



Research Article

Screening for antioxidant activity of vegetable and fruit by-products and evaluating the ability of coffee sediment to preserve fish meal

Ha Thi Hue¹ · Ho Trung Tinh² · Nguyen Van Bao¹ · Phan Thi Anh Dao¹

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Abstract

In this study, we collected and prepared ethanol extracts from 30 vegetable and fruit by-products and screened for antioxidant activities using three methods, including determination of total phenolic content (TPC), 2,2-diphenyl-1-picrylhydrazyl free radical scavenging assay (DPPH assay), and ferric reducing/antioxidant power assay (FRAP assay). The coffee sediment (**TN-16**) and ginger peel extract (**TN-17**) showed vigorous activities and higher than those of other samples ($p < 0.05$). The TPC in **TN-16** and **TN-17** were 66.14 mgGAE/g and 146.52 mgGAE/g, respectively. For the DPPH assay, the IC_{50} inhibited the values of 16.73 $\mu\text{g/mL}$ with **TN-17** and 33.57 $\mu\text{g/mL}$ with **TN-16**. For the FRAP, a significant difference in absorbance was observed between all samples ($p < 0.05$), and **TN-16** and **TN-17** have strong activities with higher absorbances. Besides, fifteen compounds may present in **TN-16** namely, metiamide, manitol, 3-amino phenol, malicyamide, phenyl ethanolamine, 3-methoxyamphetamine, caffeine, nisoldipine, doxenitoin, dicyclohexyl phthalate, febuprol, 2,4 xylidine, glycerol 2-palmitate, 4-(benzylamino) phenol, o-toluidine were identified by HPLC-EIS-MS. In addition, the coffee sediment extract was investigated the ability to preserve fish meal in 30 days at the room temperature. The result showed that the coffee sediment was the potent extract for the protection of fish meal against lipid peroxidation as compared to synthetic antioxidants.

Keywords Natural antioxidant · DPPH · TPC · FRAP · By-product · Coffee sediment

1 Introduction

Fish meal is a valuable aqua-feed and pet-food ingredient due to the high content of protein and the nutritive value of lipids, essential amino acids and other constituents [1]. The quality of fish meal can deteriorate due to the activities of insects, microorganisms, animals, processing methods as well as high temperatures and excess moisture [2]. These factors may stimulate fish meal spoilage during storage because of the high content of unsaturated fats [3]. Antioxidants are the best choice to delay the onset of oxidation by preventing the formation of free radicals. Thus, the overall purpose of using antioxidants is to enhance oxidative stability for a reasonable length of time.

Several synthetic antioxidants are authorized for use as feed additives such as ethoxyquin (EQ) and butylated hydroxytoluene (BHT). They are generally added to fish meal and fish oil, respectively, to limit lipid oxidation [4]. However, the direct application of synthetic inhibitors to fish meal is currently restricted due to considerations related to their safety. While the use of synthetic antioxidants and antibacterials to maintain the quality of seafood products has become a common method, consumer concern about their risks has heightened scientific interest in the reduction of synthetic additives or their replacement by natural alternatives [1].

The food processing industries have generated a large amount of phenolic-rich by-products, which could be

✉ Phan Thi Anh Dao, daopta@hcmute.edu.vn | ¹Faculty of Chemical and Food Technology, Ho Chi Minh City University of Technology and Education, Ho Chi Minh City, Vietnam. ²Faculty of Natural Sciences, Thu Dau Mot University, Thủ Dầu Một, Vietnam.



valuable natural sources of antioxidants and antibacterials. Some of these by-products have been the subject of investigations and have been demonstrated to be effective sources of phenolic antioxidants and antibacterials. Several antioxidants have been extracted from plant sources such as tea, sesame, wild rice, rice hulls, and crude plant drugs, citrus peels and seeds, grape seeds, mango seed kernels, canola, sunflower seeds, and sesame [5–11].

