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The Effect of Hot Water Extract of *Pluchea indica* Leaf Powder on the Physical, Chemical and Sensory Properties of Wet Noodles

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Abstract

Powdered *Pluchea indica* Less leaves have been utilized as herbal tea, brewing of pluchea tea in hot water has antioxidant and antidiabetic activities, because of phytochemical compound content, namely tannins, alkaloids, phenol hydroquinone, phenolics, cardiac glycosides, flavonoids, and sterols. Using of this extract on food, such as jelly drinks, buns, and soymilk can increase functional values and influence physic, chemical, and sensory characteristics of food. The study was carried out to assess the effect of various concentration of pluchea tea on the physical, chemical and sensory properties of wet noodles. A one-factor randomized design was applied with pluchea tea at concentrations of 0, 5, 10, 15, 20, 25 and 30% (w/v). Physical properties analyzed included water content, swelling index, cooking loss, color and texture. Chemical properties measured were bioactive contents of total phenolic content, total flavonoid content, and antioxidant ability to scavenge DPPH free radicals and to reduce iron ions. Sensory properties determined were taste, texture, color, aroma and overall acceptance. The addition of various concentrations of extract offers significantly effects on parameters of physical, chemical and sensory properties of noodles, except color (redness, chroma and hue), cooking loss, water content, swelling index and aroma. Using of 10% (w/v) of pluchea tea resulted in the best sensory properties such as color, aroma, taste, texture, and overall acceptance with the scores of 5.62 (slightly like), 5.45 (slightly like), 5.46 (somewhat like), 6.53 (like), and 6.53 (like), respectively. Generally, the study concluded that wet noodles can be made by adding pluchea tea at 10% (w/v).

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Dried samples TPC, TFC, DPPH free radical scavenging and iron ion reducing power were 82.84 mg GAE/kg, 62.44 mg CE/kg, 130.68 mg GAE/kg and 51.33 mg GAE/kg, respectively.

Introduction

Pluchea indica Less is an herb plant including *Asteraceae* family usually used by people as traditional medicine and food.[1,2] The potency of pluchea leaves is related to phytochemical compounds, such as tannins, flavonoids, polyphenols, essential oils, sterols, phenol hydroquinone, alkaloid, lignans and saponins.[2,3,4,5] Chan *et al.*[1] also reported that caffeoylquinic acids, phenolic acids, flavonoids and thiophenes in pluchea leaves are compounds with antioxidant activities. Furthermore, pluchea leaves also contain nutritive value, i.e., protein 1.79 g/100 g, fat 0.49 g/100 g, insoluble dietary fiber 0.89 g/100 g, soluble dietary fiber 0.45 g/100 g, carbohydrate 8.65 g/100 g, calcium 251 mg/100 g, β-carotene 1.225 µg/100 g.[6]

Pluchea tea brewed from pluchea leaves has been proven to exhibit antioxidant activity,[6,7,8] anti-diabetic activity,[9] anti-inflammatory activity,[7] anti-human LDL oxidation activity.[10] Previous research uses pluchea leaf powder to make several food products to increase functional values, i.e., jelly drink,[11] soy milk[12] and steamed bun[13] Using 1% (w/v) pluchea leaf powder can improve the physicochemical properties of jelly drink and increase panelists' acceptance of the product.[11] Soy milk with the addition of pluchea leaves increases the viscosity and total dissolved solids and decreases the panelist acceptance rate.[12] The addition of 6% (w/v) brewing from pluchea leaf powder on steamed bun is the best treatment with the lowest level of hardness.[13] Previous research has proven that the addition of pluchea leaves can increase the bioactive compound contents based on total phenol and total flavonoids, as well as increase the antioxidant activity based on ferric reducing power and ability to scavenge DPPH free radicals.

To the best of our knowledge, the study of the addition of pluchea tea in making wet noodles from wheat flour has not been conducted, as well as its impact on physicochemical and sensory characteristics of the noodles. Noodles are a popular food product that is widely consumed in the world. Indonesia is one of the countries with the largest noodle consumption after China.[14] Wet noodles usually contain lower protein and higher carbohydrate[15] than that of egg wet noodles as an alternative to wet noodles, which contain higher protein, and the second popular food in ASEAN regions including Thailand, Vietnam, Laos, Myanmar, Malaysia, Singapore and Indonesia.[16] The addition of other ingredients has been endeavored to enhance wet noodles' specific properties. Many researchers incorporated plant extracts or natural products to increase functional properties of wet noodles, such as red spinach,[17] green tea,[18,19] purple sweet potato leaves,[20] moringa leaves,[21] sea weed,[22] ash of rice straw, turmeric extract,[23] and betel leaf extract[24] that influenced the physical, chemical, and organoleptic properties of the wet noodles. The anthocyanin of red spinach ethanolic extract increases the hedonic score of wet noodles' flavor.[17] The addition of green tea improves the stability, elastic modulus and viscosity, retrogradation and cooking loss with, no significant effect on mouth-feel and overall acceptance from panelist on the produced wet noodles.[18] Moreover, the addition of sweet potatoes leaf extract on wet noodles increases moisture content, protein value and ash concentration, and improves hedonic score of texture.[20] Moringa extract influences protein content and decreases panelist acceptance of color, aroma and taste of wet noodles.[21] The use of seaweed to produce wet noodles influences moisture content, swelling index, absorption ability, elongation value and color.[22] The addition of ash from rice straw and turmeric extract influences the elasticity and sensory characteristics (color, taste, aroma and texture) of wet noodles.[23] Betel leaf extract used to make Hokkien (with dark soya source) noodles improves texture and acceptance score of all sensory attributes.[24]

Bioactive compounds and nutritive values of pluchea leaf can be an alternative ingredient to improve quality and sensory from wet noodles. The use of hot water extract from powdered pluchea leaves can serve as an antioxidant source in wet noodles and increase the functional value. This study was undertaken to assess the effect of various concentration of pluchea tea on the physical, chemical and sensory properties of wet noodles.

