animals - A review. Asian-Australas J Anim Sci. 2017;30(3):299–308. doi:10.5713/ajas.16.0438

58. Fiedor J, Burda K. Potential role of carotenoids as antioxidants in human health and disease. Nutrients. 2014;6(2):466–88. doi:10.3390/nu6020466

59. Setyorini D. Terpenoids: Lycopene in Tomatoes. In: Perveen S, Al-Taweel AM, editors. Terpenes and Terpenoids. London, UK: IntechOpen; 2021. doi:10.5772/intechopen.97126

60. Yin TP, Cai L, Xing Y, Yu J, Li XJ, Mei RF, et al. Alkaloids with antioxidant activities from Aconitum handelianum. J Asian Nat Prod Res. 2016;18(6):603-10. doi:10.1080/10286020.2015.1114473

61. Nafiu MO, Ashafa AOT. Antioxidant and inhibitory effects of saponin extracts from Dianthus basuticus Burtt Davy on key enzymes implicated in type 2 diabetes In vitro. Pharmacogn Mag. 2017;13(52):576-82. doi:10.4103/pm.pm_583_16

62. Chedea VS, Tomoiagă LL, Macovei ŞO, Măgureanu DC, Iliescu ML, Bocsan IC, et al. Antioxidant/Pro-Oxidant Actions of Polyphenols from Grapevine and Wine By-Products-Base for Complementary Therapy in Ischemic Heart Diseases. Front Cardiovasc Med. 2021;8:750508. doi:10.3389/fcvm.2021.750508

63. Balea SS, Pârvu AE, Pârvu M, Vlase L, Dehelean CA, Pop TI. Antioxidant, Anti-Inflammatory and Antiproliferative Effects of the Vitis vinifera L. var. Fetească Neagră and Pinot Noir Pomace Extracts. Front Pharmacol. 2020;11:990. doi:10.3389/fphar.2020.00990

64. Eghbaliferiz S, Iranshahi, M. Prooxidant Activity of Polyphenols, Flavonoids, Anthocyanins and Carotenoids: Updated Review of Mechanisms and Catalyzing Metals. Phytother Res. 2016;30(9):1379-91. doi:10.1002/ptr.5643