Evaluation of chemical composition and fermentation quality of Green Tea, Black Tea, Oolong Tea, and White Tea

Sri Wahyuni[1], *Risa* Putriliana[2], *Asep* Sudarman[2], *Ahmad* Sofyan[3], *Anuraga* Jayanegara[2]*

[1]Graduate School of Nutrition and Feed Science, Faculty of Animal Science, IPB University, Dramaga Bogor 16680, Indonesia
[2]Department of Nutrition and Feed Technology, Faculty of Animal Science, IPB University, Dramaga Bogor 16680, Indonesia
[3]Research Center for Animal Husbandry, National Research and Innovation Agency, Bogor, Indonesia

Abstract. This study evaluated the chemical composition of nutrients and fermentation quality of green tea, black tea, oolong tea, and white tea. The observed variables were physical quality, pH, chemical composition, and fleigh score. Pearson Correlation determined the relationship between nutrient chemical composition and fermentation quality pH. The fermented tea was of excellent quality, with a brownish-green color, sour aroma, crumbly texture, and no fungi. The pH value of all types of tea after fermentation was in the range of 4.68–5.24. Dry matter, ash, and organic matter showed a significant positive correlation with pH, with a correlation coefficient (r) of 0.783, 0.692, and 0.776, respectively ($p < 0.01$). Ash has a positive correlation with dry matter ($r = 0.620$, $p > 0.05$), organic matter ($r = 1.00$, $p < 0.01$), and crude fiber ($r = 0.527$, $p < 0.01$). Organic matter positively correlates with ash ($r = 0.601$, $p > 0.05$). Crude fiber positively correlates with organic matter ($r = 0.529$, $p > 0.05$). In conclusion, after 31 days of incubation, the processed tea types (green, black, oolong, and white tea) had excellent physical characteristics, pH within the normal range, and excellent chemical composition content.

1 Introduction

The dried leaves of the tea plants (*Camellia sinensis* L.) are the main ingredient in making tea. However, Indonesia only uses young leaf shoots, a plantation commodity, as raw materials for tea drinks. The average Indonesian consumes 0.32 kg of tea daily, while the world average is 0.57 kg [1]. Indonesia is the seventh largest tea producer globally, producing 127.000 metric tonnes of tea [2]. According to Statistics Indonesia (2022), tea production in Indonesia reached 124.7 thousand metric tonnes with 14.000–18.000 tea tree stems per hectare. The Gambung tea plantation survey mentioned that one tea tree can produce 8–12 kg of tea fruit annually [3]. Tea is classified as non-fermented (green, yellow,

* Corresponding author: anuraga.jayanegara@gmail.com

and white tea), semi-fermented (oolong tea), or fully fermented (black tea) based on the degree of oxidation of the catechins resulting from processing [4]. Green tea contains polyphenols, especially catechins, saponins, caffeine, and l-theanine [5]. On the other hand, black tea, in general, has a higher tannin content than green tea. Oolong tea is a semi-oxidised tea with bioactive compounds, including alkaloids, polyphenols, flavonoids, aroma, vitamins, minerals, amino acids, proteins, polysaccharides, and organic acids [6]. White tea has a high amino acid content and low polyphenol content. Apart from its health benefits, tea serves as an antioxidant, antibacterial, antimicrobial, and even anti-methanogenic feed ingredient [5], [7], [8]. Polyphenols, such as flavonoids, catechins, gallic acid, and tannins, are the main bioactive compounds of tea. Tea residues, a by-product, can also serve as feed. They contain polyphenols, saponins, and theophylline, useful as antibacterials and antioxidants [9]. Long-term feed processing is essential in Indonesia because forage production is deficient in the dry season while abundant in the rainy season. Fermentation preparation and storage are the most effective ways to ensure animal feed supply. Fermentation improves nutritional quality and increases metabolites, enzymes, and probiotics, such as *Lactobacillus* and *Bacillus* [10]. This study evaluated the nutrient chemical composition and fermentation quality of green, black, oolong, and white tea.

