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Comparative study of antioxidant properties in three salak (*Salacca zalacca*) varieties from the Sleman region, Yogyakarta

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Abstract. This study investigates the phytochemical composition and antioxidant activity of three salak (*Salacca zalacca*) varieties cultivated in Sleman, Yogyakarta: Salak Manggala Klinting, Salak Madu, and Salak Pondoh Super. Total phenolic content (TPC), total flavonoid content (TFC), and evaluated antioxidant capacity through DPPH radical scavenging, ABTS and ferric-reducing antioxidant power (FRAP) assays were quantified using spectrophotometric analysis. The results revealed significant variation among the varieties, with Salak Pondoh Super exhibiting the highest level of TPC, as well as the strongest antioxidant activities (DPPH, ABTS, and FRAP). These findings suggest that varietal differences play a crucial role in the nutritional and functional properties of salak fruit. The study highlights the potential of local salak cultivars as natural sources of antioxidants, contributing to the development of functional foods and nutraceuticals derived from indigenous Indonesian fruits.

1 Introduction

Salak (*Salacca zalacca*), a tropical fruit native to Indonesia, is recognized for both its unique flavor and potential health advantages. Salak, which is high in bioactive compounds such as polyphenols and flavonoids, has recently received attention for its antioxidant capabilities[1]–[5], which play an important role in neutralizing free radicals and lowering oxidative stress, both of which are associated many chronic diseases[1], [5]. Earlier research shows that Malaysian salak fruit contains 10.27-15.0 mg GAE/g of polyphenols and 4.9-11.04 mg CE/g of flavonoids [1], [4]. In comparison, Thai salak contains 62.57 mg GAE/g of polyphenols and 2.54 mg CE/g of flavonoids[5].

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Salak has a comparatively high production quantity in Indonesia. According to from the Department of Agriculture and Fisheries, Indonesia produced 1.1 million tons of salak in 2022, which ranked sixth in the country [6]. Salak is also an iconic fruit in Sleman, Yogyakarta. Data from the Department of Agriculture, Food, and Fisheries shows that 51,282 tons of salak were produced in Sleman Regency in 2021[7]. Turi, Tempel, and Pakem were the three districts with the largest production. Salak pondoh is a signature variety in Sleman, which has three subvarieties: Madu, Pondoh Super, and Manggala Klinting [8], [9].

The research on salak pondoh subvarieties, including Manggala Klinting, Madu, and Super from Sleman Yogyakarta, is still limited to chemical and sensory qualities, as well as shelf-life testing [8]–[11]. Djaafar [8] found that the salak Pondoh Madu, Pondoh Manggala, and Gading have the following characteristics: moisture content (80.51%; 79.51%; 78.55%), pH (4.42; 4.31; 4.15), reducing sugar (30.64 %fw; 18.92 %fw; 15.89 %fw), total dissolved solids (23.05°Brix; 22.75°Brix), and vitamin C content (1.58 mg/g; 1.10 mg/g; 1.66 mg/g), respectively. The antioxidant content and activity of these three subvarieties have never been investigated. The study aims to analyze the phytochemical composition, antioxidant content and activity of three subvarieties salak Pondoh (Manggala Klinting, Madu, and Super) cultivated in Sleman, Yogyakarta. This study offers promising insights into the phytochemical diversity and antioxidant potential of three salak Pondoh subvarieties, supporting their future use in functional foods and natural health products. It also highlights the value of local cultivars in sustainable agriculture and nutraceutical development.

2 Materials and Methods

2.1. Material

This study used three subvarieties of salak Pondoh, namely Pondoh Super, Klinting Manggala, and Madu. Salak fruits were collected from Turi, Sleman, Yogyakarta (7◦38'05.0"S 110◦21'18.5"E). Salak fruits used in this study were freshly harvested seven months after flowering.

2.2. Morphological analysis of salak fruit

The morphological parameters examined in salak fruit were length, width, and weight (Fig. 1A). The length and width of the salak fruit were measured with a vernier caliper (Nakai, Jepang), followed by the weight with an analytical scale. (Ohaus PX225D, China). Ten salak fruits from each subvariety were measured.