Materials and Methods

Preparation of Hot Water Extract from Pluchea Leaf Powder

Young pluchea leaves (1-6) (Figure 1) were picked from the shoots, sorted and washed. The selected leaves were dried at ambient temperature for 7 days to yield moisture content of 10.00 ± 0.04% dry base.[25] Dried pluchea leaves were powdered to the size of 45 mesh and sterilized at 120oC for 10 min by drying in oven (Binder, Merck KGaA, Darmstadt, Germany) and packed in tea bag for about 2 g/tea bag. Pluchea leaf powder in tea bags was extracted using hot water (95oC) for 5 min to get extract concentrations of 0, 5, 10, 15, 20, 25, and 30% (w/v), respectively (Table 1).

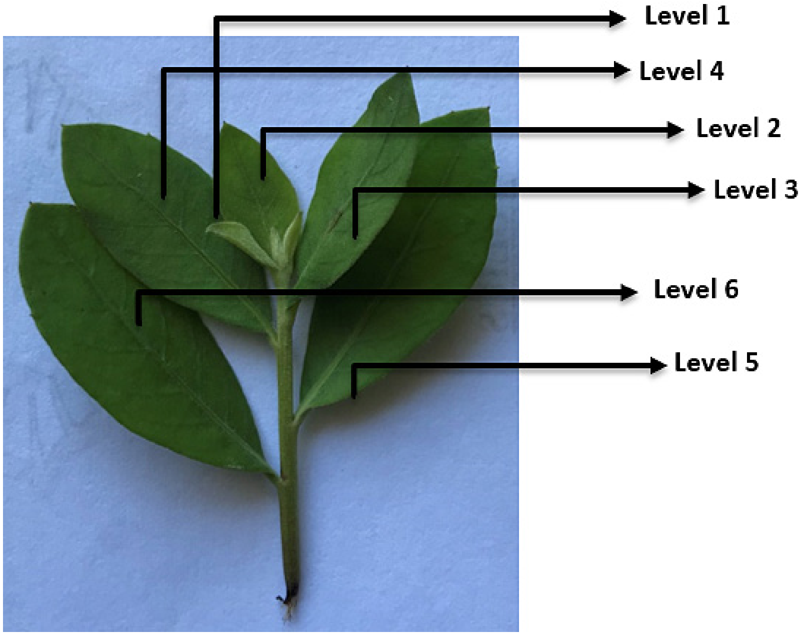

Fig. 1: Young Pluchea indica Less leaves

Table 1: Information of hot water extract of pluchea tea

Materials	Concentration of hot water extract of pluchea leaf tea (% w/v)						
	0	5	10	15	20	25	30
Pluchea leaf tea (g)	0	10	20	30	40	50	60
Hot water (mL)	200	200	200	200	200	200	200

Wet Noodles Processing

About 70 mL of hot extract from pluchea leaf powder with concentrations of 0, 5, 10, 15, 20, 25 and 30% (w/v) (Table 1) was manually mixed with egg, baking powder, salt and wheat flour for 5 min (Table 2). The mixture was kneaded to form a solid and homogenized dough using a mixer (Oxone Stand Mixer OX-855) for about 10-15 min. Furthermore, the dough was extruded to form noodle strands (Oxone Noodle Machile OX 355). The wet noodle strands were parboiled in boiled water about 3 min in 300 mL water and coated with oil to prevent the noodles from sticking to each other.[26,27,28] Wet noodles made without any addition of hot water of pluchea leaf extract were prepared as control. Wet noodles used in bioactive compounds and antioxidant activity assay were not added with oil to prevent the noodles from sticking to one another.

The final characteristics of wet noodles have width and thickness of 0.45 cm and 0.30 cm, respectively.

Table 2: Ingredients of pluchea wet noodles

Materials	Unit	Quantity
Wheat flour	g	200
Egg	g	40
Salt	g	4
Baking powder	g	2
Hot water extract	mL	70
Tapioca flour	g	10
TOTAL	g	326

Pluchea Wet Noodles Extraction

About 100 g of wet noodles were dried using a freeze-dryer at a pressure of 0.1 bar and temperature -60°C for 28 hours. Dried noodles were powdered using a chopper machine for 35 seconds. And then, 20 g of samples were mixed by 50 mL absolute methanol by a shaking water-bath at 35°C, 70 rpm for 1 hour.[29] Filtrate was separated using Whatman filter paper grade 40 and residue was extracted again with the same procedure. The filtrate was collected and evaporated by rotary evaporator until getting 3 mL of extract (Buchi Rotary Evaporator, Buchi Shanghai Ltd, China) at 200 bars, 50°C for 60 min. The extract was kept at 0°C before further analysis.

Moisture Content Assay

Moisture or water content of wet noodles was determined by thermos-gravimetric method.[30] The moisture content of wet noodles was determined by heating the samples in a drying oven (Binder, Merck KGaA, Darmstadt, Germany) and weighing the evaporated water content in the material.

Measurement of Swelling Index

The purpose of swelling index testing was to determine the capability of the noodles to swell during the boiling process.[16] The assay was done to determine the ability of wet noodles to absorb water per unit of time or the time needed to fully cooked wet noodles. The amount of water absorbed by wet noodles was measured from the weight before and after boiling.

Determination of Cooking Loss

Cooking loss is one of the necessary quality parameters to establish the quality of wet noodles after boiling.[31] The cooking loss assay was done by measuring the quantity of solids that leached out of the noodles during the boiling process, e.g., starch. A large cooking loss value affects the texture of wet noodles, which is easy to break and less slippery.

Determination of Texture

The texture of pluchea wet noodles was measured based on hardness, adhesiveness, cohesiveness, elongation and elasticity. The texture was analyzed by TA-XT2 texture analyzer (Stable Micro System Co., Ltd., Surrey, UK) fitted with a 5 kg load cell equipped with the Texture Exponent 32 software V.4.0.5.0 (SMS). The hardness, adhesiveness and cohesiveness were analyzed with a compression assay using 2 mm s^{-1} test speed and 75% strain. Five long noodle strands with the length of 4 cm for each strand were laid side by side, touching each other, perpendicular to the 35 mm compression cylinder probe on a flat aluminum base. The cylinder probe was arranged to be at 15 mm distance from the lower plate at the start of the compression test, and was pressed down through the noodle strips at the speed of 2 mm s^{-1} until it touched the flat base to compress 75% of the noodle thickness, and was drawn back to at the end of the test. The profile curve was determined using a texture analyzer software.[24,32] The hardness was determined as the maximum force per gram. The adhesiveness was evaluated when the probe was drawn at the end of the test, a negative area was obtained from the compression test under the curve. Cohesiveness was analyzed based on the ratio between the area under the first and the second peaks[24,32,33] The elongation and elasticity of the noodles were individually tested by putting one end into the lower roller arm slot and sufficiently winding the loosened arm to fasten the noodle end. Elongation was the maximum force to change of noodle form and break by extension that was analyzed by a test speed of 3.0 mm s^{-1} between two rollers with a 100 mm distance. The elongation at breaking was calculated per gram. Elasticity was determined by formula (1)[34,35]

$$\text{Elasticity} = (F x\ lo)/(A x\ to)\ \ 1/v \qquad ...(1)$$

where F is the tensile strength, lo is the original length of the noodles between the limit arms (mm), A is the original cross-sectional area of the noodle (mm^2), v is the rate of movement of the upper arm (mm/s), and t is break up time of the noodles (s). The measurement of texture was detected by the software and expressed as a graph.

