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Total Phenolic Content and In-Vitro Antioxidant Activity of Coconut Husk Extracts: Effect on Proximate Composition and Texture of Tilapia Surimi Gel

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Abstract

The coconut husk is a waste produced from the coconut industry and is a rich source of phenolic and antioxidant compounds. In this study, the total phenolic content (TPC) and antioxidant activity of the aqueous (TA) and 60% ethanol (TE) extracts were evaluated. The maximum TPC was found in the ethanol extract of coconut husk. The highest DPPH radical scavenging activity of extracts was observed in ethanolic extracts and the highest ABTS activity in aqueous extracts. FTIR analysis revealed the presence of a peak at 1283.84cm^{-1} in the ethanol extract and the disappearance of the same peak in the aqueous extract. The extracts at different levels (0.050 (TA-1/TE-1, 0.075 (TA-2/TE-2) and 0.10 (TA-3/TE-3) % based on protein content) were incorporated into single wash tilapia surimi and quality of gels were investigated. The addition of extracts decreased the pH of the gels. Addition of TA-1, TE-2 and TE-3 resulted in lower expressible moisture content. The pH, hardness and expressible moisture content demonstrated that ethanol extracts of coconut husk can be considered as a potential alternative to commonly used hen egg white powder and other animal based additives to enhance the quality of the freshwater fish surimi.

Keywords: Antioxidant activity, coconut husk extract, FTIR, total phenol content, tilapia, surimi

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Introduction

The total world fisheries and aquaculture production in 2020 reached a record 177.8 million tonnes and food fish production through aquaculture was 87.5 million tons (FAO, 2022). Tilapia (*Oreochromis niloticus*) is the most farmed finfish species after grass carp and silver carp. The world production of tilapia in 2020 was estimated as 4514.6 thousand tonnes including inland and coastal aquaculture (FAO, 2022). Surimi is the wet concentrate of myofibrillar protein processed from fresh water and marine fish sources after repeated washing with cold water. Since the production and availability of tilapia are higher, it can be utilized in surimi production. Alkaline saline washed surimi with a single wash cycle was successfully prepared from tilapia mince with improved gel strength in comparison to the conventional washed surimi (Priyadarshini et al., 2017; Priyadarshini et al., 2018).

The phenolic compounds are secondary metabolites, chemically structured as a hydroxyl group bonded to an aromatic ring (Ozdal et al., 2013). These phenolic compounds exert antioxidant, and antimicrobial properties and crosslink covalently with the proteins. The interactions between proteins and phenols are one of the main long-lasting challenges behind the valorization of proteins from plants and agri-industrial by-products (Balasundram et al., 2006). The protein-phenol interactions involve hydrogen bonds, hydrophobic binding and covalent crosslinking. Coconut husk is the major waste generated from the coconut industry with a global estimated production of 23 million tons (FAO, 2009). This waste is utilized in several ways such as fuel, mulch, for extraction of coir fiber, coco peat, etc. but

mostly it is dumped into the environment and is a major concern of pollution (Swarnam et al., 2016). The mesocarpic husk waste is a cheap alternative source of carbohydrate and phenolic compounds (Dey et al., 2003). In recent times, ethanolic coconut husk extract has been reported to induce cross-linking of myofibrils from sardine and increase the textural properties in a dose-dependent manner (Buamard & Benjakul, 2015; Buamard et al., 2017; Buamard & Benjakul, 2018). The texture is the prime factor that determines the value or price of the surimi. Since the surimi was single-cycle washed, additives from natural sources can be added to improve the quality of the surimi. The incorporation of phenolic compounds extracted from agro-waste into freshwater fish surimi has not yet been reported. Therefore, the objective of the present investigation was to study the effects of coconut husk extract on the quality of single-washed alkaline saline surimi from tilapia.