Most of the waste in the processing of fruits and vegetables are: nuts, leaves, stems, bark, and roots that contain high-value natural compounds, useful for human health [12]. The fruit and vegetable by-products should be used as a potential source of natural antioxidant compounds. Besides, the utilization of these by-products contributes significantly to reducing the amount of waste, and to prevent environmental pollution and achieve the sustainable development goals. The by-products can be processed into functional foods rather than being discarded [12].

In this study, we selected 30 by-products to investigate their antioxidant activity by using different tests, including DPPH free radical scavenging assay, ferric reducing/antioxidant power (FRAP) assay and determination of total phenolic contents (TPC). We hope that the selected byproducts could be a potential source of natural antioxidants that could be used as therapeutic agents in preventing or slowing the oxidation in fish meal.

2 Materials

2.1 Samples

By-products were obtained from the shops at Long Phuoc Market, District 9, HCM, in August 2017. The by-products were collected, thoroughly washed under tap water to remove impurities such as dirt, dust, microflora on the surface. Then they were dried in a hot air-blowing oven at 60 °C for 5h to a moisture content of about 10% and ground into a fine powder using a blender. The voucher samples (number sample on Table 1) were preserved at the department of food technology of the Ho Chi Minh City University of technology and education.

2.2 Chemicals

Gallic acid and Folin-Ciocalteu reagent were purchased from Sigma Chem. Co. DPPH, acid trichloroacetic (TCA) were obtained from Merck (Darmstadt, Germany). Ethanol solvent (EtOH), potassium iodide (KI), potassium hexacyanoferrate ($K_3[Fe(CN)_6]$), ferric chloride ($FeCl_3$), Na_2CO_3 were purchased from China with the highest grade impurities.

2.3 Preparation of samples

100 g of dried, powdered sample from each of the vegetable and fruit by-products was extracted with 300 mL of 96% (v/v) ethanol at 65 °C in a Soxhlet apparatus (reflux, 3 h, x 3). Then, the extracts were filtered using Whatman N^o4 filter paper, and the solvents were concentrated by a rotary evaporator under reduced pressure conditions (20 hPa, 50 °C) to recover the ethanol extracts and stored at 4 °C. Ethanol was used in this study as it is a green solvent with low risk for acute or chronic toxicity as compared to some other solvents. The percentage yield of extracts ranged from 0.35–24.08% w/w.

2.4 DPPH free radical scavenging assay

The DPPH radical scavenging activity of the extracts was determined according to the methodology described by P. Molyneux [13]. First, 1.5 mL of a 0.1 mM solution of DPPH in 90% ethanol was added to 1.5 mL of each extract (at 50 µg/mL) in 90% ethanol. After 30 min incubation at room temperature in the dark, the absorbance was measured at 517 nm by Hitachi UH-530 spectrophotometer. The percent inhibition (I%) was calculated as $(A-B/A) \times 100$, where A is the absorbance of the test sample, and B is the absorbance of the blank sample. The half maximal inhibitory concentration (IC_{50}) was determined using the mean values of data from three determinations at concentrations of 100, 50, 25, 10 µg/mL in 90% ethanol. Trolox used as a positive control was used at various concentrations (1.0, 2.5, 5.0, 10.0 µM).

2.5 Ferric reducing/antioxidant power assay

The experimental procedure was based on the method of Benzie [14]. Extracts (0.1, 0.5 and 1 mg) were mixed with 1.0 mL of 2.0 M phosphate (pH 6.6) and 1.0 mL potassium ferricyanide 1%. The mixture was incubated at 50 °C for 20 min. Then 1.0 mL of 10% TCA was added and centrifuged at 2000 × g for 10 min. The supernatants (1.0 mL) were mixed with distilled water (1.0 mL) and ferric chloride 0.1% (0.2 mL) and measured at 700 nm wavelength.