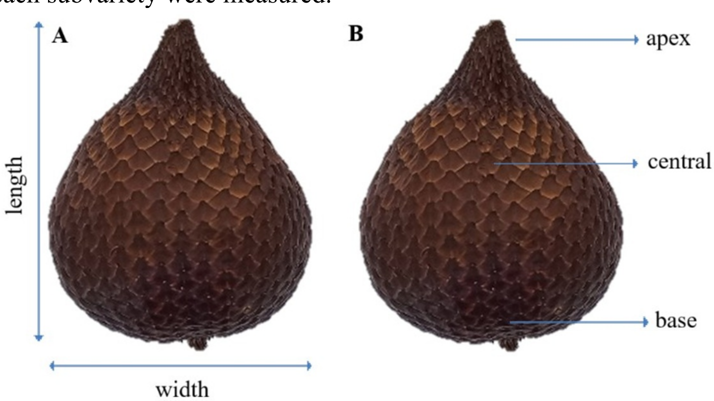

Fig. 1. Salak fruit: A) appearance of length and width measurement; B) appearance of measuring the color of the apex, central, and base part of the fruit

2.3. Color analysis of salak fruit

This study evaluated color properties of salak fruit such as lightness, redness, and yellowness (L*, a*, and b*, respectively). A chromameter (Konica Minolta CM-5, Japan) was used to assess color properties of salak fruit. The measurement of color properties was taken at the apex, central, and base part of the fruit (Fig. 1B). Each sample was measured three times.

2.4. Chamical analysis of salak fruit

The gravimetric method was used to determine moisture content [12]. The pH analysis of salak fruits was carried out using a pH meter (Eutech TM, Ion 700, Indonesia), which was calibrated using buffer solutions at pH 4 and pH 7 as standards. The pH was determined by mixing 1 g of sample with 10 ml of distilled water and testing the pH twice.

The total soluble solid (TSS) was measured using a digital portable refractometer (Atago Pal 1, Jepang). Up to 1-2 drops of salak fruit juice were placed in the glass prism of the refractometer, and the reading was taken. The total soluble solid number was measured and represented in Brix.

Total titratable acidity (TTA) was determined using the titration approach [2], which involved taking 10 mL of samples and adding 2 or 3 drops of phenolphthalein indicator. It was then quickly titrated with 0.1 M NaOH until a permanent color developed.

2.5. Antioxidant analysis of salak fruit

For the polyphenol assay, 20 µL of sample extract was combined with 100 L Folin-Ciocalteu reagent then incubated for 5 minutes. Following that, 80 µL of 7.5% Na_2CO_3 was added, then incubated for 2 hours. The absorbance of sample was measured at 750 nm using an ELISA reader (Thermo Scientific, Multiskan GO, USA). A standard curve (Y=0.0044X+0.0828, R^2=0.99) was created using gallic acid in various concentrations. The data was reported as mg GAE/100 g.

For the flavonoid assay, 10 µL sample extract was combined with 60 µL methanol, 10 µL $AlCl_3$ 10%, 10 µL KCH_3COO 1M, and 120 µL distilled water. After 30 minutes, the intensity of absorption was measured at 415 nm with an ELISA reader (Thermo Scientific, Multiskan GO, USA). The several concentrations of quercetin were used for standard curve (Y=0.0017X+0.0847, R^2=0.99). The data was represented in mg QE/100 g.

For the 2,2-Diphenyl-1-picrylhydrazyl (DPPH) assay, sample extract (80 µL) was mixed with 193 µL of 60 µM DPPH solution then allowed to react for 30 minutes. Trolox in various concentrations was utilized to create the standard curve (Y=0.0037X+0.0059, R^2=0.99). The absorbance was measured at 517 nm using an ELISA reader (Thermo Scientific, Multiskan GO, USA).

For the Ferric Reducing Antioxidant Power (FRAP) assay, the required FRAP reagent included 10 mM TPTZ in 40 mM HCl solutions, $FeCl_36H_2O$ (20 mM), and 0.3 M sodium acetate buffer at pH 3.6 (1:1:10). Sample extract (20 µL) was mixed with FRAP reagent (200 µL) and then incubated for 30 minutes. The standard curve (Y=0.0042X+0,3246, R^2=0.99) was generated using Trolox in various concentrations. The absorbance of sample and standard was measured using an ELISA reader at 593 nm.