Color Measurement

The color of the noodle sheets was determined by a colorimeter (Minolta CR 10, Minolta Co. Ltd., Osaka, Japan), and the CIE-Lab L*, a* and b* values were analyzed based on the method by Fadzil *et al.*[32] The L* value measured the position on the white/black axis, the a* value as the position on the red/green axis, and the b* value as the position on the yellow/blue axis.

Analysis of Total Phenolic Content

The total phenolic content analysis was analyzed based on the reaction between phenolic compounds and Folin Ciocalteu (FC) reagent or phosphomolybdic acid and phosphotungstic acid. The FC reagent oxidizes phenolics (alkali salts) or phenolic-hydroxy groups to become a blue molybdenum- tungsten complex solution.[36] The intensity of the blue color was detected by a UV-Vis spectrophotometer (Spectrophotometer UV-Vis 1800, Shimadzu, Japan) at λ 760 nm. In the analysis, 7.5% Na_2CO_3 solution was added to reach pH 10 that caused an electron transfer reaction (redox). The obtained data were expressed in mg of gallic acid equivalent (CE)/L sample.

Analysis of Total Flavonoid Content

The flavonoid content assay was done using the spectrophotometric method based on the reaction between flavonoids and $AlCl_3$ to form a yellow complex solution. In the presence of NaOH solution, a pink color is formed which can be detected by spectrophotometer (Spectrophotometer UV-Vis 1800, Shimadzu, Japan) at λ510 nm.[36,37,38] The obtained data were expressed in mg of catechin equivalent (CE)/L sample.

Analysis of DPPH Free Radical Scavenging Activity

The ability of antioxidant compounds to scavenge DPPH (2,2-diphenyl-1-picrylhydrazyl) free radicals can be used to evaluate antioxidant activity. The principle of the DPPH method is to measure the absorbance of compounds that can react with DPPH radicals.[39] Antioxidant compounds can donate hydrogen atoms to DPPH radicals that caused the purple DPPH to be reduced to yellow.[40] The color change was measured as an absorbance at λ517 nm by spectrophotometer (Spectrophotometer UV Vis 1800, Shimadzu, Japan).[41] The data were expressed in mg gallic acid equivalent (GAE)/L dried noodles sample.

Analysis of Iron Ion Reduction Power

This method identifies the capacity of antioxidant components using potassium ferricyanide, trichloroacetic acid and ferric chloride to produce color complexes that can be measured spectrophotometrically (Spectrophotometric UV-Vis 1800, Shimadzu, Japan) at λ 700 nm.[42] The principle of this testing is the ability antioxidants to reduce iron ions from $K_3Fe(CN)_6$ (Fe^{3+}) to $K_4Fe(CN)_6$ (Fe^{2+}). Then, potassium ferrocyanide reacts with $FeCl_3$ to form a $Fe_4[Fe(CN)_6]_3$ complex. The color change is from yellow to green.[43] The final data were expressed in mg gallic acid equivalent (GAE)/L dried noodles.

Sensory Evaluation

The hedonic test of all samples of wet noodles involved 100 untrained panelists with an age range of 17 to 25 years old, because they are students in food technology department that who have received provision about hedonic food preference test. All panelist supplied informed consent before the examination. A hedonic test used in this research was the hedonic scoring method, where the panelists gave a preference score value of all samples.[26] The hedonic scores were transformed to numeric scale and analyzed using statistical analysis.[44] The numeric scale in the sensory analysis used a 9-point hedonic scale ranging from 1 (extremely disliked) to 9 (extremely liked). The panelists were asked to score according to their level of preference for texture, taste, color, flavor and overall acceptability. All the samples were blind coded with 3 digits which differed from each other.[45]

Statistical Analysis

The research design used in the physicochemical assay was a randomized block design (RBD) with a single factor, i.e., differences in the concentration of the hot extract of pluchea leaf tea that consisted of seven levels, i.e., 0, 5, 10, 15, 20, 25 and 30% (w/v). Each treatment was repeated four times that obtained 28 experiment units. A completely randomized design (CRD) was used to evaluate sensory assay with 100 untrained panelists with an aged 17 to 25 years old.

The normal distribution and homogeneity data were stated as the mean ± SD of the triplicate determinations and determined using ANOVA at p ≤ 5% using SPSS 17.0 software (SPSS Inc., Chicago, IL, USA). Any significant effect of factors by ANOVA test was followed with the DMRT (Duncan Multiple Range Test) at p ≤ 5% to determine treatment level that gave significant different results. The best treatment of pluchea extract addition on wet noodles was analyzed by a spider web graph.

Results and Discussion

Wet noodles added with hot extract of pluchea leaf powder were produced to increase the functional values of wet noodles. This is supported by previous studies related to the potential values of water extract of pluchea leaf that exhibits biological activities.[6,7,26] In this research, the cooking quality was observed after cooking wet noodles in 300 mL water/100 g samples for 3 min in boiling water.

Table 3: Color, moisture content, swelling index, and cooking loss of pluchea wet noodles.