2.6 Determination of the total phenolic content

The TPC was determined using the Folin–Ciocalteu reagent [15]. Firstly, 1300 µL of sample solutions mixed with 1000 µL of Folin–Ciocalteu reagent (1:5) and incubated for 5 min. Then, 700 µL of Na_2CO_3 1 M solution was added and mixed thoroughly. After 30 minutes of incubation in the dark, the absorbance of samples was measured at 730 nm. Results

Table 1 The list of 30 by-products and results of DPPH assay, TPC and FRAP assay

No	Sign	Local name	Scientific name	Family	Part Used	DPPH I (%)	TPC (mgGAE/g)	FRAP		
								0.1 (µg/mL)	0.5 (µg/mL)	1.0 (µg/mL)
1	TN-1	Soy Bean	<i>Glycine max</i>	Fabaceae	Sediment (pulp)	4.6 ± 0.22 ^a	18.56 ± 0.45 ^h	0.104 ± 0.003 ^b	0.209 ± 0.005 ^{cd}	0.331 ± 0.005 ^{bc}
2	TN-2	Carrot	<i>Daucus carota</i>	Apiaceae	Sediment	5.04 ± 0.23 ^a	2.67 ± 0.2 ^a	0.057 ± 0.001 ^a	0.148 ± 0.007 ^b	0.407 ± 0.008 ^d
3	TN-3	Corn	<i>Zea mays</i>	Poaceae	Core	5.99 ± 0.99 ^{ab}	11.31 ± 0.44 ^{ef}	0.121 ± 0.004 ^{abcd}	0.228 ± 0.005 ^{de}	0.504 ± 0.009 ^e
4	TN-4	Guava	<i>Psidium guajava</i>	Myrtaceae	Seed	8.55 ± 0.02 ^{bc}	12.56 ± 0.84 ^{fg}	0.128 ± 0.007 ^{cde}	0.317 ± 0.006 ^f	0.548 ± 0.012 ^f
5	TN-5	Pine-apple	<i>Ananas comosus</i>	Bromeliaceae	Peel	8.82 ± 1.06 ^c	6.45 ± 0.57 ^{bc}	0.113 ± 0.009 ^{bc}	0.249 ± 0.005 ^{de}	0.417 ± 0.003 ^d
6	TN-6	Pine-apple	<i>Ananas comosus</i>	Bromeliaceae	Sediment	10.46 ± 1.63 ^{cd}	12.16 ± 0.24 ^{fg}	0.107 ± 0.004 ^{bc}	0.215 ± 0.002 ^{cd}	0.551 ± 0.005 ^f
7	TN-7	Guava	<i>Psidium guajava</i>	Myrtaceae	Peel	14.77 ± 0.59 ^{ef}	12.72 ± 0.28 ^{fg}	0.103 ± 0.003 ^b	0.234 ± 0.008 ^{cde}	0.402 ± 0.011 ^d
8	TN-8	Kumquat	<i>Citrus japonica</i>	Citrusaceae	Sediment	17.8 ± 0.53 ^{gh}	55.74 ± 1.84 ⁿ	0.189 ± 0.009 ^{gh}	0.472 ± 0.004 ^h	0.779 ± 0.011 ⁱ
9	TN-9	Tomato	<i>Solanum lycopersicum</i>	Solanaceae	Sediment	19.72 ± 0.26 ^{hi}	25.67 ± 0.65 ⁱ	0.046 ± 0.002 ^a	0.237 ± 0.006 ^{de}	0.428 ± 0.008 ^d
10	TN-10	Wet rice	<i>Oryza sativa</i>	Poaceae	Peel brain	20.04 ± 0.94 ^{hi}	12 ± 0.21 ^f	0.103 ± 0.003 ^b	0.218 ± 0.005 ^{cd}	0.36 ± 0.004 ^c
11	TN-11	Sticky pineapple leaves	<i>Pandanus amaryllifolia</i> Roxb	Pandanaceae	Sediment	23.23 ± 0.46 ^k	21.72 ± 1.64 ⁱ	0.129 ± 0.004 ^{cde}	0.329 ± 0.009 ^f	0.414 ± 0.004 ^d
12	TN-12	Green Bean	<i>Vigna radiata</i>	Fabaceae	Sediment	24.53 ± 0.52 ^{kl}	10.16 ± 0.13 ^{def}	0.208 ± 0.009 ^h	0.523 ± 0.005 ^{ij}	0.738 ± 0.003 ^h
13	TN-13	Grapes	<i>Vitis vinifera</i>	Vitidaceae	Sediment	41.06 ± 0.17 ^o	18.84 ± 1.33 ^{hi}	0.147 ± 0.002 ^{ef}	0.35 ± 0.003 ^f	0.557 ± 0.004 ^f