2 Material and Methods

2.1 Samples Preparation

Tea leaves were obtained from the Tea and Kina Research Centre Bandung, West Java. The tea sample weight was approximately 250 g from each green, black, oolong, and white tea. The samples used in the study consisted of tea leaves and tea residues, and then the samples were made in fermented and non-fermented treatments. The samples consisted of non-fermented tea leaves, non-fermented tea residue, fermented tea leaves, and fermented tea residue. Samples of non-fermented tea leaves and tea residue were not added to water, while fermented tea leaves and tea residue were added to water. To make tea residue, water was added with the ratio of tea to water at 1:6 and brewed at 90 ºC. Fermented leaves were added to water, and the ratio of tea to water was 1:2. All samples were put into laboratory-scale plastic silos (30 cm x 15 cm). Water was removed from the bottles, which were then sealed using a vacuum sealer and stored in a closed container for 31 days. After 31 days of storage, the plastic silo was opened, and the sample was divided into two parts with equal proportions. The first part was supplemented with water (sample: water, 1:10) and the remaining supernatant to determine fermentation quality from 30 days of incubation. In the second part, fermentation samples were freeze-dried at -20ºC for three days, ground with a blender until smooth, and used for chemical composition analysis and fermentation quality of green, black, oolong, and white tea.

2.2 Physical Quality Evaluation

The physical quality of the fermented material after 31 days was carried out by characterizing the smell, texture, color, and presence of mold based on [11]. Organoleptic tests were conducted by panelists assessing the characteristics of color, odor, texture, and presence of fungi using the senses of sight, smell, and touch. The panelists were limited to the Department of Nutrition and Feed Science panelists. After 31 days, the plastic silo was opened, and the pH of the complete silage was measured along with other physical quality assessments such as color, aroma, texture, and presence of fungi which were scored (1-3). Indicators of physical quality assessment of complete silage are presented as follows:

Table 1. Physical quality evaluation of various non-fermented and fermented tea

Indicator	Score	Condition
Color	0.00-1.00	Brown to black
	1.00-2.00	Dark green or brownish yellow
	2.00-3.00	Natural green or yellowish-green
Texture	0.00-1.00	Solid, clumped
	1.00-2.00	Solid, slightly clumped
	2.00-3.00	Solid, not clumped
Odor	0.00-1.00	Rotten
	1.00-2.00	Not sour or not rotten
	2.00-3.00	Fresh sour
Presence of fungi	0.00-1.00	Lots
	1.00-2.00	Enough
	2.00-3.00	None

2.3 Fleigh Score Evaluation

Fleigh score is a number obtained from calculating pH and fermentation dry matter to determine fermentation quality. The pH analysis followed the procedure AOAC (2005). In this study, the quality of the fermentation type was determined by the Fleigh Score formula based on Killic et al. (1994) [12] with the following standards: 100-81: very good, 80-61: good, 60-41: little good, 40-21 medium, 20-0: bad).

$$FS=220+(2x \text{ dry matter } \%-15)-40x \text{ pH})$$

2.4 Chemical Composition Evaluation

Samples of tea leaves and pulp were analyzed for chemical composition, including dry matter (DM), ash, crude protein (CP), crude fiber (CF), and ether extract (EE) using the Association of Official Analytical Chemists method (AOAC 2005).