Materials and Methods

Mesocarp of coconut (*Cocos nucifera* Linn.) was collected from the local market in Versova, Mumbai, India. Tilapia (*Oreochromis niloticus*), with a standard length and weight of 25-28 cm/fish and 700-800 g/fish respectively, were purchased from a fish farm (West Coast Fisheries, Talegaon, Pune, Maharashtra, India). The fish were packed in a polyurethane insulated container (fish/ice ratio of 1:2 (w/w)), transported to the Department of Post-Harvest Technology, Central Institute of Fisheries Education, Mumbai within 4 hours and stored in ice until processed. Single-washed alkaline-saline surimi was made using the procedure outlined Priyadarshini et al. (2017). This involved rinsing fish mince with alkaline-saline solution (0.15% NaCl and 0.2% $NaHCO_3$; pH: 8.69) at a ratio of 3 parts water to 1 part mince, followed by draining the excess water. The single-washed alkaline-saline washed surimi without incorporation of extracts was used as the control sample.

The coconut mesocarp (fibrous husk) was collected and dried at 60°C in the accelerated mechanical dryer (Yarrows Co Ltd, Glasgow, Scotland) for 16h and then defibred. The defibred husk was milled using a grinder (Philips food processer, India) and sieved to a size of < 6 mm (Woven wire sieves, India). The coarse husk was further blended and sieved using a stainless-steel sieve of 80 mesh. The obtained powder was dried in a hot air oven (Heraeus, beleuchtung, Thermo scientific) at 85°C overnight and stored in sealed LDPE packets at room temperature until further use (Buamard & Benjakul, 2015).

To prepare the aqueous extract, 50g of milled husk was soaked with 0.725L of distilled water and boiled for 3h (Esquenazi et al., 2002). The ethanolic extract was prepared by mixing 50g of husk with 1750mL (60% ethanol: water) at room temperature (30–32°C) for 3h by stirring the mixture continuously at low speed using a magnetic stirrer (Expo Hi-tech, Mumbai, India). The selection of a 60% extracting solvent was based on the higher extraction of phenolic content from coconut husk compared to alternative solvents (Buamard & Benjakul, 2015). Both the aqueous and ethanol extracts were filtered through a Whatman filter paper no.1 (Whatman International Ltd., Maidstone, UK) and subsequently evaporated using a rotary evaporator (Strike 300, Steroglass S.r.l., Perugia), with the aqueous extract at 58°C and the ethanol extract at 45°C. The extracts were freeze dried using a Scanvac Model Coolsafe 55 freeze dryer (Coolsafe, Lynge, Denmark) to obtain the dry extract. The freeze-drying operation temperature was maintained at -92°C for drying period of about 16h. Dried extracts were powdered and stored in an air-tight container wrapped with aluminium foil at 4°C.

The total phenolic content of coconut husk extracts was determined using Folin-Ciocalteau Reagent (FCR) as described by Slinkard & Singleton (1997) with slight modification. The freeze-dried powder was reconstituted with respective solvents, water and ethanol in 1:1(w/v) ratio. Coconut husk extract (100µL) was mixed with 0.75mL of FCR, which was prediluted 10-fold with distilled water. After 5 minutes, the mixture was added with 0.75mL of 6% (v/v) sodium carbonate. The solution was mixed and allowed to stand for 1h at room temperature. The absorbance at 760nm was read using a UV spectrophotometer (µQuant Biotek, Winooski, USA). Standard solutions of tannic acid (0-600ppm) were used for standard curve preparation. The phenolic content was expressed as mg tannic acid equivalents per g dry weight of coconut husk extract (Rodrigues & Pinto, 2007).

The 2,2-Diphenyl-1-picrylhydrazyl (DPPH) radical scavenging activity of coconut husk extracts were determined according to the method of Dhanabalan et al. (2017). The stock solution was prepared by

dissolving 24mg DPPH with 100mL methanol and then stored at -20°C until further use. The working solution was obtained by mixing the 10mL stock solution with 45mL methanol. The extract of 150µL was combined with 2850µL of DPPH solution for 24h in the dark. The absorbance of the DPPH solution with methanol instead of the sample was taken as a control. Then, the absorbance was taken at 515nm using a UV-visible spectrophotometer (µQuant Biotek, Winooski, USA). The inhibition percentage was calculated using the following formula

DPPH scavenging activity (%) = $(A_0 - A_1)/A_0 \times 100$

Where A_0 is the absorbance of the control, and A_1 is the absorbance of the sample