14	TN-14	Dragon fruit	<i>Hylocereus undatus</i>	Hylocereaceae	Peel	42.17 ± 1.01 ^{op}	37.53 ± 0.48 ^m	0.046 ± 0.001 ^a	0.053 ± 0.002 ^a	0.066 ± 0.002 ^a
15	TN-15	Aloe vera	<i>Aloe vera</i>	Asphodelaceae	Peel	42.95 ± 0.63 ^{op}	20.39 ± 1.33 ^{hi}	0.167 ± 0.002 ^{fg}	0.526 ± 0.001 ^j	0.793 ± 0.011 ^j
16	TN-16	Coffee	<i>Coffea arabica</i>	Rubiaceae	Sediment	75.94 ± 0.66 ^t	66.14 ± 1.15 ^p	0.264 ± 0.002 ^j	0.814 ± 0.002 ^m	1.863 ± 0.001 ^l
17	TN-17	Ginger	<i>Zingiber officinale</i>	Zingiberaceae	Peel	77.04 ± 0.52 ^t	146.52 ± 1.86 ^q	0.51 ± 0.003 ^{kl}	1.49 ± 0.004 ⁿ	2.004 ± 0.026 ^o
18	TN-18	Logan	<i>Dimocarpus longan</i>	Sapindaceae	Seed	44.44 ± 0.77 ^{pq}	33.63 ± 0.38 ^l	0.489 ± 0.01 ^k	1.106 ± 0.047 ^o	1.574 ± 0.009 ^m
19	TN-19	Mandarin	<i>Citrus reticulata</i> Blanco	Rutaceae	Peel	16.67 ± 0.48 ^{fg}	30.35 ± 0.16 ^k	0.532 ± 0.004 ^l	1.298 ± 0.005 ^p	1.266 ± 0.01 ⁿ
20	TN-20	Grape	<i>Vitis vinifera</i>	Vitidaceae	Peel	21.87 ± 1.67 ^{ij}	8.62 ± 0.13 ^{cde}	0.141 ± 0.005 ^{de}	0.263 ± 0.004 ^e	0.538 ± 0.008 ^{ef}
21	TN-21	Passion fruit	<i>Passiflora incarnata</i>	Passiflora	Peel	35.6 ± 1.5 ^{mn}	61.5 ± 3.02 ^o	0.204 ± 0.003 ^h	0.524 ± 0.029 ^j	0.824 ± 0.04 ^j
22	TN-22	Gac fruit	<i>Momordica cochinchinensis</i>	Cucurbitaceae	Peel	65.66 ± 0.35 ^s	26.4 ± 0.6 ^j	0.5 ± 0.014 ^k	0.681 ± 0.023 ^l	0.873 ± 0.006 ^k
23	TN-23	Grapefruit	<i>Citrus maxima</i>	Rutaceae	Peel	16.94 ± 0.81 ^{fg}	5.78 ± 0.17 ^{bc}	0.331 ± 0.005 ^j	0.481 ± 0.006 ^{hi}	0.668 ± 0.017 ^g
24	TN-24	Vietnam's Apple	<i>Ziziphus mauritiana</i>	Rhamnaceae	Seed	33.89 ± 0.56 ^m	25.17 ± 0.18 ⁱ	0.28 ± 0.006 ⁱ	0.348 ± 0.006 ^f	0.546 ± 0.006 ^f
25	TN-25	Watermelon	<i>Citrullus lanatus</i>	Cucurbitaceae	Peel	12.98 ± 0.83 ^{de}	12.95 ± 0.27 ^{fg}	0.1 ± 0.007 ^b	0.194 ± 0.008 ^c	0.305 ± 0.001 ^b
26	TN-26	Sapodilla	<i>Manilkara zapota</i>	Sapotaceae	Peel	20.77 ± 0.75 ^{ij}	15.06 ± 0.57 ^g	0.262 ± 0.01 ⁱ	0.493 ± 0.01 ^{hij}	0.643 ± 0.006 ^g
27	TN-27	Sapodilla	<i>Manilkara zapota</i>	Sapotaceae	Seed	37.22 ± 0.48 ⁿ	25.49 ± 0.17 ^j	0.282 ± 0.008 ⁱ	0.527 ± 0.004 ^j	0.647 ± 0.005 ^g
28	TN-28	Star apple	<i>Chrysophyllum cainino</i>	Sapotaceae	Peel	45.74 ± 0.79 ^q	7.75 ± 0.2 ^{cd}	0.279 ± 0.018 ⁱ	0.395 ± 0.013 ^g	0.501 ± 0.017 ^e
29	TN-29	Ambarella	<i>Spondias dulcis</i>	Anacardiaceae	Peel	49.59 ± 0.45 ^r	11.32 ± 0.14 ^{ef}	0.336 ± 0.011 ^j	0.603 ± 0.025 ^k	0.764 ± 0.013 ^{hi}
30	TN-30	Banana	<i>Musa basloo</i>	Musaceae	Peel	26.5 ± 0.97 ^l	4.33 ± 0.03 ^{ab}	0.179 ± 0.003 ^g	0.337 ± 0.01 ^f	0.558 ± 0.01 ^f