Concentration of hot extract from pluchea leaf powder (% w/v)	Color					Moisture content (% wb)	Swelling index (%)	Cooking loss (%)
	L*	a*	b*	C	h			
0	67.14 ± 1.77^{a}	0.97±0.30	16.18±0.62^{ab}	16.20 ± 0.63	86.47 ± 1.04	63.90±1.51	56.22±17.36	3.40±1.31
5	59.49 ± 2.67^{b}	2.18±0.93	15.47±1.46^{a}	15.62 ± 1.53	82.12 ± 3.05	65.08±4.33	62.40± 4.71	3.33±1.26
10	58.95 ± 1.80^{b}	1.95±1.66	16.76±2.33a^{bc}	17.08 ± 2.16	83.29 ± 5.37	64.97±3.89	61.50± 7.51	3.00±1.16
15	58.35 ± 2.24^{b}	1.69±1.48	19.72±3.50^{c}	19.77 ± 3.38	84.67 ± 4.64	65.56±2.18	63.09± 6.31	3.31±0.92
20	56.48 ± 2.40^{b}	1.97±1.24	19.09±2.97^{bc}	19.18 ±2.90	83.62 ± 4.33	66.81±1.81	67.74± 5.91	4.06±0.51
25	59.07 ± 2.49^{b}	1.95±1.44	19.55±2.97^{c}	19.58 ± 2.90	83.83 ± 4.41	66.04±0.85	64.46±10.32	3.93±1.37
30	57.10 ± 2.06^{b}	2.09±1.51	18.08±4.94^{abc}	18.28 ± 4.84	82.49 ± 5.22	66.65±2.16	63.96± 5.31	4.23±1.34

Note the results were presented as SD of the means that were achieved by quadruplicate.
Means with different superscripts (alphabets) in the same colum are significantly different, p≤5%

Table 4: Texture of pluchea wet noodles.

Concentration of hot extract from pluchea leaf powder (% w/v)	Texture of pluchea wet noodles				
	Hardness (N)	Adhesiveness (g sec)	Cohesiveness	Elongation (%)	Elasticity (Pa)
0	135.75±5.91^{a}	-2.67 ±0.30^{d}	0.65±0.01^{a}	86.89±0.90^{a}	25336.72±104.20^{a}
5	120.13±2.05^{a}	-3.36±0.60^{cd}	0.68±0.00^{b}	97.25±1.59^{b}	25898.27±760.94^{b}
10	134.85±1.77^{a}	-3.91±0.65^{bc}	0.74±0.00^{c}	162.10±1.49^{c}	25807.73±761.85^{b}
15	180.48±5.06^{b}	-4.91±0.47^{b}	0.74±0.01^{c}	164.74±0.60^{c}	26971.61±516.71^{b}
20	195.11±14.14^{b}	-4.95±1.26^{ab}	0.75±0.01^{cd}	221.60±1.55^{d}	2a7474.38±453.80^{b}
25	244.57±8.81^{c}	-6.03±0.29^{a}	0.75±0.00^{cd}	230.65±0.73^{e}	27367.05±287.48^{b}
30	282.79±28.31^{d}	-6.05±0.22^{a}	0.79±0.01^{d}	255.38±0.36^{f}	26687.52±449.19^{b}

Note: the results were presented as SD of the means that were achieved by quadruplicate.
Means with different superscripts (alphabets) in the same column are significantly different, p≤5%

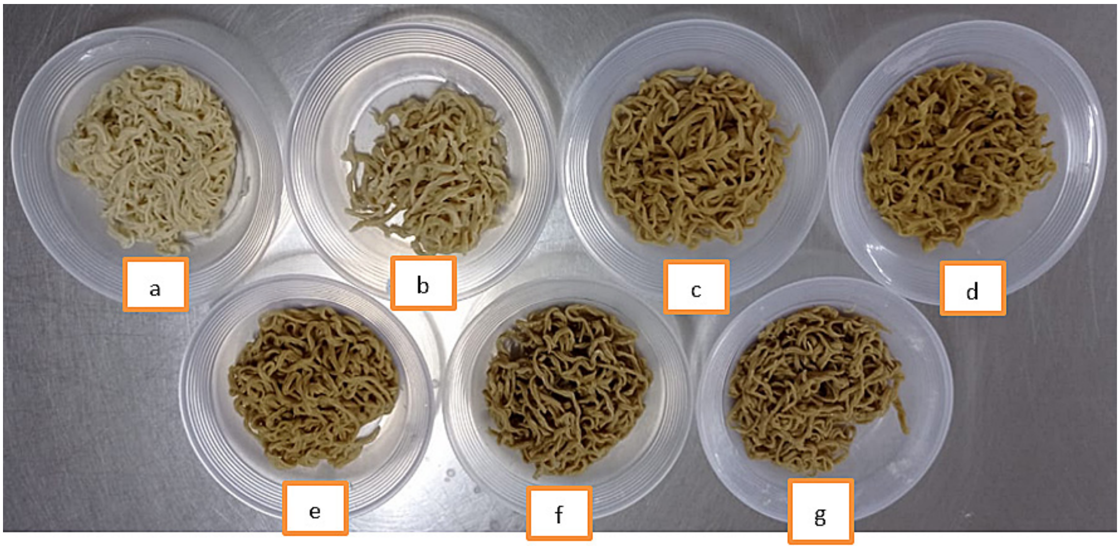

Fig. 2: Wet noodles with hot water extract of pluchea leaf powder added at concentrations a. 0%; b. 5%; c. 10%; d. 15%; e. 20%; f. 25%; and g. 30% w/v