2-azinobis (3-ethylbenzothiazoline-6-sulphonic acid) diammonium salt radical scavenging activity of the coconut husk extract was measured by the method of Arnao et al. (2001). The stock solutions including 7.4mM ABTS solution and 2.6mM potassium persulfate solution were mixed in equal quantities and allowed to react for 12h at room temperature in the dark to formulate a working solution. The solution was then diluted by mixing 1mL ABTS solution with 60mL methanol to obtain an absorbance of 1.1±0.02 units at 734nm using the UV-visible spectrophotometer (µQUANT Biotek). 150µL of coconut husk solution was allowed to react with 2850µL of the ABTS solution for 2h in a dark condition while the ABTS solution was prepared for each assay freshly. Instead of sample, methanol was used for control. The absorbance was taken at 734nm using a UV spectrophotometer (µQuant Biotek, Winooski, USA). The inhibition percentage of ABTS radical was calculated using the following formula:

ABTS scavenging activity (%) = $(A_0 - A_1)/A_0 \times 100$

Where A_0 is the absorbance of the control, and A_1 is the absorbance of the sample

The single washed alkaline saline surimi was chopped at low speed for 2 min in food processor. A homogenous surimi paste was obtained by extracting surimi myofibrillar protein with 2.5g/100g of NaCl and chopping at low speed for 1min. During chopping, the temperature was maintained below 10°C. Aqueous and 60% ethanol extracts were dissolved in cold distilled water and added into surimi paste at 0.05, 0.075 and 0.1% levels. Subsequently, the mixture was chopped for 30s, followed by 10s of a rest interval for a total time of 3min to avoid heat generation. The paste was stuffed into polyvinylidene casings (diameter: 2.5cm, length: 17.5cm) by using stainless steel sausage stuffer (Kitchener, 5 lb, China) and casings were tightened from both sides. Surimi pastes were cooked in a temperature-controlled water bath (Steroglass strike 300, Perugia, Italy) at 40°C for 30min and followed by heating at 90°C for 20min. The gels were then cooled in iced water and stored overnight at 4°C prior to analysis.

The proximate composition of the sample was determined using standard methods (AOAC, 2005). The moisture content of the surimi gels of single-washed tilapia surimi was determined by heating the sample initially at 100°C and later at a temperature of 170°C using an automatic moisture analyzer (Citizen, Model MB 54, Citizen Scale India Private Limited, India). Nitrogen content was analyzed using a Kjeldahl nitrogen analyzer (Kelplus-KES12L VAI, Pelican, India). Crude protein content was calculated by multiplying the nitrogen value with the conversion factor (N x 6.25). Total lipid in a sample was determined by Soxhlet extraction, and ash content was estimated by charring pre-dried sample in a crucible at 600°C until white ash was formed in a muffle furnace (Expo Hi Tech I therm, AL-7941, Mumbai, Maharashtra) up to 6h. The results were expressed as g/100g (wet weight basis).

The expressible moisture (EM) was estimated, as the quantity of liquid squeezed from surimi gels upon an applied force (Ng, 1978). A gel sample of 0.5 cm in thickness was weighed (X, g) and positioned between two layers at the top and three layers of Whatman filter paper No. 1 (Whatman International Ltd., Maidstone, England) at the bottom. The gels and papers were pressed and maintained for 2min under applied force with a 5kg weight. The samples were then removed and weighed again (Y, g). Expressible moisture content was calculated and expressed as the percentage of sample weight as follows:

Expressible moisture content (%) = [(X-Y) / X] x 100

The pH of the surimi gels was measured using a pH meter (Lanier, 1992). The sample was weighed for 5g, added with 45mL of distilled water and then homogenized by using a homogenizer (Polytron 2100, KINEMATICA AG, Switzerland) for 30s at 7000 rpm. The pH of the homogenate was measured using a digital pH meter (HI 2211 pH/ ORP Meter,

Hanna instruments, Romania, Europe) and the probe was calibrated at pH 4 and 7.

Textural profile analysis (TPA) of surimi gel was performed using a texture analyzer (Texan touch, Lamy Rheology, France) equipped with a stainless-steel cylindrical probe of 50mm diameter. The gels were cut into a cylinder (diameter of 25mm, height of 25mm), then compressed at a compression degree of 40% with a down speed 1mm/s, force to start: 0.5N, distance: 10mm; delay: 5s and up speed: 1mm/ s.