Values are expressed as mean ± standard deviation (n = 3). Means with different letters in each column indicate statistically significant differences between treatments for the same species according to Duncan's multiple range test (p < 0.05). Sediment means leftover juice pulp (as a solid waste) created during the juicing process

were expressed as mg gallic acid equivalents in 1 g of the dried sample (mgGAE/g), which is based on the standard curves at concentrations of 1, 5, 10, 15 and 20 $\mu\text{g}\cdot\text{mL}^{-1}$ ($R^2=0.9976$).

2.7 HPLC-EIS-MS analysis of coffee sediment extract

The compositions of the ethanolic extract of coffee sediment (TN-16) were analyzed by HPLC-EIS-MS technique using an Agilent 1200 series (USA) equipped with ESI-MS system (microTOF-QII Bruker Daltonic, Germany). A ACE3- C₁₈ (4.6 × 150 mm, 3.5 μm , Merck, Germany) column was used. The mobile phase consisted of 0.1% formic acid in water (v/v, solvent A) and 0.1% formic acid in methanol (v/v, solvent B). The gradient program was as follows: 0 min 95:5 (A:B% ratio), 2 min 5% B, 25 min 100% B, 30 min 100% B. The flow rate was 0.5 mL/min, the column temperature was 40 °C, and the sample injection volume was 20 μL . The optimized ESI-MS operating conditions were as follows: nebulizer gas at 1.2 bar, dry gas heater temperature of 200 °C, and at a flow rate of 0.8 mL/min. The mass scan range was set at m/z 150–2000.

2.8 The production process and preservation of fish meal

Fish meal was produced according to a method by Damberg with some modifications [16]. Raw materials were small fish, fish fillet by-products which were washed, and then heated in 10 min to precipitate proteins, destroy microorganisms, separate lipids, and water. The materials were finely ground, mixed with ethanol 80% in the ratio of 1:2 (w/v), and then heated at 80 °C in 15 min. The mixture was filtered to remove the solvents. Ethanol was added to the mixture, and the procedure was repeated for one more time. After that, the mixture was dried at 80 °C in 3 h to approximately 20% moisture content, ground into a fine fish meal.