Cooking Quality

Cooking quality of wet noodles added with hot water extract from pluchea leaf powder at 0, 5, 10, 15, 20, 25 and 30% (w/v) was shown in Figure 2, Table 3 and Table 4. The addition of pluchea extract no significantly influenced the water content, cooking loss, swelling index, chroma, and hue of the produced wet noodles using statistical analysis by ANOVA at $p \leq 5\%$. Water content is one of the chemical properties of a food product determined shelf life of food products, because the water content measures the free and weakly bound water in foodstuffs.[46,47] This study identified that the moisture content of the cooked wet noodles ranged between 64-67% wb. Previous study showed that the water content of the cooked egg wet noodles was around 54-58% wb47 and maximum of 65%.[20] Chairuni *et al.* [46] stated that the boiling process could cause a change in moisture content from about 35% to about 52%. The Indonesian National Standard[48] stipulates that the moisture content of cooked wet noodles is a maximum of 65%. This means that only control noodles (without treatment) exhibited a moisture content similar to the previous information. The obtained data showed a trend that an extract addition caused an increase in the water content of wet noodles, but statistical analysis at $p \leq 5\%$ showed no significant difference. This phenomenon was in accordance with the experimental results of Juliana *et al.*[49] that the using of spenochlea leaf extract for making wet noodles, as well as Hasmawati *et al.*[20] that the sweet potato leaf extract increased the moisture of fresh noodles. The water content of pluchea wet noodles was expected by reaction between many components in the dough that impacted to the swelling index and cooking loss. Mualim *et al.,*[14] Bilina *et al.*[22] and Setiyoko *et al.*[31] reported that the presence of amino in protein and hydroxyl groups in amylose and amylopectin fractions in wheat flour as raw material for making dough determines the moisture content, swelling index and cooking loss of wet noodles. The contribution of glutelin and gliadin proteins in wheat flour to form gluten networks determines the capability of noodles to swell and retain water in the system. Gliadin acts as an adhesive that causes dough to be elastic, while glutenin makes the dough to be firm and able to withstand CO_2 gas thus, the dough can expand and form pores. Fadzil *et al.*[32] found that thermal treatment during the boiling process results in the denaturation of gluten and causes a monomer of proteins to determine other reactions at the disulfide or sulfhydryl chain. The existence of phenolic compounds from pluchea extract also increased the capacity of noodles to absorb water and determined water mobility. Widyawati *et al.*[26] confirmed that hydrophilic compounds of proteins, carbohydrates, and polyphenolic components determine water mobility due to their ability to bind with water molecules through hydrogen bonding.

Tuhumury *et al.*[50] informed that gluten formation can inhibit water absorption by starch granules so that can prevent gelatinization. Therefore, the addition of phenolic compounds from the hot extract of pluchea leaf powder can inhibit the formation of gluten so that stimulates gelatinization of starch granules.

As a result, the impact of increased the moisture content during boiling had an effect on the value of the swelling index and cooking loss of the wet noodles. Widyawati *et al.*[26] claimed that the swelling index is the capability to trap water which is dependent on the chemical composition, particle size, and water content. Gull *et al.*[51] further confirmed that the swelling index is an indicator to determine water absorption by starch and protein to make gelatinization and hydration. Setiyoko *et al.*[31] explained that cooking loss is the mass of noodle solids that come out of the noodle strands for boiling. Gull *et al.*[51] added that soluble starch and other soluble components leach out into the water during the cooking process, making the cooking water turned thicker. The moisture content results (64-67% wb) showed that the produced wet noodles exceeded the moisture content limit of wet noodles after cooking, which is between 54-58%,[46] while the cooking loss value of wet noodles should not be more than 10%.[31] In this study, the cooking loss value was 3-4.2%. The cooking loss of samples during boiling noodles were caused the breaking of the bonding network that the polysaccharides are released and the gluten network breaks because of the addition of pluchea leaf extract. Widyawati *et al.*[26] supported that polyphenol can be bound with protein and starch with many non-covalent interactions, such as hydrogen bonding, electrostatic interaction, hydrophobic interaction, Van der Waal's interaction, and π-π stacking. This interaction can inhibit amylose and amylopectin from starch to undergo gelatinization and gliadin and glutelin from the protein of wheat flour to form gluten.

The swelling index value derived from this research was about 56-68 %. Based on the previous research, the swelling index of egg wet noodles incorporated with angkung (*Basella alba* L.) fruit was around 51%.[51] This means that the addition of pluchea leaf extract in wet noodles also affects the ability of noodles to absorb water. Widyawati *et al.*[26] and Suriyaphan[6] noted that bioactive compounds in hot water extract of pluchea leaf tea include 3-O-caffeoylquinic acid, 4-O-caffeoylquinic acid, 5-O-caffeoylquinic acid, 3,4-O-dicaffeoylquinic acid, 3,5-O-dicaffeoylquinic acid, 4,5-O-dicaffeoylquinic acid, chlorogenic acid, caffeic acid, quercetin, kaempferol, myricetin, total anthocyanins, β-carotene, and total carotenoids. The swelling index of pluchea wet noodles was higher than the addition of angkung fruit extract, due to the involvement of hydroxyl groups from extract in absorbing water, in inhibiting the formation of gluten and in increasing the ability of starch granules to absorb water so that the swelling index and cooking loss increased. Suriyaphan6 informed that hot extract of pluchea leaf tea contains 1.79 g/100 g protein, 8.65 g/100 g carbohydrate, and fiber (0.45 g/100 g soluble and 0.89 g/100 g insoluble), these compounds can involve in increasing the swelling index from pluchea wet noodles.

Color is one of the physical characteristics possessed by wet noodles that becomes a benchmark for consumer acceptance. This research found that the color of wet noodles was influenced by the addition of pluchea extract. The addition of pluchea leaf extract no significant affected the redness (a*), chroma (C), and hue (ºh) of the wet noodles, but it influenced the yellowness (b*) and lightness (L*) values. Using of pluchea leaf powder brewing decreased the brightness of wet noodles significantly, as the concentration of the extract increased. This is related to the bioactive compounds of pluchea leaves, especially tannins, carotenoids, and flavonoids that cause the wet noodles to experience color changes. According to Widyawati *et al.*[8] tannins are water-soluble compounds that can give a brown color. Suriyaphan[6] and Widyawati *et al.*[26] also stated that Khlu tea from pluchea leaves contained β-carotene, total carotenoids, and total flavonoids of 1.70 ± 0.05, 8.74 ± 0.34, and 6.39 mg/100 g fresh weight, respectively. This pigment is a water-soluble pigment that gives a yellow color. Gull *et al.*51 stated that this pigment was easily changed in the paste sample due to the swelling and discoloration of the pigment during cooking.

Thus, the addition of hot water extract of pluchea leaf powder significantly reduced the brightness of wet noodles, because brown-colored noodles were produced as the concentrations of added pluchea leaf extract increased. However, increasing the concentration of this extract had no influenced on the redness, hue, and chroma values in ANOVA at p ≤ 5%. The results showed that the redness value of wet noodles revolved from 0.97 ± 0.30 to 2.18 ± 0.93, whereas the hue value of wet noodles ranged from 82.12 ± 3.05 to 86.47 ± 1.04. Based on this value, the color of wet noodles is in the yellow to the red color range,[53] thus the visible color of the wet noodle product was yellow to brown (Figure 2). Yellowness increased significantly with the addition of pluchea leaf extract and the value ranged from 16.18 ± 0.62 to 19.72 ± 3.50. This was due to the availability of tannins and chlorophyll compounds from pluchea leaf extract. The chroma value of wet noodles was obtained within the range of 15.6 ± 1.5 to 19.8 ± 3.4. This means that the brewing of pluchea leaf powder did not change the intensity of the brown color in the resulting wet noodles.