2.5 Data Analysis

The physical quality characteristics of the samples were analyzed descriptively. pH value and fleigh score were analyzed using Microsoft Excel 2013. For chemical composition (DM, ash, CP, CF, EE) with pH was analyzed using Pearson correlation (r) calculated using IBM SPSS 25 version statistical software. In this study, the Pearson correlation was used to assign the relationship between the chemical composition of feedstuff and the pH value. A correlation coefficient, represented by the symbol r, quantifies the strength of the link. It is a measurement of linear association and is occasionally referred to as Pearson's correlation coefficient after its creator. A type of memory-based communitarian filtering calculation is Pearson's algorithm. The range of Pearson's connection, from +1 to -1, reflects the level of direct relationship between two elements or the degree to which the components are connected. A connection of +1 suggests that there is a strong positive relationship between the variables, or indicates that the samples have fundamentally the same structure, whereas a connection of -1 demonstrates a strong negative relationship or that the sample structures are different [13].

$$P_{xy} = \frac{E(K_x K_y) - E(K_x)(K_y)}{\sigma_x \sigma_y}$$

Where $E(K_xK_y)$ signifies the mean value of the product of the corresponding variables in the two data sets, x and y, $E(K_x)$ represents the sample x average value, $E(K_y)$represents the sample y average value, σ_x represents the sample x standard deviation, and σ_y represents the sample y standard deviation. The degree of correlation between chemical composition and pH samples was determined according to the criteria outlined in Table 2.

Table 2. Degree of correlation relationship between two variables

Condition	Degree of correlation
$0.8 < P_{x,y} < 1.0$	remarkably strong correlation
$0.6 < P_{x,y} < 0.8$	strong correlation
$0.4 < P_{x,y} < 0.6$	moderate correlation
$0.2 < P_{x,y} < 0.4$	weak correlation
$0.0 < P_{x,y} < 0.2$	remarkably weak or correlated

3 Result and Discussion

3.1 Physical Quality

Table 3. Physical characterization of various non fermented and fermented tea

Treatment	Average Score			
	Color	Texture	Odor	Presence of Fungi
NGL	2.00	3.00	3.00	3.00
NBL	1.00	2.00	2.20	3.00
NOL	2.00	2.00	2.00	3.00
NWL	3.00	2.00	2.00	3.00
NGR	1.00	3.00	3.00	3.00
NBR	1.00	2.00	3.00	3.00
NOR	1.00	2.00	2.00	3.00
NWR	3.00	2.00	2.00	3.00
FGL	2.00	3.00	2.80	3.00
FBL	1.00	2.00	3.00	3.00
FOL	2.00	2.00	3.00	3.00
FWL	1.00	2.00	2.80	3.00
FGR	2.00	3.00	1.60	3.00
FBR	1.00	2.00	1.80	3.00
FOR	1.00	2.00	2.00	3.00
FWR	1.00	2.00	2.00	3.00

Note: NGL, non fermented green tea leaves; NBL, non fermented black tea leaves; NOL, non fermented oolong tea leaves; NWL, non fermented white tea leaves; NGR, non fermented green tea residue; NBR, non fermented black tea residue; NOR, non fermented oolong tea residue; NWR, non fermented white tea residue; FGL, fermented green tea leaves; FBL, fermented black tea leaves; FOL, fermented oolong tea leaves; FWL, fermented white tea leaves; FGR, fermented green tea residue; FBR, fermented black tea residue; FOR, fermented oolong tea residue; FWR, fermented white tea residue

The results showed that the color has varying results from yellow to brown or brownish green, ranging from 1.00-3.00. According to [14], flavin and therubigin affect the color brightness of tea. Catechins are components that affect the color of tea [15]. Brownish-yellow and brown-black color due to the processing of tea leaves [14]. According to [16], the tea leaves turn a blackish-brown color during the oxidation process. Table 3 shows that there is an absence of mold or contaminants in each sample. According to [17], fermentation results of good quality do not have mold present. With good fermentation, the surface is not moldy, and the growth of fungi can be caused by not maximizing airtight conditions so that fungi

will be active in aerobic conditions and grow on the surface [18]. Table 3 shows the aroma values of all samples ranged from 1.60 -3.00, with the value for the nonfermented green tea leaves treatment having a sour aroma (still fresh). The treatment scores of nonfermented green tea residues and nonfermented black tea residue had an assessment score of 3 (sour/fresh aroma).

