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FULL PAPER

Incorporation of fingerroot (*Boesenbergia* sp.) rhizome extract powder on chemical, microbial and sensory properties of dry-roasted macadamia (*Macadamia* sp.) nut during 12 months of storage

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Abstract

Macadamia nut is an important crop with high economic value. It is commonly dried and roasted into an instant crisp. Due to high oil content, the dry-roasted macadamia nut is feasible to oil rancidity as well as microbial contamination. In order to improve the economic value of macadamia nuts, it is very urgent to stabilise the quality of roasted macadamia nuts during storage and distribution. Fingerroot (*Boesenbergia* sp.) belonging to the Zingiberaceae family is one of the most important Vietnamese perennial medicinal plants. Its rhizome contained numerous bioactive phytoconstituents like essential oils, flavonoids, phenolics exhibiting diversified biological activities beneficial for human health. This research evaluated the possibility of incorporation of fingerroot rhizome extract powder (0-6%) into the dry-roasted macadamia nut to improve its chemical, microbial and sensory properties during 12 months of storage. Results showed that 4.5% of fingerroot rhizome extract powder could be supplemented into the dry-roasted macadamia nut to reduce coliform load (1.28±0.03 log CFU/g), peroxide value (0.78±0.02 meq/kg), thiobarbituric acid reactive substances (0.65±0.03 mg malonaldehyde/kg), free fatty acid (0.76±0.02% oleic acid) while enhancing overall acceptance (8.24±0.17 score). This research revealed that fingerroot rhizome extract would be a promising antimicrobial and antioxidant natural source to preserve fatty foodstuffs efficiently.

1. Introduction

The macadamia tree (*Macadamia* sp.) is widely cultivated in Central Highlands and other provinces in the Southeast region of Vietnam (Figure 1). It is a diversified tree with a great cultivation potential, a high socio-economic efficiency with an open international market. It could be propagated in remote and mountainous areas as defending forests to improve the forest coverage proportion and the ecological balance. By planting this tree, the income of farmers is greatly enhanced due to its high economic value compared to other fruit trees and industrial plants. Macadamia nut is a rich source of vitamins (especially tocotrienols and squalene), essential minerals, dietary fibres, proteins, phenolics with antioxidant capacities (Maguire *et al.*, 2004; Wall, 2010; Minh *et al.*, 2018). Macadamia nut is highly valued by its oil content with the high percentage of monounsaturated fatty acids, especially omega-7 palmitoleic acid (Akhtar *et al.,* 2006; Silva *et al*., 2008; Saez *et al.,* 2014). The oleic acid content is an important indicator reflecting the attributes of macadamia nut (Suporntip *et al.,* 2012). Consumption of macadamia nuts is beneficial for those with cardiovascular ailments (Garg *et al.,* 2003; Amy *et al.,* 2008).

Fingerroot (*Boesenbergia* sp.) belongs to the ginger (Zingiberaceae) family widely cultivated in Vietnam and other Asian countries (Figure 2). Its rhizome had several slender and long tubers about 1.0–1.5 cm thick in diameter and 5–10 cm long (Tan *et al.*, 2012). Fingerroot rhizome varied pale yellow colour depending on the soil in cultivation, cultivation technique and maturity at harvesting (Iijima and Joh, 2014). Its rhizome is used as folk medicine, culinary spice and seasoning vegetable

Figure 1. Macadamia nut (*Macadamia* sp.)

Figure 2. Fingerroot (*Boesenbergia* sp.)