The data obtained from this study were subjected to one-way analysis of variance (ANOVA) using the Duncan's multiple range test (DMRT). The statistical analyses of data were performed using SPSS (SPSS 20.0 for Windows, IBM, SPSS Inc., Chicago, IL, USA). The data are reported as mean values ± standard deviation (SD). All the experiments were conducted in triplicate (n = 3).

Results and Discussion

Phenolic compounds are a large group of phytochemicals, subsisting ubiquitously in different parts of plants as secondary metabolites (Tian et al., 2017). Phenolic compounds are classified as phenolic acids (hydroxybenzoic and hydroxycinnamic acids and their derivatives), flavonoids, lignans, stilbenes, and condensed as well as hydrolyzable tannins (Amarowicz & Shahidi, 2017). In the present study, the extracts of coconut husk exhibited differences in the total phenolic contents due to the polarities of the solvents. The concentrated 60% ethanol extract of coconut husk had a total phenolic content of 710mg tannic equivalent (TAE)/g of extract, which was higher in comparison with the concentrated aqueous extracts (639mg tannic equivalent (TAE)/g extract). The values of ethanolic extract were higher than the reported values of Buamard & Benjakul (2015), where the highest total phenolic content was observed in E60 of 464mg TAE/g of the sample. In the present study, it was observed that as the concentration of coconut husk powder increased, the total phenolic content increased and ranged from 99.60 to 522.30mg TAE/g of sample in aqueous and 395.83 to 1092.00mg TAE/g in ethanol extracts respectively (Fig. 1). These distinctive changes may be due to various factors such as the

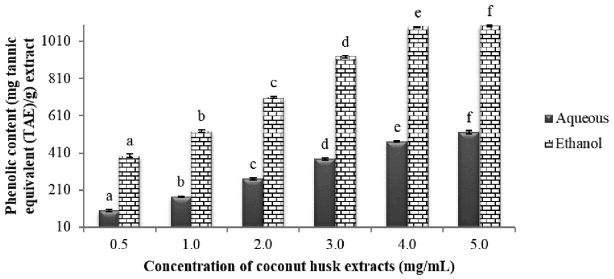

Fig. 1. Total phenolic content of coconut husk extracts at different concentrations (TA, Aqueous extract; TE, 60% ethanol extract). Bars represent the standard deviation (n = 3)

Table 1. Effect of coconut husk extracts on the proximate composition of tilapia surimi gel

Treatments	Parameters (g /100g, wet weight basis)			
	Moisture	Protein	Fat	Ash
C	79.70±0.29^{d}	15.29±0.31^{a}	1.92±0.09^{d}	2.65±0.26^{ab}
TA-1	79.37±0.17^{bc}	15.37±0.05^{a}	1.66±0.10^{bc}	2.82±0.11^{bc}
TA-2	78.61±0.07^{a}	15.86±0.05^{b}	1.40±0.11^{a}	3.42±0.04^{d}
TA-3	78.49±0.01^{a}	15.29±0.02^{a}	1.82±0.10^{cd}	3.48±0.06^{d}
TE-1	78.74±0.12^{a}	15.36±0.05^{a}	1.76±0.20^{bcd}	2.67 ±0.04^{ab}
TE-2	79.65±0.03^{d}	15.47±0.06^{a}	1.74±0.02^{bcd}	2.70±0.01^{ab}
TE-3	79.16±0.14^{b}	15.37±0.07^{a}	1.70±0.07^{bc}	2.91±0.04^{c}

Mean ± Standard deviation (n = 3). Means within a column followed by different letters are significantly different ($p < 0.05$)

C: alkaline saline washed surimi without extract; TA-1: surimi added with 0.05% aqueous extract; TA-2: surimi added with 0.075% aqueous extract; TA-3: surimi added with 0.1% aqueous extract; TE-1: surimi added with 0.05% of 60% ethanolic extract; TE-2: surimi added with 0.075% of 60% ethanolic extract; TE-3: surimi added with 0.1% of 60% ethanolic extract

nature of the sample matrix and the chemical properties of the phenolics, including molecular structure, polarity, concentration, number of aromatic rings, hydroxyl groups (Khoddami et al., 2013) and agronomic factors (Tomás Barberán and Espín, 2001). The low phenolic content in aqueous extract in the present investigation may be due to the existence of cell-wall bound phenolic compounds and a non-soluble form (Dey et al., 2003).