Meanwhile, the fermented oolong tea residue treatment has a non-acidic or non-fresh aroma. According to [17], good fermentation results in a sour odor caused by the fermentation process and active anaerobic bacteria that produce organic acids. The length of incubation causes the aroma to be slightly sour due to the fermentation process that can produce lactic acid. Table 3 shows that the texture produced from each type of tea has an average score of 2.00-3.00 or a slightly soft to firm texture. Green tea treatments, either non fermented or fermented, have a solid texture. Good fermentation has the physical characteristics of a transparent texture, like natural ingredients with a solid texture and natural green color [11].

3.2 pH

Table 4. Average pH score of various non fermentated and fermented tea.

Treatment	Average Score
NGL	5.74
NBL	5.20
NOL	5.94
NWL	5.56
NGR	5.20
NBR	4.94
NOR	5.31
NWR	5.38
FGL	5.08
FBL	5.07
FOL	5.24
FWL	4.83
FGR	4.87
FBR	4.86
FOR	4.68
FWR	4.95

Note: NGL, non fermented green tea leaves; NBL, non fermented black tea leaves; NOL, non fermented oolong tea leaves; NWL, non fermented white tea leaves; NGR, non fermented green tea residue; NBR, non fermented black tea residue; NOR, non fermented oolong tea residue; NWR, non fermented white tea residue; FGL, fermented green tea leaves; FBL, fermented black tea leaves; FOL, fermented oolong tea leaves; FWL, fermented white tea leaves; FGR, fermented green tea residue; FBR, fermented black tea residue; FOR, fermented oolong tea residue; FWR, fermented white tea residue

Table 4 shows that the average pH of processed tea types ranges from 4.68-5.94. According to [19], a suitable pH for ECGC stabilisation in tea ranges from 4-6. The pH standard may vary depending on the processing method, tea plant variety, or additives added. The stability of polyphenols in tea is influenced by pH, where tea is relatively stable at pH 3 and 4 but can be degraded at pH 5 and 6. Table 4 showed the highest pH in the non-fermented oolong tea leaf sample, with a pH of 5.94. This showed that oolong tea leaves tend to be acidic because the pH value is less than 7; the pH range depends on the oxidation process of tea leaves.

3.3 Fleigh Score

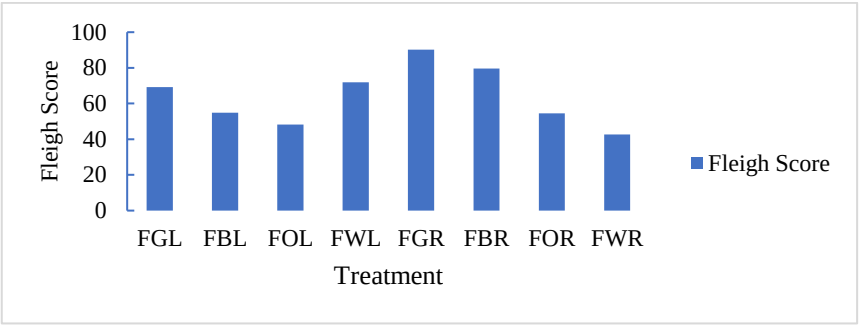

Fig. 1. *Fleigh Score*

Note: NGL, non fermented green tea leaves; NBL, non fermented black tea leaves; NOL, non fermented oolong tea leaves; NWL, non fermented white tea leaves; NGR, non fermented green tea residue; NBR, non fermented black tea residue; NOR, non fermented oolong tea residue; NWR, non fermented white tea residue; FGL, fermented green tea leaves; FBL, fermented black tea leaves; FOL, fermented oolong tea leaves; FWL, fermented white tea leaves; FGR, fermented green tea residue; FBR, fermented black tea residue; FOR, fermented oolong tea residue; FWR, fermented white tea residue

The fleigh score produced after fermentation for 31 days is presented in Figure 1. The highest fleigh score is green tea residue (90.00), with very good criteria. This is in line with research by [12] who obtained the best fleigh score (92.29) from fermentation. This indicates that the fermentation process went well during the 30 days incubation [20].