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(Agus *et al.*, 2014). *Boesenbergia* rhizome extract is an important seasoning vegetable in preparation of "Nuoc leo" rice noodle soup, a speciality of Khmer people in the Mekong Delta. *Boesenbergia* rhizome extract contained a high content of essential oils, flavonoids and polyphenols contributing to multiple pharmacological activities such as anti-fungal, anti-bacterial, anti-parasitic, anti-ulceration, hepatoprotective, anti-cancer, antioxidant, anti-anthelmintic, anti-inflammatory (Ling *et al.*, 2010; Abdelwahab *et al.*, 2011; Isa *et al.*, 2012; Salama *et al.*, 2013; Chahyadi *et al.*, 2014; Chiang *et al.*, 2017; Yonna *et al.*, 2018; Rosdianto *et al.*, 2020). It is utilised to cure stomach discomfort, aphthous ulcers, dysentery, dry mouth, leucorrhoea (Fahmi *et al.*, 2020). Fingerroot is highly perishable with a short shelf-life after harvesting. Dehydration into powder is the most common practice to stabilise its quality for long-term usage. Fingerroot powder could be utilised for different purposes like soup, spice, food sanitiser, condiment, confectionery, due to its aromatic flavour, which promotes appetite (Fahmi *et al.*, 2020). Isopanduratin A originated from fingerroot is an ideal anti-bacterial agent against cariogenic mutans (Tan *et al*., 2012), while panduratin A effectively inhibits *Escherichia coli* and *Staphylococcus aureus* (Rukayadi *et al*., 2010).

In order to improve the quality as well as the economic value of the dry-roasted macadamia nut, the purpose of this study was to verify the influence of supplementation of fingerroot rhizome extract powder in different proportions into the dry-roasted macadamia nut to improve its chemical, microbial and sensory properties during storage. Phytochemical constituents in fingerroot rhizome extract would be effective to retard coliform growth and proliferation, inhibit lipid oxidation, enhance overall acceptance of the dry-roasted macadamia nut.

2. Materials and methods

2.1 Materials

Raw *Boesenbergia* sp. rhizomes were purchased from Thu Duc market, Ho Chi Minh City, Vietnam. Raw macadamia nuts were supplied from Dong Nai province, Vietnam. They were washed under clean water to remove dirt and foreign matter. Chemical reagents such as phosphate buffer, acetic acid, chloroform, KI, $Na_2S_2O_3$, thiobarbituric acid, trichloroacetic acid, and 4-Butoxybenzyl alcohol, petroleum ether, ethanol, phenolphthalein, NaOH were all analytical grade supplied from Fluka (Switzerland), Sigma Aldrich (USA) and Merck (Germany). 3M-Petrifilm coliform count plates were purchased from Van Dai Phat Co. Ltd., Ho Chi Minh City, Vietnam.

2.2 The preparation of roasted Macadamia nuts incorporated with Boesenbergia powder

Raw *Boesenbergia* sp. rhizomes were finely ground by a grinder. The fine powders (100 g) were soaked in ethanol 90% (900 mL) for 20 mins at room temperature at agitation speed 600 rpm. The filtrate was filtered using Whatman No. 2 filter paper with a vacuum pump. The filtrate was concentrated by a vacuum rotary evaporator (RV 3V, IKA, Germany) at 45^{o}C to obtain the *Boesenbergia* crude extract. Maltodextrin 12% was mixed with *Boesenbergia* crude extract. The freeze dehydration was conducted by freeze dryer (model: Coolsafe Superior XS/XL, Labogene, Denmark) with a condenser temperature of -65°C, the pressure of 250 μmHg for 28 hrs. The *Boesenbergia* powder (BP) was kept in a laminated bag ready for experiments.

Raw macadamia nuts were convective-dried (model: OF-01E/11E/21E, Lab Companion, Korea) at temperature 45^{o}C for 8 hrs, and then roasted at 145^{o}C for 15 mins. The roasted macadamia nuts were cooled to room temperature. The roasted macadamia nuts were mixed with *Boesenbergia* powder in different proportions (0, 1.5, 3.0, 4.5, and 6.0%). These roasted macadamia nut samples previously incorporated by *Boesenbergia* powder were stored in laminated PET/AL/PE (Polyethylene Terephthalate/Aluminium/Polyethylene, supplied from Binh Minh Packaging Joint Stock Company) bag for 12 months. Periodically (3 months), the treated samples were taken to determine coliform, peroxide value, thiobarbituric acid reactive substances content, free fatty acid content, and overall acceptance.

2.3 Chemical, microbial and sensory evaluation

Peroxide value or PV (meq/kg) was estimated by weighing 5 g of sample, adding 15 mL acetic acid and 10 mL chloroform, supplemented with 1 mL KI solution. This mixture was kept in a dark place for 15 mins, and a starch indicator is added. The final titration was defined by adding 0.01 N $Na_2S_2O_3$ until colourless.

