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Research Article
Potential of Waste Tea Leaves (*Camellia sinensis*) in West Sumatra to Be Processed into Poultry Feed

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Abstract

Background and Objective: West Sumatra is the third largest tea-producing area in Indonesia. Tea plantations in this area produce top quality leaves that can be marketed both domestically and internationally. To maintain a high level of tea leaf productivity, plants should be pruned every 3 years using a rotation system that involves monthly prunings. These prunings produce waste tea leaves that can serve as alternative feed resource for poultry as they have good nutritional value. Tea leaves contain high concentrations of antioxidants, such as polyphenols and policosanol as well as minerals and vitamins, which are known to improve poultry health. Unfortunately, tea leaves also contain high levels of tannins and crude fiber-components known to be detrimental to poultry. This study was designed to evaluate the potential of waste tea leaves (*Camellia sinensis*) as poultry feed in West Sumatra by reducing their tannin content through immersion in fresh and hot water. **Materials and Methods:** This research consisted of two phases. The first phase was a survey of the potential of waste tea leaves as poultry feed through interviews and measurement of waste tea leaf production. The second phase was to experimentally process waste tea leaves through immersion in fresh and hot water. Variables measured during phase 1 included the size of tea plantations, ownerships, tea varieties produced, waste tea leaf production and estimated potential for poultry feed. The experiment conducted in phase 2 was performed using a completely randomized design involving 2×4 factorial arrangement of treatments with 4 replicates. The first experimental variable was water temperature (room temperature or 80°C). The second experimental variable was based on immersion at 6, 12, 18 or 24 h. Response variables measured included change in tannin content, dry matter (DM), organic matter (OM), crude protein (CP) and crude fiber (CF). **Results:** The results of the first phase indicated that the area of tea plantations in West Sumatra was 4,246.6 ha, ownership consisted of small holders (2,172 ha), the government (604.58 ha) and a private company (1,470 ha), total waste tea leaf production was 25,208.28 t/year, tea varieties or clones were *Camellia sinensis* assamica TRI 2024 and assamica TRI 2025 and waste tea leaves had the potential to feed 4,201,380,000 laying hens. The results of the second phase indicated that there was an interaction between water temperature and immersion duration on tannin reduction ($p<0.05$). Water temperature significantly influenced ($p<0.01$) reductions in OM and CP content and significantly affected ($p<0.05$) CF augmentation. Immersion duration significantly affected ($p<0.05$) DM reductions and highly significantly influenced ($p<0.01$) reductions in OM and CP. **Conclusion:** Waste tea leaves can be immersed in hot water (80°C) for 12 h to reduce their tannin content without affecting their protein content.

Key words: Waste tea leaf, potency, immersion, tannin, poultry feed

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Indonesia is the 5th largest tea producer in the world after Sri Lanka, Kenya, India and China, with levels of production reaching 154,598 t/year. This quantity of tea is grown on an area of only 118,441 ha^{-1}. Tea plants are shrubs or small trees that originate from the mainland of East Asia, the Indian subcontinent and Southeast Asia but are now cultivated throughout the world in both tropical and subtropical regions. Left to grow naturally, tea plants can become trees of 6 to 10 m in height[2]. Cultivated tea plants are often subjected to periodical pruning to a height of 1 m in order to facilitate leaf harvest and to maintain high levels of productivity.

Tea plant pruning is performed every 3 years to keep the plants in a vegetative state[3]. This pruning is employed because tea plants older than 3 years will produce smaller leaves and fewer shoots, decreasing the economic value of the tea crop[4]. The process of trimming tea plants produces leaves that are wasted and usually cover the growing shoots. Therefore, it would be more profitable to use trimmed tea leaves as feed for animals, especially poultry, given that tea leaves contain essential nutrients. This approach could reduce the use of commercial ingredients that are relatively expensive-feed costs often constitute 60-70% of the total cost of poultry production[5].