3.4 Chemical composition characteristics

Table 5 shows that the dry matter results of non-fermented tea leaf treatments ranged from 85.07-89.14%. Processed tea has hygroscopic properties that can absorb moisture from the surrounding environment [16]. The results showed that the ash content of tea, in general, ranged from 2.94-5.67%. According to [21], in China's white, black, and green tea products, the ash content ranges from 4-6%. Analysis of ash content in tea is needed to determine the quality parameters of a tea product [22]. High ash content can be influenced by different processing methods, factories, and the period of tea shoot picking [16]. Crude fiber content is one of the important chemical components in the quality requirements of tea products.

The study results showed that the treatment of nonfermented green tea leaves had the highest crude fiber of 16.24% compared to other types of tea. The table above showed that the crude fiber of nonfermented green tea pulp is higher than that of other types of tea at 17.52%. According to [23], tea waste contains 17.06% crude fiber. From the results of the study, it is known that green tea leaves and pulp have high crude fiber from both fermented and non-fermented treatments. Factors that can affect the crude fiber content of green tea are different processing processes from other types of tea, plant varieties, and parts, as well as harvesting and brewing methods. The study results in Table 5 showed that tea's crude protein nutrient content ranges from 14.32-30.39%. The highest result of crude protein content is in white tea for non-fermented treatment in tea leaves, which is 29.42% and tea residues 30.39%, while the fermented treatment in tea leaves has a protein content of 29.20% and tea residues 23.03%. The protein content in tea has a role in the aroma formation process. According to [24], the protein content of white tea is 29.75%. At the same time, tea waste from tea beverage production contains crude protein 20.08%. White tea contains higher crude protein than other types of tea because the white tea processing process uses young leaves that have not been fermented. Minimal processing can retain more nutrients in tea, including

protein, than more fermented teas like black tea [23]. Table 6 shows the average fat content in green tea, which is in line with other studies, showing that green tea's fat content is higher than black tea's. This is due to the processing of tea, which affects its fat content.

Table 5. Chemical composition of non fermentated and fermented tea.

Treatment	Nutrient (%)				
	DM	Ash	CF	CP	EE
NGL	87.07	5.67	16.24	17.87	1.84
NBL	85.07	5.63	13.31	22.30	0.69
NOL	89.14	5.66	12.41	25.23	0.27
NWL	87.00	4.94	13.11	29.41	9.12
NGR	72.60	4.53	17.52	17.79	2.04
NBR	64.16	4.23	14.09	22.98	0.74
NOR	68.28	4.67	13.65	25.16	3.00
NWR	69.20	4.20	14.43	30.39	0.75
FGL	33.62	5.47	14.89	17.49	4.89
FBL	26.29	4.96	10.87	22.49	2.40
FOL	26.38	4.66	9.96	24.86	2.36
FWL	29.94	4.12	12.18	29.20	1.65
FGR	39.90	3.69	15.19	14.32	3.23
FBR	34.49	3.97	12.99	18.55	0.48
FOR	18.30	3.88	12.55	22.27	1.24
FWR	17.84	2.94	10.26	23.03	0.43

Note: DM, dry matter; CF, crude fiber; CP, crude protein; EE, ether extract; NGL, non fermented green tea leaves; NBL, non fermented black tea leaves; NOL, non fermented oolong tea leaves; NWL, non fermented white tea leaves; NGR, non fermented green tea residue; NBR, non fermented black tea residue; NOR, non fermented oolong tea residue; NWR, non fermented white tea residue; FGL, fermented green tea leaves; FBL, fermented black tea leaves; FOL, fermented oolong tea leaves; FWL, fermented white tea leaves; FGR, fermented green tea residue; FBR, fermented black tea residue; FOR, fermented oolong tea residue; FWR, fermented white tea residue

3.5 Pearson Correlation between Chemical Composition and pH

Table 6. Pearson correlation coefficient (r) between pH and various chemical composition