FTIR spectra were used to study the functional groups of the aqueous and 60% ethanolic extracts (Fig. 2) and the assignments of bands are discussed as follows. The presence of peaks in the range of 3200-3400cm^{-1} is for the O-H stretch of a phenol group, and 800-600cm^{-1} regions (for C-H out of plane bend) represent aromatic phenols (Rao & Paria, 2013). The characteristic peaks observed in both the extracts between 1650–1450cm^{-1} and 1420–1330cm^{-1} correspond to phenolic compounds, which is due to the aromatic ring stretching vibration and the O-H in-plane deformation but the intensity of peaks is higher in the ethanolic extract (Vázquez et al., 2008). The presence of a peak at 1283.84cm^{-1} in the ethanolic extract is a characteristic feature of the flavonoid-based tannins (Falcão & Araújo, 2013) and the disappearance of the same peak in the aqueous extract was observed. The absorption region between 1300–1200cm^{-1} is due to C-O stretching related to phenols (Ma et al., 2016). Therefore, from the observations, it can be concluded that coconut husk extracts are a rich source of different phenolic compounds.

Utilizing antioxidants derived from plants as potential substitutes for synthetic ones has garnered considerable attention. Different methods have been developed to determine the antioxidant activity of plant extracts. The appropriate method of measuring the antioxidant activity of a plant extract is by using a combination of two or more complementary test systems together (Ozer et al., 2018). A wide

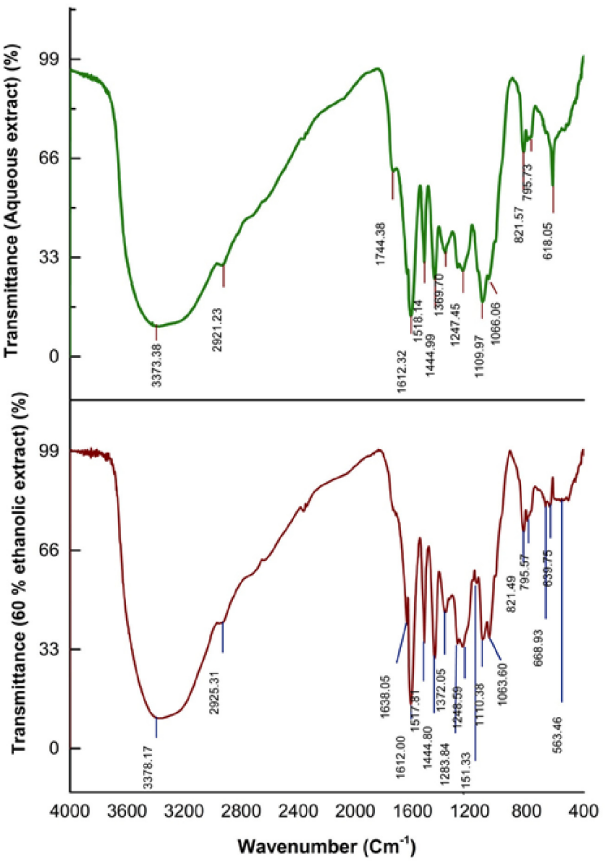

Fig. 2. FTIR spectra of aqueous and 60% ethanolic extracts of coconut husk

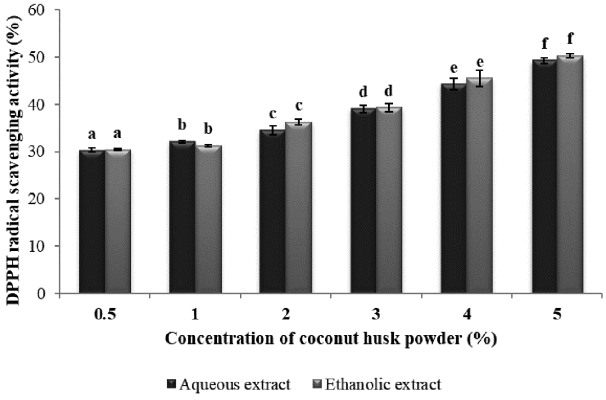

Fig. 3(a). DPPH radical scavenging activity of coconut husk extracts. Bars represent the standard deviation (n = 3)