Tea leaves have fairly high nutritional value and contain antioxidant compounds (polyphenols) that can improve poultry health[6]. According to Cabrera *et al.*[7] the chemical composition of tea leaves is very complex. They have been found to contain crude protein (15-20% d.wt.), amino acids, such as theanine, aspartic acid, tyrosine, tryptophan, glycine, serine, valine, leucine and arginine (1-4% d.wt.), carbohydrates, such as cellulose, pectin, glucose, fructose and sucrose (5-7% dry weight), fat in the form of linoleic and linolenic acids, sterols in the form of stigmasterol, vitamins B, C and E, xanthic bases, such as caffeine and theophylline, pigments, such as carotenoids and chlorophyll, volatile compounds, such as aldehydes, alcohols, lactones, esters and hydrocarbons and minerals and other elements such as Ca, Mg, Mn, Fe, Cu, Zn, Mo, Se, Na, P, Co, Sr, Ni, K, F and Al (5%). Tea leaves also contain other compounds, such as carotenoids, which can lower cholesterol levels in the blood[8].

The utilization of tea leaves as poultry feed is limited by the high content of crude fiber (26%[7]) and tannins that can impede the absorption of nutrients. Tannin content in tea leaves ranges from 7-15%[9]. Tannin is a secondary metabolite compound in plants and belongs to a group of polyphenol compounds that can form complex compounds with other molecules, such as carbohydrates and proteins, in the digestive tract to impede their absorption[10]. According to Wiharto[11], the tolerance limit of crude fiber content in poultry feed is 4-5% and the maximum tannin content is 0.3%[12]. Muharlien[13] reported that the addition of 2% green tea leaves to laying chicken diet lowered the cholesterol levels of egg yolks. In another experiment by Anita *et al.*[14], old tea leaves were added to chicken diet at levels of up to 4.5% without affecting the performance of the poultry.

One of many ways to reduce the content of anti-nutritional substances is to subject the tea leaves to immersion[12,15]. According to Kawamoto *et al.*[16], tannins are soluble in glycerol, water, hydro alcohol and alcohols. Meanwhile, Goodarznia and Govar[17] found that the best method of extraction is to immerse leaves in hot water (130°C) for 10 min and generate a mass of 0.1800 g of catechin. Oematan[18] reported that immersing cashew leaves in hot water (80°C) for 20 min can decrease their levels of tannin by 11.28%. Subandriyo and Setianingsih[19] reported that the best method for tannin extraction in mangrove fruit is immersion in hot water (80°C) for 60 min.

Based on the above evidence, there seems to be an opportunity to utilize the waste tea leaf byproducts from tea plantations because pruned tea leaves still have good nutritional value. This research therefore, aimed to ascertain the importance of hot water immersion at different h on nutritive value of waste tea leaves.

MATERIALS AND METHODS

Experiment 1 (Survey potency of wasted tea leaves): The survey of the availability of waste tea leaves from tea plantations was performed in West Sumatra province, Indonesia from 20, February-25, March, 2017 on lands owned by small holders, the government and a private company. Data were collected through personal interview and observation.

Interviews: Interviews were performed to obtain secondary data from each tea plantation owner, such as the size of the tea plantation area, the rate of waste tea leaf production, the ownership of the tea plantation (small holder, government or private company), the varieties of tea planted and the cycle of tea pruning performed.

Observation: Waste tea leaf production was quantified by weighing pruned tea leaves. The tool used to measure tea leaves in a sample area was a 1 m^2 quadrant, which was randomly placed at 9 points within the tea plantation. The tea leaves within the quadrant area were pruned by knife and then weighed. The weight of tea leaves in each of the 9 quadrants was summed and subsequently divided by 9 to obtain the average tea leaf production in every 1 m^2. Finally, the tea leaf production per hectare was calculated by multiplying the average tea leaf production in a 1 m^2 by 10,000.

Experiment 2 (Immersion of waste tea leaves in fresh and hot water): This experiment was conducted at the non-ruminant laboratory of University of Andalas, Padang City, West Sumatera province, Indonesia.

Preparation for immersion of waste tea leaves: Before immersion, waste tea leaves were sun dried to obtain their dry weight. Water was heated using a hot plate. Water temperature was measured by thermometer until it reached 80°C. Dry waste tea leaves were divided into units of 100 g and then put into jars for immersion according to their assigned treatment for 6, 12, 18 and 24 h.

Response variables: Tannin content was measured by Lowenthal-procher[20], while dry matter, organic matter, crude protein and crude fiber were quantified by proximate analysis according to AOAC[21].

Experimental design: Experiments were performed in a completely randomized design using a 2×4 factorial arrangement of treatments. The first treatment variable was water temperature [fresh water (ambient temperature) or hot water (80°C)]. The second treatment factor was immersion duration (6, 12, 18 or 24 h).