For the 2,2'-Azino-bis(3-ethylbenzothiazoline-6-sulfonic acid) (ABTS) assay, ABTS solution was prepared by mixing ABTS (7 mM) with $K_2S_2O_8$ (2.45 mM), and incubated in the dark conditions for 16 h. The ABTS solution was achieved an absorbance of 0.7±0.02 at 734 nm by adding with ethanol. Sample extract (10 µL) was combined with 190 µL of ABTS ethanol solution and left to react for 1 minute. The several concentrations of Trolox were utilized to generate the standard curve (Y=0.0071X-0.0168, R^2=0.99). The absorbance was measured at 734 nm on a microplate using an ELISA reader (Thermo Scientific, Multiskan GO, USA).

3 Results and Discussion

3. 1. Morphological properties of salak fruit

The morphological properties of salak fruit including length, width and weight are presented in Table 1. Salak Pondok Manggala Klinting was longer and wider than Madu and Pondoh Super. The Manggala Klinting and Pondoh Super had a similar weight of about 60 g. Moreover, the Madu was heavier than Manggala Klinting and Pondoh Super. Supriyadi [13] found that salak Pondoh at stage 6, or the final stage, has a fruit weight of around 62 g, with glucose and fructose content increasing dramatically followed by a drop in sucrose content, suggesting that the salak fruit is ripe.

Table 1. Morphological properties of salak fruit.

Parameters	Manggala Klinting	Madu	Pondoh Super
Length (mm)	70.70±0.95^{a}	62.07±2.18^{b}	61.37±1.05^{b}
Width (mm)	49.57±0.58^{b}	55.43±1.15^{a}	50.27±0.64^{b}
Weight (g)	61.95±3.57^{b}	85.46±2.47^{a}	65.85±2.09^{b}

Note: The variation in letter groupings within the analysis results indicates a statistically significant difference at the 95% confidence level.

3. 2. Color properties of salak fruit

Salacca pondoh is a variation of Salacca zalacca, an indigenous fruit in Indonesia, recognizable for its reddish-brown scaly skin, which looks like snake skin [4], [8]. The salak Pondoh Manggala Klinting was darker in color than Madu and Pondoh Super, as evidenced by lower values for lightness (L*), redness (a*), and yellowness (b*) (Table 2). Salak Pondoh Madu had higher L*, a*, and b* values than the others, indicating that it was lighter. In line with previous research, the peel color of Salak Pondoh Super was dark brown, while Madu was shiny brown [8]. Susanti [10] found that the peel of salak Pondoh had L* and a* values of around 25.91 and 8.88, respectively. Fig. 2 shows the appearance of salak Pondoh Manggala Klinting (A), Madu (B), and Pondoh Super (C).

Table 2. Color properties of salak fruit

Parameters		Manggala Klinting	Madu	Pondoh Super
Apex part of the fruit	L*	30.28±0.57^{b}	36.52±1.64^{a}	32.42±1.78^{b}
	a*	11.14±0.62^{c}	14.19±0.03^{a}	12.85±0.76^{b}
	b*	11.75±0.38^{b}	21.22±0.42^{a}	12.22±2.25^{b}
Central part of the fruit	L*	35.84±1.20^{b}	43.49±1.07^{a}	33.44±0.09^{c}
	a*	14.47±1.06^{a}	13.45±0.48^{b}	13.10±0.74^{c}
	b*	17.17±1.62^{b}	27.18±0.41^{a}	15.06±0.04^{c}

Base part of the fruit	L*	26.65±0.57^{c}	31.16±0.33^{a}	29.78±0.25^{b}
	a*	4.66±0.91^{c}	11.93±0.37^{a}	8.67±0.38^{b}
	b*	2.50±0.29^{c}	11.42±0.93^{a}	7.39±0.32^{b}

Note: The variation in letter groupings within the analysis results indicates a statistically significant difference at the 95% confidence level.