Texture analysis of pluchea wet noodles added with various concentrations of hot water extract from pluchea leaf powder was showed at Table 4, including hardness, adhesiveness, cohesiveness, elongation, and elasticity. Hardness is the maximum force given to a product until deformation.[54,55] From the texture analyzer graph, hardness is measured from the highest height of the peak. The higher peak of graph shows the harder product.[32] Adhesiveness is force or tackiness that is required to pull the product from its surface, its value is obtained from the area between the first and second compressions.[56,57] Adhesiveness values show negative value, the bigger negative value means the product is stickier. Cohesiveness or compactness is the ratio of the positive force area to the first and second compressions,[55,57] This is an indication of the internal forces that make up the product.[58] Elongation is the change in length of noodles when being exposed to a tensile force until the noodles break.[59] Elasticity is the time required for the product to withstand the load until it breaks. The more elastic a product, the longer the holding time. The data showed that the higher concentration of pluchea leaf powder within the hot water extract caused a significant increase in the hardness, stickiness, compactness, elasticity, and elongation of the resulting wet noodles. Widyawati *et al.*[26] informed that the polyphenols contained in pluchea leaf extract can be weakly interacted either covalently or non-covalently (hydrogen bonds, van der Waals forces, and hydrophobic interactions) with starch and protein. Phenolic compounds can be dissolved in water because they have several hydroxyl groups that are polar. Amoako and Akiwa[60] and Zhu *et al.*[61] have also proven that polyphenolic compounds can be interacted with carbohydrates through the interaction of two hydrophobic and hydrophilic functional groups with amylose. Diez-Sánchez *et al.*[62] stated that polyphenolic compounds can be reacted with amylose and protein helical structures and largely determined by molecular weight, conformational mobility, and flexibility, as well as by the relationship between hydrogen donor/acceptor groups in protein, amylose, and polyphenols. The interactions between polyphenolic compounds, amylose and amylopectin can affect the gelatinization process in the amylose helical structure and interfere with the interaction between gliadin, glutenin, and water to form gluten, so that the distance of the network that functions to trap water and gas decreases. This phenomenon is in line with the trend of moisture content, swelling index and cooking losses. As a result, the wet noodles' texture increased. Based on the high cooking loss (> 98%) and swelling index (56.2 to 67.7%) data, it can be concluded that the interaction that occurs between the phenol group in pluchea leaf extract with amylose and protein was weak. The bioactive components of pluchea leaf extract are thought to affect the formation of disulfide cross-links (S-S) and turn into to form sulfhydryl groups (-SH) under the influence of heat. Ananingsih and Zhou[63] said that antioxidant compounds are a reducing agent that can have an impact on reducing S-S bonds and increasing the number of SH groups in the dough to produce a harder texture. According to Rahardjo *et al.*[56] phenolic compounds are hydroxyl compounds that influence the strength of the dough, where the higher the component of phenol compounds will weaken the gluten matrix and the dough thus becoming unstable. The instability of the dough can cause the texture to become hard.

Many researchers also find that tannins and phenols influence the networking S-S bond in the dough of wet noodles. Wang *et al.*[64] showed that tannins increase the relative amount of large, medium polymers in the gluten protein network so as to improve the dough quality. Zhang *et al.*[65] claimed that these polymer compounds are the results of interactions or combinations of protein-tannin compounds that form bonds with the type of covalent, hydrogen, or ionic bonds. Rauf and Andini66 also added that phenol compounds can reduce S-S bonds to SH bonds. SH is a type of thiol compound group, where the thiol group can influence the stickiness, viscosity, cohesiveness, elongation, and extensibility of the dough. Wang *et al.*[67] discovered the effect of phenolic compounds from green tea extract to increase the stickiness of wheat bread. The cohesiveness of the dough is formed due to a large number of thiol bonds formed, thus increasing the viscosity of the dough. The increased viscosity of the dough is thought to be due to the formation of polyphenolic compounds with thiol groups, as in the research of Ananingsih and Zhou[63] that the formation of catechin-thiol can increase the viscosity of the dough and the stability of the dough. Zhu *et al.*[68] mentioned that the addition of phenolic compounds from green tea was able to increase the PV (peak viscosity) of wheat flour. Wang *et al.*64 also found that the cohesiveness of the dough is influenced by tannins, where tannins can produce micro-glutens so as to produce a compact dough and increase the gluten network. The addition of pluchea leaf extract in making wet noodles could influence the elongation of wet noodles due to the components of polyphenol compounds such as tannins that can reduce the number of free amino groups. This is supported by Zhang *et al.*[32] and Wang *et al.*[64] that the formation of other types of covalent bonds, such as bonds between amino and hydroxyl groups, by forming hydrogen bonds between phenolic compounds and protein gluten so as to improve the quality of dough strength and dough extensibility.

Table 5: Total phenol content, total flavonoid content, the DPPH free radical scavenging activity, and iron ion reducing power of the pluchea wet noodles.

Concentration of Hot Extract from Pluchea Leaf Powder (% w/v)	TPC (mg GAE/kg Dried Noodles)	TFC (mg CE/kg Dried Noodles)	DPPH (mg GAE/kg Dried Noodles)	FRAP (mg GAE/kg Dried noodles)
0	39.26±0.66[a]	32.36±1.47[a]	96.75±4.26[a]	25.96±0.25[a]
5	61.09±3.80[b]	46.31±2.15[b]	121.36±3.58[b]	34.50±1.71[b]
10	82.84±3.11[c]	62.44±0.55[c]	130.68±4.82[c]	51.33±2.19[c]
15	101.48±2.16[d]	84.67±1.22[d]	142.48±2.14[d]	58.69±2.14[d]
20	114.94±4.20[e]	100.14±1.50[e]	148.84±3.20[e]	67.26±0.06[e]
25	128.06±1.38[f]	107.93±0.89[f]	157.51±7.69[f]	69.53±1.06[f]
30	136.35±1.16[g]	131.69±1.56[g]	166.97±1.53[g]	84.98±0.11[g]

Note the results were presented as SD of the means that were achieved by quadruplicate.
Means with different superscripts (alphabets) in the same column are significantly different, p ≤ 5%.