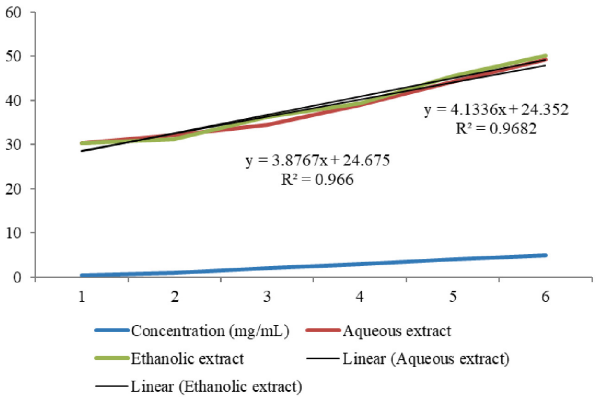

Fig. 3(b). IC_{50} concentration value for DPPH radical scavenging activity of coconut husk extracts

range of spectrophotometric assays have been embraced to measure the antioxidant capacity of foods where the most common being ABTS and DPPH assay (Floegel et al., 2011).

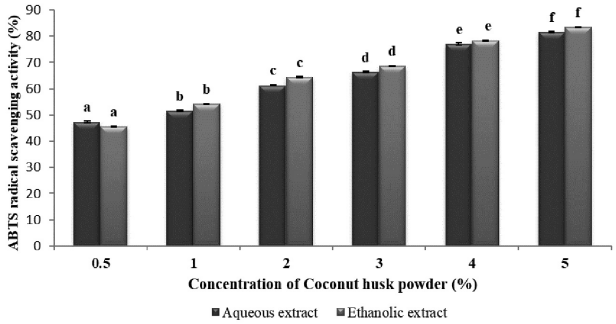

Fig. 4(a). ABTS radical scavenging activity of coconut husk extract. Bars represent the standard deviation (n = 3)

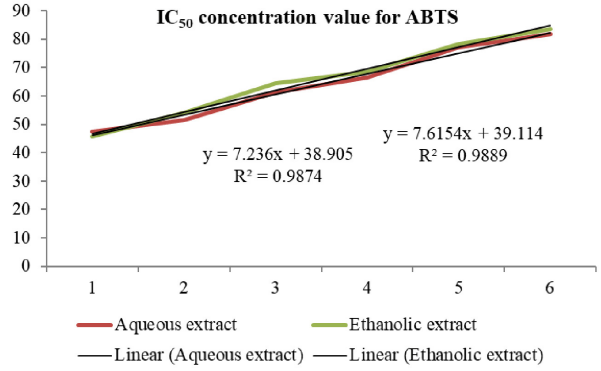

Fig. 4(b). IC_{50} concentration value for ABTS radical scavenging activity of coconut husk extract

In this study, the DPPH scavenging activity of ethanol and aqueous extracts were found to be in the range of 30.29% to 50.41% and 30.29% to 48.96%, respectively. The ethanol extracts revealed more DPPH scavenging activity than aqueous extracts, which was in concomitant with the total phenolic content (Fig. 3(a)). This might be due to the presence of active components such as phenols and polyphenols (Siddhuraju et al., 2002). The phenolic compounds may contribute to antioxidant activity due to the presence of hydroxyl groups, which can act as hydrogen donors (Dreosti, 2000). The IC_{50} concentration for DPPH radical scavenging activity (Fig. 3(b)) in aqueous and ethanolic extracts were found to be 6.558 and 6.196 mg/ml. A higher concentration of polyphenolics was identified in coconut flower hydrosol, leading to enhanced antioxidant activity (Shen et al., 2017). Furthermore, an analysis of the DPPH activity of the methanolic extract derived from *Cocos nucifera* L. mesocarp revealed that aged and mature mesocarp exhibited a reduced percentage of scavenging when compared to young mesocarp (Chakraborty & Mitra, 2008).