Statistical analysis: Data were statistically analyzed by a two-way analysis of variance of CRD with a 2×4 factorial arrangement of treatments. Differences among treatments were determined using Duncan's multiple range test (DMRT) according to Steel and Torrie[22].

RESULTS AND DISCUSSION

Survey of waste tea leaves

Ownership of tea plantations: The tea plantations in Indonesia were owned by the small holders, the government and a private company. "Small holders" means that the tea plantation belongs to farmers. Government plantations are owned by PTP N 6 (BUMN) and private company plantations are owned by PT. Rajawali Nusantara Indonesia (Persero/Ltd.co). Most tea plantations belong to small holders, who owned a combined area of 2,172 ha, while the government and a private company owned 604.58 and 1,470 ha, respectively.

Varieties of tea plant and tea pruning time in West Sumatra: Varieties of tea plant in the tea plantations of West Sumatra were *Camellia sinensis* (Assamica variety), clones TRI2024 and TRI2025. This variety (*Camellia sinensis*) contains high levels of polyphenols, especially catechins[23], vitamins such as A, B and C and minerals such as fluoride[24] and demonstrates high leaf production[25]. The Assamica tea variety originated in the forests of Assam in North-Eastern India[26]. This variety provides the advantage of high productivity by growing quickly and producing larger leaves[27]. The pruning regimen for tea leaf production is every 3 years with a rotation system that depends on near-daily pruning.

Chemical composition of waste tea leaves: The following are results from the analysis of tannin content and the proximate analysis of waste tea leaves (Table 1).

Tea plantation area and waste tea leaf production: The total tea plantation area in West Sumatra was 4,246.6 ha and the total production of waste tea leaves was 25,308.28 t/year (Table 2).

The size of West Sumatera tea plantations decreases annually. In 2015, the total area of tea plantations was 4,945 ha[1], while in 2017, it decreased to 4,246.6 ha. This finding is due to the conversion of tea plantations into other forms of agricultural production and settlement.

Potential of waste tea leaves as animal feed: The potential of waste tea leaves as poultry feed can be illustrated as follows: Waste tea leaf production totaled 25.25 thousand tons in fresh form, while according to Lin *et al.*[28], fresh tea leaf moisture content is approximately 70%, meaning that when waste tea leaves are dried, their weight is approximately 17.64,000 t. In previous research, Krisnan[29] found

Table 1: Tannin, dry matter, organic matter, crude fiber and crude protein content before processing of waste tea leaves

Tannin (%)	DM (%)	OM (%)	CF (%)	CP (%)
7.915	93.597	88.084	17.405	19.634

DM: Dry matter, OM: Organic matter , CF: Crude fiber, CP: Crude protein

Table 2: Tea plantation areas and production of waste tea leaves in West Sumatra

	Small holder		Government		Private companies		Total	
Year	Area (ha)	WTLP (t)	Area (ha)	WTLP (t)	Area (ha)	WTLP (t)	Area (ha)	WTLP (t)
2017	2,172	12,887.2	604.58	3,605.08	1,470	8,722	4,246.6	25,208.28

Ha: Hectare, WTLP: Waste tea leaf production

Table 3: Effect of water temperature and immersion duration on tannin content (%)

	Immersion duration (h)				
Water temperature	6	12	18	24	Means
Fresh water (Ambient temperature)	6.50 ± 0.36^{a}	4.99 ± 0.83^{b}	4.22 ± 0.74^{bc}	3.87 ± 0.44^{c}	4.89^{a}
Hot Water (80°C)	3.58 ± 0.26^{c}	3.47 ± 3.43^{c}	2.82 ± 0.96^{d}	2.48 ± 0.36^{d}	3.03^{b}
Means	5.04^{a}	4.23^{b}	3.52^{c}	3.17^{c}	

a,b,c,d Means with different superscripts in the same rows or columns are significantly different (p<0.05)

Table 4: Effect of water temperature and immersion duration on dry matter content (%)

	Immersion duration (h)				
Water temperature	6	12	18	24	Means
Fresh water (Ambient temperature)	93.51 ± 0.68	93.08 ± 1.28	92.74 ± 0.36	92.55 ± 0.75	92.97
Hot water (80°C)	93.47 ± 0.48	93.04 ± 0.55	92.56 ± 0.88	92.05 ± 92.30	92.78
Means	93.49^{a}	93.06^{ab}	92.65^{b}	92.30^{b}	

a,b Means with different superscripts are significantly different (p<0.05)

that fermented tea dregs of the *Aspergillus niger* variety could be included as up to 7.5% of the diet for laying hens. Meanwhile, Anita *et al.*[14] reported that old tea leaves could comprise as much as 4.5% of the diet for broilers. From these findings, it is estimated that waste tea leaves could meet the dietary requirements of as many as 4,201,380,000 laying-hens/year.