Bioactive Compounds and Antioxidant Activity
Wet noodles added with pluchea leaf powder were analyzed based on its bioactive compounds and antioxidant activities. The analysis was conducted to determine the functional properties of wet noodles. Data analysis of the bioactive compound contents and antioxidant activity of wet noodles were presented in Table 5. The measured bioactive compounds (BC) involved total phenolic content (TPC) and total flavonoid content (TFC) and antioxidant activity (AA), including DPPH free radical scavenging activity/DPPH and iron ion reducing power/FRAP). The higher the concentration of the added pluchea leaf powder extract, the higher the BC and AA of wet noodles. Statistical analysis at p ≤ 5% showed that the addition of pluchea extract had a significant effect on BC and AA wet noodles. There was a tendency for the increase in BC in line with the increase in AA. Pearson correlation (PC) test showed that there was a positive and strong correlation between TPC and DPPH (r = 0.990), TPC and FRAP (r = 0.986), TFC and DPPH

(r = 0.974), and TFC and FRAP (r = 0.991). This means that the antioxidant activity of wet pluchea noodles was strongly influenced by TPC and TFC. Muflihah *et al.*[69] informed that the PC (r) > 0.699 indicates the strength and linear correlation between antioxidant activity (AA) and TPC, and also shows a strong positive relationship but PC (r) < 0.699 obtains a moderately positive relationship. If the r value of TFC and AA is lower than TPC and AA, it indicates that the contribution of TPC to AA is greater than TFC to AA. PC is lower than 1 and there are other components that affect AA. The PC of TPC and TFC is r > 0.913 showing a strong positive relationship which is expected because both classes contributed to AA plants. Aryal *et al.*[70] and Muflihah *et al.*[69] informed that phenolic compounds are soluble natural antioxidants and potential donating electrons depend on their number and position of hydroxyl groups contributed to antioxidant action. Consequently, these groups are responsible to scavenge the free radicals which is expressed as TPC of pluchea wet noodles. DPPH free radical can accept electrons from phenolic compounds to change the stable purple-colored to the yellow-colored solution. Based on FRAP analysis, it was showed that the bioactive compounds contained in pluchea wet noodles were a potential source of antioxidants because they can transform Fe^{3+}/ferricyanide complex to Fe^{2+}/ferrous. Therefore, the bioactive compounds in pluchea wet noodles can function as primary and secondary antioxidants. Research data showed that the cooking quality of wet noodles tends to increase along with the increase in the values of TPC, TFC, DPPH and FRAP.

Sensory Evaluation

Sensory assay of pluchea wet noodles, namely color, aroma, taste, texture, and overall acceptance, was carried out using a hedonic test to determine the level of consumer preference for the product. This test was conducted to determine the quality differences between the products and to provide an assessment on certain properties.[44] The hedonic test is the most widely used assessment to determine the level of preference for product.[71] The results of the sensory evaluation of pluchea wet noodles were presented in Table 6.

Table 6: Effect of hot water extract from pluchea leaf powder to preferences for color, aroma, taste, texture, and overall acceptance of wet noodles at various concentrations

Concentration of Hot Extract from Pluchea Leaf Powder (% w/v)	Hedonic Score				
	Color	Aroma	Taste	Texture	Overall acceptance
0	6.19±1.25[d]	5.52±1.08	5.50±1.18[c]	6.20±1.13[b]	6.63±1.49[c]
5	5.62±1.28[c]	5.52±0.83	5.51±1.29[c]	6.37±1.14[bc]	6.40±1.52[c]
10	5.62±1.21[c]	5.45±0.85	5.46±1.12[c]	6.53±1.14[c]	6.53±1.64[c]
15	5.14±1.25[b]	4.81±1.04	4.61±1.11[b]	6.13±1.09[b]	5.78±1.67[b]
20	4.91±1.32[b]	4.54±1.18	4.47±1.15[ab]	5.80±1.06[a]	5.17±1.70[a]
25	4.54±1.40[a]	4.26±1.23	4.20±1.24[a]	5.50±1.04[a]	5.23±1.75[a]
30	4.47±1.33[a]	4.05±1.34	4.15±1.40[a]	5.59±1.05[a]	5.37±1.91[a]

Note the results were presented as SD of the means that were achieved by quadruplicate. Means with different superscripts (alphabets) in the same column are significantly different, p ≤ 5%.

The results of the sensory evaluation for color preference ranged from 4.47 ± 1.33 to 6.19 ± 1.26 (neutral-like). The statistical analysis showed that the higher concentration of hot water extract addition decreased lower color preference of wet noodles. The higher concentration of pluchea extract could reduce the level of color preference because the color of the wet noodles was darker than control and turned to dark brown. This color change was due to the pluchea extract containing several components, including chlorophyll and tannins, which can alter the of wet noodles' color to be browner along with the increase in the concentration of pluchea extract. This result was in accordance to the effect of color analysis performed using color reader where the pluchea wet noodles' brightness declined, yellowness increased, and the color intensity increased with an increased concentration of pluchea extract. The occurrence of this process is related to the effect of light and heat on pluchea leaf powder which causes the degradation of chlorophyll into brown pheophytin due to drying, where the nature of chlorophyll itself is sensitive to light, heat, oxygen, and chemicals.[72,73]

Aroma is one of the parameters in sensory evaluation using the sense of smell and an indicator of the assessment of a product.[74] The results of the preference values for aroma were ranged from 4.05 ± 1.34 to 5.52 ± 1.23 (neutral-slightly like). Higher concentration of pluchea extract in wet noodles reduced the preference score for aroma due to distinct dry leaves (green) aroma. According to Lee *et al.*[75] the unpleasant aroma on leaves comes from a group of aliphatic aldehyde compounds. The appearance of a distinctive leaf aroma in noodles is due to aromatic compounds. According to Martiyanti and Vita[76] aromatic compounds are chemical compounds that have an aroma or odor when the conditions are met, which is volatile, while Widyawati *et al.*[77] informed that pluchea leaves were detected to have 66 volatile compounds. The appearance of the aroma is due to the volatile compounds in the raw material reacting with water vapor when boiling the noodles. In addition, there is also an oxidation process of polyphenolic compounds such as catechins or tannins that can produce an aroma in pluchea wet noodles.