Thiobarbituric acid reactive substances or TBARS content (mg malonaldehyde/kg) was determined following the 2-thiobarbituric acid spectrophotometric method (Anna *et al.*, 2017). 5 g of sample was mixed with thiobarbituric acid, trichloroacetic acid, and 4-Butoxybenzyl alcohol. This mixture was conditioned in a water bath at 45^{o}C for 30 mins and then centrifuged (Eppendorf Centrifuge 5920R, Sigma Aldrich, USA) at 4,000 rpm for 5 mins. The absorbance was measured by UV-VIS spectrophotometer (model UV-1800, Shimadzu, Japan) at wavelength 532 nm.

Free fatty acid (FFA) content (% oleic acid) was

determined following the titration method described by Calvo *et al.* (2017). Approximately 10 g sample was homogenised with 100 mL of petroleum ether. The mixture was filtered by Whatman paper No. 2 (Sigma Aldrich, USA) to obtain the filtrate. A 10 mL filtrate was taken to determine the residual fat. Another set of 10 mL filtrate was mixed with 5 mL of ethanol. It was titrated with NaOH 0.1 N in the presence of phenolphthalein (1%) until a light pink appearance was achieved. The FFA content was calculated from the following equation:

$$\text{FFA (\% oleic acid)} = (v-b) \times N \times 28.2 / w$$

Where v was the volume of the titrant (mL), b was the blank volume (mL), N was the normality of NaOH and w was the weight of the sample (g)

Coliform (log CFU/g) was enumerated by 3M Petrifilm coliform count plates. Approximately 5 g of the sample was homogenised with 45 mL of phosphate buffer dilution. Lifting the top film, 1 mL of sample suspension was dispensed onto the centre of the bottom film, leaving the top film down. The counting plates were incubated at 37±1 °C for 24±2 hrs in a horizontal position in an incubator (model IF450, Memmert, Germany). Coliform was identified by red or blue colonies with associated gas bubbles. Coliform was well-enumerated by using a standard colony counter (model SC6Plus, Stuart, UK).

Overall acceptance (score) was determined by a group of specialists using a 9-point Hedonic scale. Panellists of 9 assessors (age 30-40 years old) were previously trained (90 hours) to utilize a 9-point strength ratio to evaluate sweetness, taste, flavour, and colour in dry-roasted nuts. During the training, panellists were individually evaluated to determine the overall panel mean and to ensure that all panellists were able to scale the properties of interest. Following training, panellists discussed together an agreeing mark for each attribute of the dry-roasted nuts, which were prepared directly from dry-roasted nuts and were provided as a reference sample. Panellists were provided samples in an ordinary order to prevent prediction based on the order of sample display. Three to five pickle pieces were set in each sample cup. Panellists examined a set of 5 to 7 samples per session. They were also offered two 2 oz. sample cups specified as the neutral sample to calibrate scoring of taste and texture characteristics on the 9-point scale. Each panellist was guided to first taste the neutral sample, neutralise the panellist's palate, and bite an unidentified roasted sample. Panellists were required to relax in two-minute intervals between two samples to minimize tasting tiredness. They could either swallow or expectorate their samples. Three sensory replications were executed on each sample during the research. Sensory evaluation was performed on dry-roasted samples, which were preserved at room temperature (Peryam and Girardot, 1952).

2.4 Statistical analysis

The experiments were run in triplicate with different groups of samples. The data were presented as mean ± standard deviation. Statistical analysis is performed by Statgraphics Centurion version XVI. The mean value ($\bar{x}$) and standard deviation ($2s$) of a set of data were obtained by analysis of random samples estimating the population statistics. Around 95% of results would be expected to lie within the range ($\bar{x}\pm 2s$) we described the lower and upper bounds of this range as the 95% confidence limits of the results. The differences between the pickling samples were analysed using a one-way analysis of variance (ANOVA). A significant value was set at a 95% confidence interval ($p<0.05$). If significant differences were found, then post hoc analysis was performed using Duncan's multiple range tests.