Processing of waste tea leaves

Effect on tannin content: There was an interaction (p<0.05) between water temperature and immersion duration on tannin content. Experimental results show that hot water significantly decreased (p<0.01) tannin content as shown in Table 3. Longer immersion duration also significantly decreased (p<0.01) tannin content. The interaction between water temperature and immersion duration indicated that fresh water immersion for 6 h resulted in the highest tannin content. When the duration of immersion was increased to 24 h the tannin content of waste tea leaves decreased. However, when the water temperature was increased to 80°C, tannin content declined dramatically once the immersion duration was increased to 18 h but failed to drop further when the immersion duration was increased to 24 h. Therefore, the appropriate immersion method for reducing tannin content appears to be at 80°C for 18 h. This indicates that the longer the immersion in hot water, the lower the tannin content. This decrease is due to the high solubility of tannin in water at high temperatures. According to Makkar and Becker[30], high temperature is more effective at reducing tannin levels, while Rehman *et al.*[31] performed tannin extraction on tea leaves by using water at temperatures reaching 100°C.

Effect on dry matter (DM) content: There was no interaction (p>0.05) between water temperature and duration of immersion on DM content. Water temperature also did not affect (p>0.05) the DM content of waste tea leaves. However, immersion duration significantly affected (p<0.05) DM content as seen in Table 4. The DM content at 6 and 12 h was not different (p>0.05). However, the DM content at 6 h was significantly higher (p<0.05) than at 18 and 24 h. The DM content after 12, 18 and 24 h of immersion was not significantly different (p>0.05). The highest dry matter content was at 6 and 12 h. Longer immersion times decreased DM content. This is likely because dry matter consists of organic and inorganic matter[32] and organic matter contains carbohydrates that are soluble in water[33,34]. Martinson *et al.*[35] reported that the dry matter content of straw decreases by as much as 11% after immersion in water for 15 min and 28% after immersion in water for 12 h. The dry matter content will decrease further with longer immersion. Decreases in dry matter content could also occur because of the loss of dissolved substances such as proteins[36], vitamins[37] and soluble fiber[38] in water after 18 and 24 h of immersion.

Effect on organic matter (OM) content: There was no interaction (p>0.05) between water temperature and immersion duration on OM content. High water temperature significantly decreased (p<0.01) the OM content of waste tea

Table 5: Effect of water temperature and immersion duration on organic matter content (%)

	Immersion duration (h)				
Water temperature	6	12	18	24	Means
Fresh water (Ambient temperature)	87.46±0.75	87.16±0.26	86.58±0.35	86.00±0.63	86.80[a]
Hot water (80°C)	86.63±0.21	86.01±0.58	85.53±0.92	85.07±0.72	85.81[b]
Means	87.04[a]	86.59[a]	86.06[b]	85.53[c]	

[a,b,c]Means with different superscripts in the same rows or columns are significantly different (p<0.05)

Table 6: Effect of water temperature and immersion duration on crude protein content (%)

	Immersion duration (h)				
Water temperature	6	12	18	24	Means
Fresh water (Ambient temperature)	19.46±0.44	19.35±0.74	18.62±0.22	18.53±0.17	18.99[a]
Hot water (80°C)	18.58±0.53	18.45±0.14	17.95±0.10	17.15±0.08	18.03[b]
Means	19.02[a]	18.90[a]	18.28[b]	17.84[c]	

[a,b]Means with different superscripts in the same rows or columns are significantly different (p<0.05)

Table 7: Effect of water temperature and immersion duration on crude fiber content (%)

	Immersion duration (h)				
Water temperature	6	12	18	24	Means
Fresh water (Ambient temperature)	17.65±0.66	17.89±0.93	17.94±1.02	17.34±1.14	17.70[b]
Hot water (80°C)	17.72±0.69	18.65±0.71	18.39±1.38	18.78±0.47	18.39[a]
Means	17.68	18.27	18.17	18.06	