According to Martiyanti and Vita[3] taste attribute is one important sensory aspect in food products and has a great impact on the food selection by consumers. Tongue is able to detect basic tastes, such as sweet, salty, sour, and bitter, at different points. Lamusu[73] declared that taste is a component of flavor and an important criterion in assessing a product that is accepted by the tongue. The preference test of the taste of pluchea wet noodles resulted in values ranging from 4.15 ± 1.40 to 5.50 ± 1.28 (neutral-slightly like). The increase in concentrations of pluchea extract was negatively correlated to the preference level of the taste of pluchea wet noodles assessed by the panelists. The statistical analysis results showed that the difference in the concentration of the extract significant influenced on the preference score for the taste of pluchea wet noodles. The increased concentration of pluchea extract produced a distinctive taste on wet noodles, such as a bitter and astringent tastes, due to the presence of compounds such as tannins and alkaloids from the pluchea leaves. Susetyarini[78] said that pluchea leaves contain tannins (2.35%), and alkaloids (0.32%). According to Pertiwi[79] tannin compounds dominate the bitter and astringent taste, while alkaloid compounds cause a bitter taste. The high level of taste preference for wet noodles was found in noodles with lower content of pluchea extract.

Texture is a sensation of pressure that can be observed by mouth (when bitten, chewed, and swallowed) or touched with fingers.[80] Texture testing performed by the panelist is called mouthfeel testing. According to Martiyanti and Vita,[76] mouthfeel is the kinesthetic effect of chewing food in the mouth. In this study, the preference test results on the texture of pluchea wet noodles revolved from 5.50 ± 1.04 to 6.53 ± 1.13 (rather like). The higher concentration of pluchea extract resulted in chewy and hard wet noodles, which reduced the panelists' preference level. Changes in the texture of wet noodles are influenced by polyphenolic compounds' contents, as well as several processing steps that can determine textures of wet noodles, such as mixing ingredients, developing dough, boiling, and draining noodles. Subjective testing results based on sensory evaluation were in line with the objective testing the texture analyzer. The noodles' texture that was getting harder, sticky, compact, not easy to break, and tough were not preferred by the panelists. Therefore, mentioned final texture of pluchea wet noodles was influenced by the fiber and protein components. According to Shabrina,[81] the components of fiber, protein, and starch complete to bind water. Texture changes are also influenced by the polyphenol compositions in the pluchea extract which is able to reduce S-S bonds to SH bonds, where the increase in SH (thiol) groups can cause a hard, sticky, and compact texture.[64,66,67] Besides, a high concentration of tannins capable of binding to proteins to form complex compounds into tannins-proteins are also able to build noodles' texture.

The interaction between color, aroma, taste, and texture created an overall taste of the food product and was assessed as the overall preference. The highest value on the overall preference was derived from control wet noodles, i.e., 6.63 (slightly like it), while the wet noodles added with 20% (w/v) concentration of pluchea extract had a low overall preference i.e., 5.17 (neutral-rather like). The addition of pluchea extract at 0% (w/v) concentration produced an overall preference value closed to 10% (w/v) concentration with scores of 6.63 and 6.53, respectively. The area of the spider web chart for each treatment with the various concentrations of pluchea extract was seen in Figure 3. The best treatment of the wet noodles was the addition of 10% (w/v) of pluchea extract with an area of 66.37 cm^2 based on an average sensory value of color, aroma, taste, texture, and overall acceptance with the scores of 5.62 (slightly like), 5.45 (slightly like), 5.46 (somewhat like), 6.53 (like), and 6.53 (like), respectively.

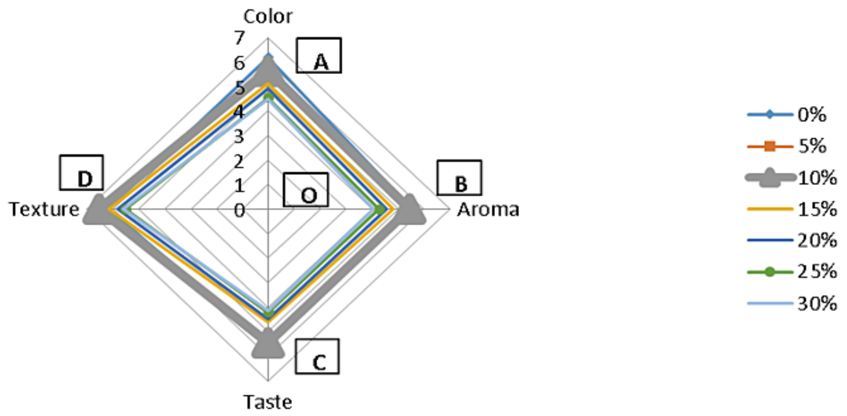

Fig. 3: Spider web graph of sensory evaluation on wet noodles at various concentrations of hot water extract from pluchea leaf powder

The use of pluchea leaf extract in the making of wet noodles was able to increase the functional values of wet noodles, based on the levels of bioactive compounds and antioxidant activity without changing the quality of cooking, which included water content, swelling index and cooking loss. Besides that, the use of pluchea leaf extract did not significantly change the color and color intensity of the resulting wet noodles, only slightly decreased the brightness level of the noodles. However, the wet noodles produced were still acceptable to the panelists, the addition of pluchea leaf extract as much as 10% (w/v) was the best treatment with an assessment that was almost closed to the control wet noodles (without treatment).

Conclusion

Addition of hot water extract of pluchea leaf powder influenced physical, chemical and sensory properties of wet noodles. Lightness, texture, bioactive compound content, antioxidant activity, and sensory properties of samples underwent significant difference. The higher concentration of pluchea extract caused the bigger these parameters of pluchea wet noodles. Using 10% (w/v) of hot water extract from pluchea leaf powder was the best treatment with color, aroma, taste, and texture scores 5.62 (slightly like), 5.45 (slightly like), 5.46 (somewhat like), and 6.53 (like), respectively. Utilization of hot water extract of pluchea leaf powder at 10% (w/v) resulted functional wet noodles with TPC, TFC, DPPH free radical scavenging and iron ion reducing power were 82.84 mg GAE/kg dried samples, 62.44 mg CE/kg dried samples, 130.68 mg GAE/kg dried samples and 51.33 mg GAE/kg dried samples, respectively.

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Conflict of Interest

The authors declare no conflict of interest.

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