The fish meal was divided into four parts. Each of these three parts was mixed with BHT (150 ppm), coffee sediment extract (300 ppm), and a blank sample. The four pieces were dried by a air-blowing oven at 80 °C in 1 h to decrease the moisture content to below 10% before being graded by a 1 mm sieve. The obtained product was stored in polyethylene (PE) bags at room temperature (32 ± 2 °C) and used for determining nutrient compositions and peroxide values during 1 month of storage at room temperature.

2.9 Determination of peroxide value of the fish meal

The oxidation of fat in the fish meal was evaluated by peroxide value (PV), which was determined by the

method described by Cox [17]. To start, moved 0.5 gram of sample into a 250 mL erlenmeyer flask and added 0.5 mL of a saturated solution of KI and 20 mL of a 3:2 (v/v) acetic acid-chloroform mixture. The flask was kept in the dark space for 5 min before the addition of 30 mL of distilled water and 1 mL of a 1% starch solution. The solution turned into a deep purple color and titrated until turning to colorless. It has carried out a blank titration under the same conditions.

2.10 Statistical analysis

All results were expressed as mean ± SD (standard deviation). The significant differences between means were determined by analysis of variance (ANOVA) using the Duncan's multiple range tests was applied at a level of $p < 0.05$. Statistical calculations were carried out by SPSS 15.0 for Window Evaluation Version (IBM Corporation, USA).

3 Result and discussion

3.1 DPPH free radical scavenging assay

30 EtOH extracts prepared from 30 selected by-products were screened for their antioxidant activities by DPPH and FRAP assay (Table 1). For DPPH assay, all samples were carried out at a concentration of 50 $\mu\text{g}/\text{mL}$. Of the extracts assayed, 30 extracts (100%) demonstrated DPPH inhibitory activity at 50 $\mu\text{g}/\text{mL}$, among which 27 (90.0%) showed weak activities with 1 % under 50%. It is showed that most samples have weak antioxidant activity. Besides, the strong active extracts for antioxidant activity were ginger (TN-17) and coffee sediment (TN-16), followed by gac fruit (TN-22) with the percent inhibition values of 77.04%, 75.94% 65.66%, respectively. Three extracts were tested further for determining IC₅₀ values of 16.73 $\mu\text{g}/\text{mL}$, 33.57 $\mu\text{g}/\text{mL}$, and 42.85 $\mu\text{g}/\text{mL}$, respectively. IC₅₀ of trolox was 8.7 μM (2.2 $\mu\text{g}/\text{mL}$).

The DPPH analysis is a quick and simple assay that guarantees reliable results and needs only a UV-Vis spectrophotometer to carry out, which probably explains its widespread use in antioxidant screening [18]. The effect of antioxidants on DPPH radical scavenging is due to their hydrogen donating ability. Base on analyzing the results obtained in DPPH assay, it was noticed that extracts act as good hydrogen donating agents, thereby bleaches the DPPH absorbance at 517 nm.

3.2 Ferric reducing/antioxidant power (FRAP) assay

In general, the reduction capacity of the samples with increasing sample concentration levels were shown in Table 1. It is observed that the higher the concentration, the greater the reduction capacity, and the stronger the antioxidant activity. At the highest concentration (1.0 mg), there was a significant difference in absorbance values between the three most active samples, ginger peel (**TN-17**, 2.004) and coffee sediment (**TN-16**, 1.863), logan seed (**TN-18**, 1.574) ($p < 0.05$). This is suggested that these samples inhibited the ability to reduce Fe^{3+} to Fe^{2+} was higher than that of the other samples.

Reducing properties is related to the presence of potent reducing agents and the antioxidant activity of the potent reducing agents is attributed to the breakdown of free radicals by the release of a hydrogen atom [19–20]. It was suggested that antioxidant properties coincide with an increase in reducing capacity. Therefore, the intense antioxidant activity of the extract from the ginger shell and coffee grounds may correlate with the reducing ability of the extracts.