3. Results and discussion

3.1 Coliform

The effectiveness of *Boesenbergia* powder in different incorporation ratios (0, 1.5, 3.0, 4.5, 6.0%) on the coliform load of dry-roasted macadamia nut during 12 months of storage is presented in Table 1. There is an increasing trend of coliform load by the time of storage, with the highest accumulation on the control and the lowest on the BP 6%. There is no significant difference in coliform load between the BP 4.5% and BP 6.0%. At the end of 12 months of storage, the coliform load in the dry-roasted macadamia nut treated by BP 4.5% is quite low, with 1.28±0.03 (log CFU/g). According to Southern African Macadamia Growers' Association (SAMAC), coliform should be less than 300 CFU/g in macadamia nuts. Meanwhile, the Brazilian Macadamia Association (ABM) set the maximum limit of coliform at 350 CFU/g in macadamia nuts.

In the study by Pattaratanawadee *et al.* (2006), *Boesenbergia* revealed the highest inhibitory activity against *L. monocytogenes*, *B. cereus*, and *S. aureus* with minimum inhibitory concentration (MIC) value of 0.2–0.4% (v/v); against Gram-negative bacteria with MIC value of 8-10%. *Boesenbergia* at 10% (v/v) showed bactericidal effect against *E. coli* population (log CFU/mL) at 9 hrs. *Boesenbergia* extract showed antimicrobial activity against *Staphylococcus* with MIC_{50} of 0.5 µg/mL and MIC_{90} of 1 µg/mL, both comparable to vancomycin (Rukayadi *et al.*, 2009).

Giardia lamblia is a protozoan parasite causing diarrhoea and nutrient deficiency in patients.

Table 1. Coliform (log CFU/g) load on the dry-roasted macadamia nut incorporated by *Boesenbergia* powder (BP) in different proportions (0, 1.5, 3.0, 4.5, 6.0%) during 12 months of storage

Storage (month)	0	3	6	9	12
BP 0%	0.18±0.01^{a}	1.59±0.04^{a}	2.07±0.02^{a}	2.92±0.01^{a}	3.71±0.02^{a}
BP 1.5%	0.18±0.01^{a}	0.98±0.03^{b}	1.43±0.05^{b}	1.84±0.03^{b}	2.28±0.04^{b}
BP 3.0%	0.18±0.01^{a}	0.74±0.05^{bc}	1.01±0.01^{bc}	1.39±0.02^{bc}	1.89±0.01^{bc}
BP 4.5%	0.18±0.01^{a}	0.40±0.01^{c}	0.70±0.03^{c}	1.03±0.04^{c}	1.28±0.03^{c}
BP 6.0%	0.18±0.01^{a}	0.36±0.03^{c}	0.65±0.02^{c}	0.97±0.01^{c}	1.23±0.02^{c}

Values are presented as mean±SD of three replications. Values with different superscripts within the same column are significantly different (p<0.05).

Boesenbergia extract showed an inhibitory concentration IC_{50} value of 20 µg/mL against *Giardia lamblia,* while metronidazole antibiotic showed an IC_{50} value of 0.48 µg/mL against *Giardia lamblia* (Sawangjaroen *et al.*, 2005). Gram-positive cocci like *Enterococcus faecalis* and *Enterococcus faecium* were responsible for intestinal and urinary infections. *Boesenbergia* extract showed bactericidal effect against *Enterococci* at MIC of 2 µg/mL lower than that of gentamycin (512 µg/mL), erythromycin (256 µg/mL), ampicillin (256 µg/mL), tetracycline (64 µg/mL) (Rukayadi *et al.*, 2010).