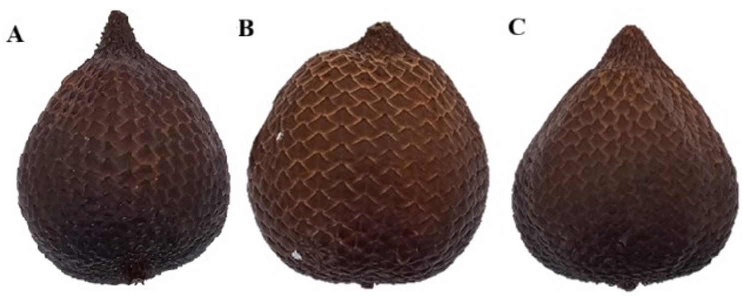

Fig. 2. Salak Pondoh: A. Manggala Klinting, B. Madu, and C. Super

3. 3. Chemical properties of salak fruit

The chemical properties of salak fruit, including moisture content, TSS, pH, and TTA are presented in Table 3. The moisture content of salak Pondoh Manggala Kliting, Madu, and Super range in 78.17% to 79.43%. The salak Pondoh Madu had a higher moisture content compared to Pondoh Super and Manggala Klinting. According to Djaafar[8], the moisture levels in salak Pondoh Super and Madu were 80.51% and 79.51%, respectively. Other research reported that salak Pondoh had moisture content of approximately 71% [11].

Table 3. Chemical properties of salak fruit

Parameters	Manggala Klinting	Madu	Pondoh Super
Moisture (%)	78.17±0.05^{c}	79.43±0.28^{a}	78.67±0.07^{b}
TSS (◦Brix)	19.17±0.29^{a}	18.17±0.29^{b}	18.00±0.50^{b}
pH	4.47±0.02^{b}	4.82±0.09^{a}	4.91±0.07^{a}
TTA (%)	5.86±0.27^{a}	4.44±0.27^{b}	4.60±0.28^{b}

Note: The variation in letter groupings within the analysis results indicates a statistically significant difference at the 95% confidence level.

Salak Pondoh Manggala Klinting, Madu, and Super had a TSS range in 18.00◦Brix to 19.17◦Brix. This result corresponds with earlier studies that indicated the TSS of salak pondoh was 18.80◦Brix [10]. Other research reported that the salak Pondoh had a TSS about 20◦Brix [11] and 13.0◦Brix [3]. As reported by Djaafar [8], the Total Soluble Solid (TSS) in salak Pondoh Super and Madu were 23.05◦Brix and 22.75◦Brix. The higher of moisture content the lower of TSS in all of salak fruits, indicating a negative correlation. Research on strawberries showed that the TSS was negatively correlated with moisture content [14], indicating that as strawberries ripen and their TSS increases, their moisture content decreases, a pattern that might be applicable to salak as well.

The pH and TTA values of salak Pondoh Manggala Klinting, Madu, and Super had inversely related values. This result is similar to previous research, where low pH values in salak Pondoh and Madu result in higher TTA values [2], [3]. Zubaidah [2] reported that salak Pondoh and Madu had a pH (4.05 and 4.38) and TTA values (0.35 and 0.33), respectively. The lower of pH value the higher of TTA. The pH value of salak Pondoh Super and Madu were 4.42 and 4.31 [8], which are comparable to the results of this research. Other studies found salak Pondoh had pH and TTA values of approximately 3.12 and 1.74 [3].

3. 4. Antioxidant properties of salak fruit

The antioxidant content (polyphenol) and activities (DPPH, ABTS, FRAP) of salak Pondoh Super were higher than salak Manggala Klinting and Madu. In contrast, the flavonoid content in salak pondoh super was lower than that of salak Manggala Klinting and Madu. The antioxidant properties of salak fruit shows in Fig 3. The content of polyphenols (52.22, 50.10, and 88.89 mg GAE/100 g) and flavonoids (72.88, 78.53, and 67.90 mg QE/100 g) in Salak Pondoh varieties Mandala Klinting, Madu, and Super has been measured respectively. Salak contains a higher number of phenolic compounds than flavonoids. According to several earlier studies, the polyphenol and flavonoid content in Malaysian salak fruit varieties ranges from 10.27 to 15.0 mg GAE/g and from 4.9 mg to 11.04 mg CE/g [1], [4]. Meanwhile, the polyphenolic and flavonoid content of salak varieties from Thailand were 62.57 mg GAE/g and 2.54 mg CE/g, respectively [5].