3.3 Determination of the total phenolic content

The total phenolic contents in the extract samples were shown in Table 1. The values of total phenolic content of the samples were from 2.67 to 146.52 mgGAE/g. The extract from ginger peel (**TN-17**) showed the highest value of total phenolic content (146.52 mgGAE/g), following by the extract from coffee sediment (**TN-16**) and kumquat peel (**TN-8**) with 66.14 mgGAE/g and 55.74 mgGAE/g, respectively. The lowest value of total phenolic content belonged to the extract from carrot sediment (**TN-2**) with 2.67 mgGAE/g. In general, the values of the total phenolic content in the extract samples showed a significant difference ($p < 0.05$).

The correlation between antioxidant capacity and total phenolic content in food has been extensively studied [15, 21]. According to a study by Panusa et al. [22], the values of antioxidant activity in the DPPH test correlate with the total phenolic content in coffee grounds under different extraction conditions [22]. Two sample extracts ginger peel (**TN-17**), and coffee sediment (**TN-16**) had not only high DPPH inhibitory activity but also potent phenolic content.

In fact, coffee sediment extract is more suitable to preserve fish meal because of its high availability and affordability. That is the reason coffee sediment extract was chosen to investigate its chemical compositions and the ability to preserve fish meal.

3.4 Chemical composition of coffee sediment

Fifteen compounds have been identified in **TN-16** by high performance liquid chromatography with MS probes (Table 2).

Among them, 3-amino phenol, salicyamide, phenyl ethanolamine, caffeine, and 4-(benzylamino) phenol belong to the phenolic group. In particular, caffeine is a potent antioxidant compound. The high levels of chlorogenic acid and caffeine in coffee grounds suggest the potential for using them as a natural source of antioxidants [22].

3.5 The evaluation of fish meal quality

The yield of producing fish meal was 20% by weight of the raw material, the yield of filtered fish meal (1 mm sieves) was 94.74% by weight of the dry fish meal. The fish meal showed nutrient compositions as follows: moisture of 10.25%; total protein of 44.69%; total fat of 16.81%; and ash of 15.34%. In commerce, fish meal has protein content of 12–66%; moisture of 0–9%; fat of 6% and ash of 13–21% [23]. There is variation in the protein content of the fish meal, depending on the ingredients used. Besides, the fish meal has a low ash value and the high-fat content as compared to commercial fish meal. This leads fish meal to deteriorating faster than commercial fish meal due to lipid oxidation [24].

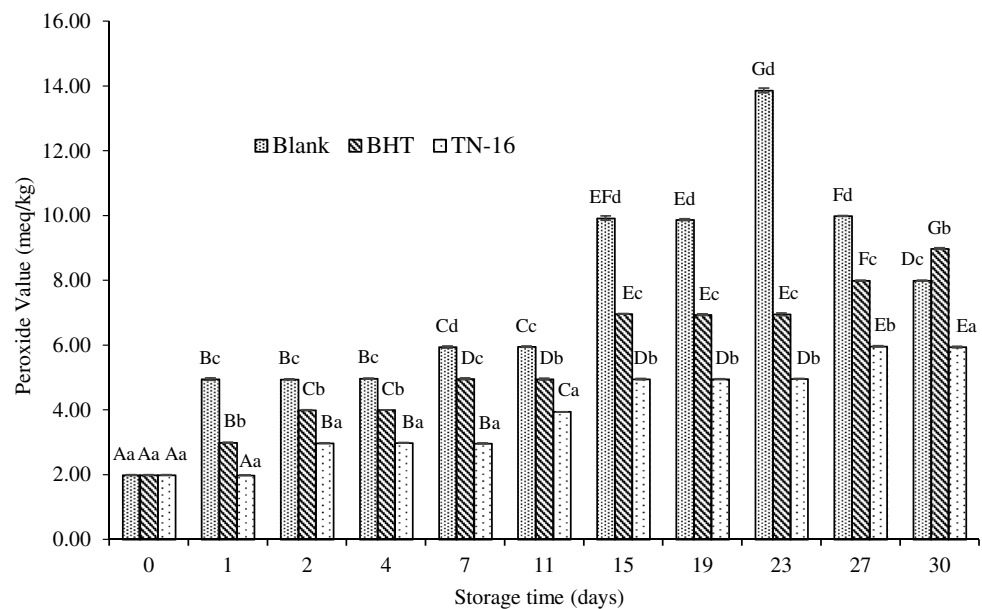
3.6 Determination of peroxide values of the fish meal during storage