Boesenbergia extract could retard spoilage fungi like *Aspergillus flavus*, *Aspergillus niger*, *Aspergillus parasiticus*, and *Fusarium oxysporum* with MICs of >10% (v/v), 8% (v/v), 10% (v/v), and <8% (v/v), respectively (Pattaratanawadee *et al.*, 2006). *Boesenbergia* rhizome extract showed high inhibition of HIV-1 protease with IC_{50} values of 18.7 µM (Cheenpracha *et al.*, 2006). Essential oil of fingerroot rhizome is effective against dermatophytes, filamentous fungi and yeast (Jantan *et al.*, 2001). Fingerroot rhizome extract showed the capacity to modify the morphology of the hyphae by disrupting the hard profile (Rasooli *et al.*, 2006). 0.5% of *Boesenbergia* rhizome extract revealed anti-fungal properties against filamentous fungi of *Penicillium* sp., *Aspergillus* sp., *Geotrichum* sp., *Fusarium* sp., *Aureobasidium* sp. after 10 min treatment (Zakuan *et al.*, 2018). Anti-fungal activity of fingerroot rhizome extract is due to 4-hydroxypanduratin, pinostrobin and pinocembrin (Seniya *et al.*, 2013). These substances invade the cell membranes to the core of the cell and modify the critical intercellular attributes (Cristani *et al.*, 2007). Cell disruption due to the structural vulnerability of cell membranes is induced by these substances; moreover, these substances interacted with the hyphal cell wall of fungi and led to the demise of the fungal mycelium (Gill and Holley, 2006).

3.2 Peroxide value

The efficacy of *Boesenbergia* powder in different incorporation ratios (0, 1.5, 3.0, 4.5, and 6.0%) on the peroxide value of the dry-roasted macadamia nut during 12 months of storage is presented in Table 2. There is an increasing trend of peroxide value by the time of storage, with the highest accumulation on the control and the lowest on the BP 6%. There is no significant difference in peroxide value between the BP 4.5% and BP 6.0%. At the end of 12 months of storage, the peroxide value in the dry-roasted macadamia nut treated with BP 4.5% is quite low at 0.78±0.02 (meq/kg). According to the Australian Macadamia Society (AMS), Southern African Macadamia Growers' Association (SAMAC) and Brazilian Macadamia Association (ABM), the peroxide value in macadamia nut should be ≤ 2 meq/kg, ≤ 3 meq/kg and ≤ 5 meq/kg, respectively. Primary lipid oxidation is followed by the peroxide value (Servet and Hudayi, 2011). The effectiveness of rancidity retardation by *Nepenthes* extract is similar to other plant extracts. Green tea extract strongly retarded the oxidative rancidity in eel oil (Song and Kim, 2018). The peroxide value of anchovy oil is kept at low content by green tea extract (Kang *et al.*, 2007). Basil leaf essential oil is effective in limiting peroxide value in Sea bass slices (Arfat *et al.*, 2015). Pomegranate peel extract is also appropriated for Nile tilapia fillets to slow down peroxide value (Alsaggaf *et al.*, 2017). *Eryngium caucasicum* extract is a beneficial substance to decrease peroxide value in Silver carp fillets (Raeisi *et al.*, 2017). *Boesenbergia* rhizome

Table 2. Peroxide value (meq/kg) on the roasted macadamia nut incorporated by *Boesenbergia* powder (BP) in different proportions (0, 1.5, 3.0, 4.5, 6.0%) during 12 months of storage

Storage (month)	0	3	6	9	12
BP 0%	0.11±0.02^{a}	1.05±0.01^{a}	1.56±0.03^{a}	1.99±0.04^{a}	2.74±0.03^{a}
BP 1.5%	0.11±0.02^{a}	0.63±0.02^{b}	0.85±0.01^{b}	1.05±0.02^{b}	1.29±0.01^{b}
BP 3.0%	0.11±0.02^{a}	0.49±0.04^{bc}	0.61±0.03^{bc}	0.83±0.01^{bc}	1.02±0.04^{bc}
BP 4.5%	0.11±0.02^{a}	0.25±0.03^{c}	0.43±0.02^{c}	0.64±0.03^{c}	0.78±0.02^{c}
BP 6.0%	0.11±0.02^{a}	0.24±0.02^{c}	0.41±0.04^{c}	0.60±0.02^{c}	0.76±0.03^{c}

Values are presented as mean±SD of three replications. Values with different superscripts within the same column are significantly different (p<0.05).

extract revealed two powerful lipid peroxidation inhibitors, (−)-panduratin A (IC_{50} 15 μM) and (−)-4-hydroxypanduratin A (IC_{50} 4.5 μM) (Shindo *et al.*, 2006).