[a,b]Means with different superscripts are significantly different (p<0.05)

leaves and longer immersion also significantly reduced (p<0.01) the OM content of waste tea leaves as shown in Table 5. The OM content after hot water immersion was lower than after ambient temperature immersion. According to Paramitha[39], mango flour (*Mangifera indica* L.) immersion in hot water (100°C) can decrease the content of organic matter by up to 3.7%. Ekarius[40] defined organic matter as the dry matter of a substance that has been reduced to ash. Organic matter consists of carbohydrates, fats, proteins and vitamins. If one of these components decreases, the organic matter content also decreases.

The longer the immersion was the lower OM content of waste tea leaves. After 6 h of immersion, OM content was the highest but it was not different from levels measured after 12 h of immersion. After 18 h of immersion, the OM content was lower than after 6 and 12 h but higher than after 24 h of immersion. Therefore, immersion for 24 h resulted in the lowest OM content. Zuhro *et al.*[41] reported that immersion of taro tuber flour for 24 h at a temperature of 80°C decreased OM content to 3.1%. The longer the immersion, the more the OM content decreased because some of the substances that contribute to OM dissolve in water. Morrison and Pirie[42] reported the OM is part of the DM, so that when the DM decreases the OM will also decrease[43].

Effect on crude protein (CP) content: There was no interaction (p>0.05) between water temperature and immersion duration in the crude protein content of waste tea leaves. Hot water significantly decreased (p<0.01) the CP content of waste tea leaves. Longer immersion durations also significantly decreased (p<0.01) the CP content of waste tea leaves as depicted in Table 6. The CP content of waste tea leaves immersed in hot water was significantly lower (p<0.01) than that in ambient temperature water. This result was in accordance with the results of experiments by Djafarr *et al.*[44], who found that immersion of kerandang seeds (*Canavalia virosa*) in hot water (80°C) for 24 h significantly reduced crude protein content and decreased phenolic compounds by up to 74.93%. Experiments by Kajihausa *et al.*[45] demonstrated that soaking sesame seed flour for 16 h could decrease crude protein content. Therefore, it is helpful to limit the immersion duration such that the crude protein content can be maintained. Runyons *et al.*[36] reported that there are dissolved proteins in water-soluble foods that degrade at elevated temperatures. For example, proteins associated with albumin and prolamin are damaged by heat treatment.

Effect on crude fiber (CF) content: There was no interaction (p>0.05) between water temperature and immersion duration on the crude fiber content of waste tea leaves and immersion duration did not affect (p>0.05) the CF content of waste tea leaves. However, hot water immersion significantly increased (p<0.05) the CF content of waste tea leaves as shown in Table 7. The increase in crude fiber content of waste tea leaves was caused by a decrease in OM content. This result might be related to the study conducted by Chen *et al*.[46], who reported that several components of food such as carbohydrates, crude protein, crude fiber, crude fat and others are lost during immersion in hot water. These losses result in increases in the crude fiber content. Waste tea leaves contain two types of fiber-soluble fiber[47] and crude fiber[48]. Hot water immersion resulted in a decrease in soluble fiber, so the percentage of crude fiber increased. According to Cristianita *et al*.[49], extracting soluble fiber (pectin) at a temperature of 90°C for 60 min produced a yield of 18.57%.

The results of this experiment show that immersion using hot water for a long time is more effective at reducing the tannin content of waste tea leaves. However, longer immersion times will also lower DM, OM and CP content and increase crude fiber. To maintain high levels of crude protein, our recommendation is to immerse waste tea leaves in hot water for 12 h.

CONCLUSION

The area of tea plantations in West Sumatra was 4,246.6 ha in 2017. These plantations belonged to small holders, the government and a private company and produced tea plants of the variety *Camellia sinensis* Assamica, Clones TRI2024 and TRI2025. The CP content of waste tea leaves was not notably high, while levels of tannin and CF content were high. The pruning time of tea leaves was every 3 years with a rotation system that involved pruning almost every day. The total production of waste tea leaves was 25,208.28 t/year, a volume with the potential to feed 4,201,380,000 laying-hens/year if included as 5% of the diet. The best processing of waste tea leaves was found to be immersion in hot water (80°C) for 12 h to reduce tannin content from 6.50-3.47% without decreasing crude protein content.

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