ABTS assay is based on the measurement of the ability of antioxidants towards scavenging the stable ABTS radical (Fig.4 (a)). In the present study, the ABTS activity was found in the range of 47.35% to 81.60% (aqueous) and 45.58% to 83.51% (ethanol) respectively. The IC_{50} concentration for ABTS radical scavenging activity in aqueous and ethanolic extracts was found to be 1.536 and 1.430 mg/ml (Fig.4(b)). The variation in DPPH and ABTS values can be due to the stereoselectivity of the radicals or the different capacity of extracts to react and quench different radicals (Almoulah et al., 2017). The variations in the results of the present study may be because DPPH radical reacts with polyphenols (catechins, proanthocyanidins), but not with phenolic acids and sugars (Kaneda et al., 1995), whereas ABTS radical has its high reactivity, and thus likely the ability to react with a broader range of antioxidants (Stratil et al., 2007). The DPPH and ABTS in foods, might differ depending on which solvent is used, the growing season, geographical origin, and agricultural practices (Klunklin & Savage, 2017).

The moisture content, crude protein, total fat, and ash content of surimi gels with the addition of coconut husk extract were determined and are shown in Table.1. The moisture content of the surimi gels incorporated with the extracts (both aqueous and ethanol) shown decreased values in comparison with the control gels. This can be explained by the excessive aggregation of proteins that might have released the water and thus reduced the moisture content of the surimi gels. The protein content exhibited a significant increase in TA-2-treated gels and decreased values in other treatments. The aqueous-treated surimi gels showed a decreasing trend in fat content up to a concentration of 0.075% and further increased. Whereas ethanol extract-treated gels exhibited a decreasing trend ($p>0.05$) in comparison to control surimi gels. The fluctuations observed in aqueous-treated surimi gels may be due to the reflection of changes in moisture content. The surimi gels have shown an increase in ash content irrespective of the extract used as their concentration increased. This increase can be due to the addition of NaCl to the surimi paste. Higher ash content in

aqueous extracts treated surimi (TA-2 and TA-3) gels might be influenced by coconut husk extracts which are regarded to have high mineral content (Konduru et al., 1999).

The pH of the surimi gels added with aqueous and ethanol extracts of coconut husk at different levels is shown in Table 2. The highest pH was observed in the control surimi gel, which is due to washing with alkaline saline solution (Priyadarshini et al., 2018). The reduced pH of the gels is due to phenolic acids such as chlorogenic acid, alpha amino diphenyl acetic acid, 4- methoxy cinnamic acid and salicin; their presence in extracts is confirmed by HRLC-MS (data not shown). In the present study, TA-1 (Surimi added with 0.05% aqueous extract), TE-1 (Surimi added with 0.05% of 60% ethanolic extract) and TE-2 (Surimi added with 0.075% of 60% ethanolic extract) gels exhibited pH within the range of 6.5–7.5, which is optimum for gelation (Park et al., 2013).

The expressible moisture content of gel from tilapia surimi added with aqueous and ethanol coconut husk extracts at different levels is depicted in Table 2. The TA-1 surimi gels showed lowest expressible moisture content compared to C surimi gel. The ethanol extract treated surimi gels showed lower expressible moisture content. The reduced values of expressible moisture content can be due to the formation of cross-links, resulting in the formation of a porous protein matrix with a high capacity to soak up water and retain it (Gaspar & de Góes-Favoni, 2015). Buamard et al. (2017) reported that phenolics in ECHE could enhance the cross-linking of proteins via a hydrogen bond and hydrophobic interaction which leads to more retention of water in a gel matrix (Buamard et al., 2017). At higher concentration, the values of expressible moisture content increased (TE-3) in surimi gels. A similar result was observed by Balange & Benjakul (2009) when a high concentration of the extracts or phenolic were incorporated to surimi. From the results it can be noticed that the addition of ethanol coconut husk, specifically at a level of 0.075%, was able to reduce the water holding capacity thereby increasing water holding capacity of surimi gels.