3.3 Thiobarbituric acid reactive substances

Different supplementation ratios of *Boesenbergia* powder (0, 1.5, 3.0, 4.5, and 6.0%) on TBARS of the dry -roasted macadamia nut during 12 months of storage were shown in Table 3. There is an increasing trend of TBARS by the time of storage, with the highest accumulation on the control and the lowest on the BP 6%. There is no significant difference in TBARS between the BP 4.5% and BP 6.0%. At the end of 12 months of storage, the TBARS in the dry-roasted macadamia nut treated with BP 4.5% is quite low, with 0.65±0.03 (mg malonaldehyde/kg). This TBARS value is in the range of the acceptable limit (2 mg malonaldehyde/kg). Thiobarbituric acid reactive substances (TBARS) are also one of the most important indicators to determine the oxidative rancidity of polyunsaturated fatty acids via the formation of malonaldehyde facilitating to release of ketones and aldehydes by peroxidase reaction (Bremner, 2002; Feliciano *et al.*, 2010). TBARS should be below 2 mg malonaldehyde/kg sample to avoid bad smell and poor taste accumulation (Connell, 1990). Panduratin A in *Boesenbergia* rhizome extract showed a protective effect against oxidative vulnerability by tert-Butylhydroperoxide. Tert-Butylhydroperoxide is an organic hydroperoxidant that triggers fat rancidity through its metabolism to free-radical intermediates, leading to oxidative vulnerability to tissues. Panduratin A in *Boesenbergia* rhizome extract could minimise malondialdehyde accumulation and glutathione depletion. Intracellular reactive oxygen species accumulation is also decreased by panduratin A treatment (Sohn *et al.*, 2005).

3.4 Free fatty acids

Various proportions of *Boesenbergia* powder (0, 1.5, 3.0, 4.5, and 6.0%) incorporated into the dry-roasted macadamia nut during 12 months of storage on free fatty acid content were noticed in Table 4. There is an increasing trend of free fatty acid value by the time of storage, with the highest accumulation on the control and the lowest on the BP 6%. There is no significant difference in free fatty acid value between the BP 4.5% and BP 6.0%. At the end of 12 months of storage, the free fatty acid value in the dry-roasted macadamia nut treated with BP 4.5% is quite low, with 0.76±0.02 (% oleic acid). Panduratin A in *Boesenbergia* rhizome extract is a natural AMP-activated protein kinase (AMPK) activator. The trigger of AMPK would accelerate fatty acid oxidation by triggering fatty acid oxidation-related genes. This behaviour would retard fat synthesis by elimination of sterol regulatory element-binding protein-1c (SREBP-1c) and PPARγ phosphorylation. Panduratin A in *Boesenbergia* rhizome extract would facilitate AMPK signalling to induce nuclear translocation of AMPKα2, following the activation of PPARα/δ, with LKB1 being the vital mediator of these effects. Trigger of PPARα/δ enhanced fatty acid oxidation (Kim *et al.*, 2011).

3.5 Overall acceptance (score)

Overall acceptance of the dry-roasted macadamia nut incorporated by *Boesenbergia* powder (0, 1.5, 3.0, 4.5,

Table 3. TBARS (mg malonaldehyde/kg) on the roasted macadamia nut incorporated by *Boesenbergia* powder (BP) in different proportions (0, 1.5, 3.0, 4.5, 6.0%) during 12 months of storage

Storage (month)	0	3	6	9	12
BP 0%	0.08±0.00^{a}	1.14±0.02^{a}	1.71±0.03^{a}	2.42±0.01^{a}	2.96±0.02^{a}
BP 1.5%	0.08±0.00^{a}	0.56±0.04^{b}	0.83±0.04^{b}	0.98±0.03^{b}	1.13±0.04^{b}
BP 3.0%	0.08±0.00^{a}	0.39±0.03^{bc}	0.60±0.01^{bc}	0.73±0.02^{bc}	0.91±0.01^{bc}
BP 4.5%	0.08±0.00^{a}	0.18±0.01^{c}	0.35±0.03^{c}	0.49±0.01^{c}	0.65±0.03^{c}
BP 6.0%	0.08±0.00^{a}	0.16±0.03^{c}	0.31±0.02^{c}	0.47±0.03^{c}	0.62±0.01^{c}

Values are presented as mean±SD of three replications. Values with different superscripts within the same column are significantly different (p<0.05).