The ability of **TN-16** for preserving fish meal was evaluated by the formation of primary oxidation products

Table 2 Identification of 15 compounds in **TN-16** by HPLC–ESI–MS

No.	Compounds	[M–H] [−] (m/z)	Predicted formula
1	Metiamide	245,0871	C ₉ H ₁₆ N ₄ S ₂
2	Manitol	205,0683	C ₆ H ₁₄ O ₆
3	3-amino phenol	110,0601	C ₆ H ₇ NO
4	Salicyamide	138,0551	C ₇ H ₇ NO ₂
5	Phenyl ethanolamine	138,0919	C ₈ H ₁₁ NO
6	3-Methoxyamphetamine	166,1225	C ₁₀ H ₅ NO
7	Caffeine	217,0696	C ₈ H ₁₀ N ₄ O ₂
8	Nisoldipine	411,1502	C ₂₀ H ₂₄ N ₂ O ₆
9	Doxenitoin	239,1179	C ₁₅ H ₁₄ N ₂ O
10	Dicyclohexyl phthalate	331,1908	C ₂₀ H ₂₆ O ₄
11	Febuprol	225,1485	C ₁₃ H ₂₀ O ₃
12	2,4 Xylidine	122,0965	C ₈ H ₁₁ N
13	Glycerol 2-palmitate	330,2773	C ₁₉ H ₃₈ O ₄
14	4-(Benzylamino) phenol	200,1069	C ₁₃ H ₁₃ NO
15	o-Toluidine	108,0808	C ₇ H ₉ N

Fig. 1 Changes in peroxide values of fish meal with different treatments during storage at room temperature. Bars represent standard deviation ($n = 3$). Different capital letters on the bars within the same treatment indicate significant differences ($p < 0.05$). The different letters on the bars within the same storage time indicate significant differences ($p < 0.05$)



(peroxides). Figure 1 indicates the peroxide values of coffee sediment, BHT, and blank samples from homogenous fish meal samples.

Overall, peroxide values of fish meal with preservatives were lower and remained more stable than the blanks over the period shown. It was found that the peroxide values of blanks increased considerably from an initial value of 1.99 meq/kg to reach the peak at 13.86 meq/kg for the first 24 days, and decreased afterward. The values for samples with BHT were lower, rising significantly for the first 15 days (from 1.99 to 6.96 meq/kg) and slightly for the rest (6.94 meq/kg to 8.98 meq/kg). The smallest peroxide values were found in the fish meal with extracts of coffee sediment (TN-16) with the number growing marginally from 1.99 to 5.94 meq/kg at the end of the period. The quality of fish meat products is decreased by the lipid peroxidation, which results in a reduction in nutritional quality. Coffee sediment act as antioxidant reagents that delay or prevent the formation of free radicals through different mechanisms: hydrogen atom transfer, single-electron transfer mechanism (SET), or the combination of both HAT and SET mechanisms [25].

4 Conclusions

In conclusion, we have carried out a systematic investigation of vegetable and fruit by-products for DPPH assay, determination of phenolic content, and ferric reducing/antioxidant power (FRAP) assay. The results indicate a limited number of by-products that may be useful for the treatment of diseases relating to free radical damages such

as coffee sediment (TN-16), ginger peel (TN-17), and gac peel (TN-22). Among them, the coffee sediment extract exhibits potent abilities to inhibit the oxidation of fish meal during storage. In Viet Nam, a large amount of fish meal is produced to meet the increasing need for domestic and foreign fisheries and aquaculture industries. On the market, coffee sediment is a highly abundant and low-cost raw material; thus, the potential for using the byproduct as a natural source of antioxidants is going to be promising.

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Compliance with ethical standards

Conflict of interest All authors declare that there is no conflict of interest.

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