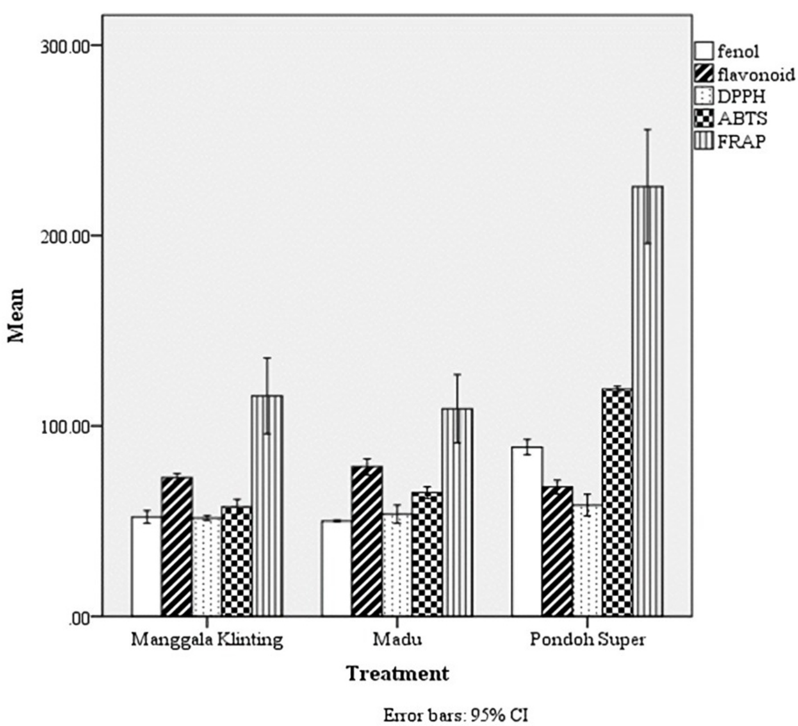

Fig. 3. Antioxidant properties of 3 varieties (Manggala Klinting, Madu and Pondoh Super) of salak fruit

The antioxidant activities of Salak Pondoh Mandala Klinting, Madu, and Super showed using the DPPH (51.63, 53.73, and 58.46 mg TE/100g), ABTS (57.57, 64.92, and 119.30 mg TE/100g), and FRAP (115.80, 108.97, and 225.76 mg TE/100g) approaches as illustrated in Fig 3. The DPPH assay allows for rapid and easy assessments of radical scavenging activity via Single Electron Transfer (SET) and Hydrogen Atom Transfer (HAT) reactions; the FRAP assay is suitable for evaluating reducing power for antioxidants that involve SET reaction; and the ABTS assay, which can measure both SET and HAT reactions, offers a more thorough evaluation of antioxidant capacity [15]. A higher FRAP value indicates that the three varieties of salak have a strong antioxidant capacity for reducing metal ions. The high DPPH, ABTS, and FRAP values in salak Pondoh Super indicate that this salak contains comprehensive and effective antioxidant compounds, as well as antioxidant capabilities that include metal reduction, free radical scavenging, and electron/hydrogen donation, and has a high potential for applications in oxidative stress prevention. Tan [1] found similar results, with Malaysian salak varieties had greater FRAP value (191,83 µmol Fe^{2+}/g) than DPPH (83,96 %RSA) and ABTS (20,70 µmol TE /g) values. The DPPH (837.8, 922.5, 892.7, and 691.5 mg AEAC/100 g) and FRAP (100.33, 113.33, 91.66, and 92.83 mM Fe^{2+}/g) values of Malaysian salak varieties SS1, SS2, SS3, and SS4 had been reported by Aralas [4].

4 Conclusion

This study found differences in the phytochemical composition and antioxidant activity of three salak (Salacca zalacca) types cultivated in Sleman, Yogyakarta. Salak Pondoh Super exhibited the highest total phenolic content and antioxidant capacity in the DPPH, ABTS, and FRAP assays. These findings emphasize the importance of varietal variation in the nutritional and functional properties of salak fruit, as well as the potential of local cultivars as natural antioxidant sources for generating functional foods and nutraceuticals derived from Indonesian indigenous fruits.

5 Acknowledgments

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6 Reference

1. S. S. Tan, S. T. Tan, and C. X. Tan, Antioxidant, hypoglycemic and anti-hypertensive properties of extracts derived from peel, fruit and kernel of Salak, Br. Food J., **122**, 10, 3029–3038 (2020). https://doi.org/10.1108/BFJ-03-2020-0233.
2. E. Zubaidah, F. J. Dewantari, F. R. Novitasari, I. Srianta, and P. J. Blanc, Potential of snake fruit (S*alacca zalacca* (Gaerth.) Voss) for the development of a beverage through fermentation with the Kombucha consortium, Biocatal. Agric. Biotechnol., **13**, 198–203 (2018). https://doi.org/10.1016/j.bcab.2017.12.012.