Texture profile analysis (TPA) is a two-compression testing method to simulate the mastication process (Figura & Teixeira, 2007). Five textural parameters Hardness 1, 2, cohesiveness, adhesiveness and elasticity of surimi gels added with coconut husk extracts at different levels were analyzed and depicted in Table 2. Hardness represents the maximum force generated by resistance to the first compression and hardness is directly related to the fish protein content (Gani & Benjakul, 2018). Hardness 1, 2 and adhesiveness increased significantly ($p<0.05$) as the additives were incorporated to control surimi. The highest hardness and cohesiveness were observed in TE-2 gels ($p<0.05$). Cohesiveness is defined as the extent to which the sample could be deformed before rupture (Chen & Opara, 2013). The cohesiveness values of C and TE-2 gels were close to 1, suggesting that they are highly cohesive as an almost full recovery was acquired at the second compression (Moon et al.,

Table 2. Effect of coconut husk extracts on pH, expressible moisture content and texture profile analysis of tilapia surimi gel

Treatment	pH	Expressible moisture	Hardness 1 (N)	Hardness 2 (N)	Cohesiveness	Adhesiveness (mj)	Elasticity
C	7.03±0.12^{f}	3.89±0.44^{bcd}	94.39±14.60^{a}	101.98±9.32^{a}	0.99±0.12^{b}	1.47±2.37^{a}	1.05±0.02^{a}
TA-1	6.56±0.04^{cd}	3.15±0.37^{abc}	112.03±1.50^{a}	119.41±4.16^{bc}	0.90±0.01^{b}	2.67±1.84^{ab}	1.05±0.02^{a}
TA-2	6.42±0.02^{ab}	3.82±0.43^{bcd}	151.29±12.94^{bc}	168.06±20.10^{cd}	0.90±0.08^{b}	3.47±0.92^{ab}	1.06±0.01^{a}
TA-3	6.36±0.01^{a}	4.44±0.34^{d}	144.12±15.76^{bc}	160.84±15.70^{c}	0.93±0.05^{a}	5.13±0.68^{ab}	1.07±0.04^{a}
TE-1	6.63±0.01^{d}	2.25±0.23^{a}	123.30±9.55^{ab}	140.71±7.17^{bc}	0.95±0.09^{b}	2.58±1.50^{ab}	1.07±0.03^{a}
TE-2	6.55±0.03^{cd}	2.95±0.52^{ab}	159.50±18.40^{c}	196.29±41.11^{d}	0.98±0.10^{b}	2.77±1.95^{ab}	1.09±0.03^{a}
TE-3	6.49±0.01^{bc}	3.58±0.46^{bc}	102.52±14.87^{a}	112.87±14.14^{ab}	0.94±0.07^{b}	2.53±2.48^{ab}	1.05±0.03^{a}

Values expressed as Mean ± Standard deviation (n = 3). Means within a column followed by different letter are significantly different ($p<0.05$).

C: alkaline saline washed surimi extract; TA-1: surimi added with 0.05% aqueous extract; TA-2: surimi added with 0.075% aqueous extract; TA-3: surimi added with 0.1% aqueous extract; TE-1: surimi added with 0.05% of 60% ethanolic extract; TE-2: surimi added with 0.075% of 60% ethanolic extract; TE-3: surimi added with 0.1% of 60% ethanolic extract

2017). The lower cohesiveness values in other gels demonstrate that surimi gel tended to detach the gel network. Elasticity can be correlated with the deformation of the surimi gels. The treated surimi gels did not exhibit significant differences in adhesiveness and elasticity values. The highest adhesiveness was observed in TA-3 gels revealing that the surface of surimi gels was sticky and non-smooth (Liu et al., 2014). The lower adhesiveness values observed in C gels might be due to a greater loss of liquid during compression in the TPA test (Jridi et al., 2015).

Coconut husk extracts are a good source of antioxidants and phenolic compounds. These phenolic compounds depending on the concentration can affect proteins. The FTIR analysis of coconut husk extracts revealed that it's a rich source of different phenolic compounds. In the present study, TE-2 gels resulted in better EM content, indicating formation of three-dimensional gel structures. This work exemplifies the utilization and valorization of the coconut husk waste in improving the quality of the single washed tilapia surimi gels at dose dependent manner.

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