Table 4. FFA (% oleic acid) on the roasted macadamia nut incorporated by *Boesenbergia* powder (BP) in different proportions (0, 1.5, 3.0, 4.5, 6.0%) during 12 months of storage

Storage (month)	0	3	6	9	12
BP 0%	0.26±0.03^{a}	1.53±0.01^{a}	1.98±0.04^{a}	2.67±0.02^{a}	3.32±0.03^{a}
BP 1.5%	0.26±0.03^{a}	0.98±0.03^{b}	1.13±0.02^{b}	1.25±0.04^{b}	1.46±0.02^{b}
BP 3.0%	0.26±0.03^{a}	0.72±0.01^{bc}	0.88±0.03^{bc}	0.90±0.01^{bc}	1.02±0.03^{bc}
BP 4.5%	0.26±0.03^{a}	0.43±0.00^{c}	0.49±0.02^{c}	0.63±0.03^{c}	0.76±0.02^{c}
BP 6.0%	0.26±0.03^{a}	0.39±0.02^{c}	0.46±0.01^{c}	0.61±0.02^{c}	0.73±0.03^{c}

Values are presented as mean±SD of three replications. Values with different superscripts within the same column are significantly different (p<0.05).

Table 5. Overall acceptance (sensory score) on the roasted macadamia nut incorporated by *Boesenbergia* powder (BP) in different proportions (0, 1.5, 3.0, 4.5, 6.0%) during 12 months of storage

Storage (month)	0	3	6	9	12
BP 0%	8.71±0.19^{a}	8.12±0.14^{c}	7.96±0.15^{c}	7.71±0.15^{c}	7.57±0.14^{c}
BP 1.5%	8.71±0.19^{a}	8.30±0.17^{bc}	8.15±0.13^{bc}	8.06±0.16^{bc}	7.93±0.15^{bc}
BP 3.0%	8.71±0.19^{a}	8.44±0.18^{b}	8.31±0.17^{b}	8.23±0.14^{b}	8.10±0.13^{b}
BP 4.5%	8.71±0.19^{a}	8.58±0.13^{ab}	8.43±0.12^{ab}	8.35±0.14^{ab}	8.24±0.17^{ab}
BP 6.0%	8.71±0.19^{a}	8.64±0.15^{a}	8.51±0.18^{a}	8.42±0.16^{a}	8.31±0.13^{a}

Values are presented as mean±SD of three replications. Values with different superscripts within the same column are significantly different (p<0.05).

and 6.0%) during 12 months of storage was reported in Table 5. There is a decreasing trend of the sensory score by the time of storage, with the lowest score on the control and the highest on the BP 6%. There is no significant difference in sensory score between the BP 4.5% and BP 6.0%. At the end of 12 months of storage, the sensory score in the dry-roasted macadamia nut treated with BP 4.5% is very high, with 8.24±0.17 (score). Fingerroot extract showed a higher polyphenol content, ascorbic acid content, DPPH radical scavenging activity, and ABTS radical scavenging activity than those in ginger extract (Lee *et al.*, 2020).

4. Conclusion

Fingerroot rhizome is normally utilised as food seasoning and ethnomedicine. *Boesenbergia* sp. revealed a wide range of biological properties. This research has successfully investigated the influence of different ratios of fingerroot rhizome extract powder incorporated into the dry-roasted macadamia nut on its chemical, microbial and sensory attributes during preservation. Results revealed that 4.5% of fingerroot rhizome extract powder is sufficient to retard coliform proliferation, limit the formation of the peroxide value, thiobarbituric acid reactive substances, free fatty acid and maintain the overall acceptance of the dry-roasted macadamia nut for 12 months of storage.

Conflict of interest

The author strongly confirms that this research is conducted with no conflict of interest.

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