3. E. Zubaidah et al., Anti-diabetes activity of Kombucha prepared from different snake fruit cultivars, Nutr. Food Sci., **49**, 2, 333–343 (2019). https://doi.org/10.1108/NFS-07-2018-0201.
4. S. Aralas, M. Mohamed, and M. F. Abu Bakar, Antioxidant properties of selected salak (*Salacca zalacca*) varieties in Sabah, Malaysia, Nutr. Food Sci., **39**, 3, 243–250 (2009). https://doi.org/10.1108/00346650910957492.
5. S. Nanasombat, K. Yansodthee, and I. Jongjaited, Evaluation of antidiabetic, antioxidant and other phytochemical properties of Thai fruits, vegetables and some local food plants,Walailak J. Sci. Technol., **16**, 11, 851–866 (2019). https://doi.org/10.48048/wjst.2019.3731.
6. Badan Pusat Statistik RI, Produksi Tanaman Buah-buahan, (2023). https://www.bps.go.id/indicator/55/62/1/produksi-tanaman-buah-buahan.html (accessed Jul. 02, 2023).
7. Dinas Pertanian Pangan dan Perikanan, Data Hortikultura di Kabupaten Sleman Tahun 2017 s.d. 2021, (2022). https://data.slemankab.go.id/data/dataset/a35a0519-2475-4c7b-9863-a8f2a0c07da0/resource/29bcd9a4-14c5-4e48-a977-a7ebe3df5f5b/download/3.27.2-data-hortikultura-di-kabupaten-sleman-tahun-2017-s.d.-2021.xlsx (accessed Jul. 03, 2023).
8. T. F. Djaafar, T. Marwati, T. Budiyanti, Riska, and S. Hadiati, Chemical and Sensory Evaluation on Several Varieties of Salak *(Salacca zalacca*) Fruit from Indonesia, Int. J. Adv. Sci. Eng. Inf. Technol., **14**, 2, 723–729 (2024). https://doi.org/10.18517/ijaseit.14.2.19175.
9. T. F. Djaafar et al., Mutu Fisik Buah Salak Pondoh (*Salacca edulis* Reinw): Pengaruh Pelilinan dan Pengemasan Menggunakan Kantong Plastik Low Density Polyethylene, agriTECH, **42**, 2, 113 (2022). https://doi.org/10.22146/agritech.55376.
10. L. Susanti, K. Suketi, A. Kurniawati, and Setyadjit, Effects of Chitosan and 1-MCP on the Physical and Chemical Quality of Salak 'Pondoh' (*Salacca edulis* Reinw.) Fruits, J. Trop. Crop Sci., **11**, 1, 39–48 (2024). https://doi.org/10.29244/jtcs.11.01.39-48.
11. S. B. Anoraga and N. Bintoro, The effect of packaging and storage method on Snake fruit (*Salacca edulis* Rainw.) quality, IOP Conf. Ser. Earth Environ. Sci., **475**, 1 (2020). https://doi.org/10.1088/1755-1315/475/1/012022.
12. Association of Official Analitical Chemist (AOAC), Official Methods of Analysis of The Association of Official Analytical Chemist, 18th ed. Gaithersburg, USA: AOAC International, (2005).
13 Supriyadi et al., Changes in the volatile compounds and in the chemical and physical properties of snake fruit (*Salacca edulis* Reinw) cv. Pondoh during maturation, J. Agric. Food Chem., **50**, 26, 7627–7633 (2002). https://doi.org/10.1021/jf020620e.
14. D. Xie, D. Liu, and W. Guo, Relationship of the optical properties with soluble solids content and moisture content of strawberry during ripening, Postharvest Biol. Technol., **179**, 111569 (2021). https://doi.org/10.1016/j.postharvbio.2021.111569.
15. J. Rumpf, R. Burger, and M. Schulze, Statistical evaluation of DPPH, ABTS, FRAP, and Folin-Ciocalteu assays to assess the antioxidant capacity of lignins, Int. J. Biol. Macromol., **233**, (2023). https://doi.org/10.1016/j.ijbiomac.2023.123470.