Parameter	pH	DM	Ash	OM	CF	CP	EE
pH	1						
DM	.783**	1					
Ash	.692**	.620*	1				
OM	.776**	1.000**	.601*	1			
CF	0.183	.527*	0.248	.529*	1		
CP	0.244	0.159	-0.016	0.162	-0.460	1	
EE	0.183	0.154	0.228	0.150	0.125	0.103	1

Note: *, $p<0.05$; *, $p<0.01$; DM, dry matter; OM, organic matter; CF, crude fiber; CP, crude protein; EE, ether extract; NGL, non fermented green tea leaves; NBL, non fermented black tea leaves; NOL, non fermented oolong tea leaves; NWL, non fermented white tea leaves; NGR, non fermented green tea residue; NBR, non fermented black tea residue; NOR, non fermented oolong tea residue; NWR, non fermented white tea residue; FGL, fermented green tea leaves; FBL, fermented black tea leaves; FOL, fermented oolong tea leaves; FWL, fermented white tea leaves; FGR, fermented green tea residue; FBR, fermented black tea residue; FOR, fermented oolong tea residue; FWR, fermented white tea residue

Table 6 showed that pH has a positive correlation with the values of dry matter ($r = 0.783$; $p<0.01$), ash ($r = 0.692$; $p<0.01$), and organic matter ($r = 0.776$; $p<0.01$). The relationship

illustrates that the higher the pH value, the higher the levels of dry matter, ash, and organic matter. The correlation value of water content with pH positively correlates; the two parameters have a proportional relationship. Table 6 showed that BK has a positive correlation with ash ($r = 0.620$; $p<0.05$), BO ($r = 0.0$; $p<0.01$), and SK ($r = 0.527$; $p<0.01$). The relationship illustrates that the higher the dry matter value, the higher the ash, organic matter, and crude fiber content. The higher the ash content, the higher the inorganic material content in the feedstuff. This is because of the correlation value of ash content with pH, which is positively correlated. Table 6 shows that the BO value has a positive correlation with ash ($r=0.601$; $p < 0.05$) and SK ($r=0.529$; $p < 0.05$). The relationship illustrates that the higher the BO value, the higher the ash and crude fiber content.

4 Conclusion

After 31 days of incubation, processed tea (green tea, black tea, oolong tea, and white tea) from residues and tea leaves, both non-fermented and fermented, has good physical characteristics (odor, texture, color, and fungal presence), pH, and chemical composition content in the normal range.

References

1. J. Chandra *et al.*, "Perancangan Interior Holistic Tea House di Malang,". 5, **2**, 430–439, (2017).
2. N. Fatmala, H. Hermansyah, dan M. Marlin, "Stimulasi pertumbuhan bibit teh (camellia sinensis) dengan pemberian urin sapi dan penggunaan bahan stek yang berbeda," *J. Ilmu-Ilmu Pertan. Indones.* 22, **1**, 52–57, (2020), doi: 10.31186/jipi.22.1.52-57.
3. S. Prasetyo dan F. Yosephine, "Model Perpindahan Massa Pada Ekstraksi Saponin Dengan Pengontakan Secara Dispersi Menggunakan Analisis Dimensi Dimensional Analysis for Mass Transfer Model for Saponin From Tea," *Reakt. Chem. Eng. J.* 14, **2**, 87–94 (2012).
4. W. Ke *et al.*, "Influence of Condensed and Hydrolysable Tannins on the Bacterial Community, Protein Degradation, and Fermentation Quality of Alfalfa Silage," *Animals*. 12, **7**, (2022), doi: 10.3390/ani12070831.
5. G. J. Kolling *et al.*, "Performance and methane emissions in dairy cows fed oregano and green tea extracts as feed additives," *J. Dairy Sci.*, 101, **5**, 4221–4234, (2018), doi: 10.3168/jds.2017-13841.
6. K. W. Ng, Z. J. Cao, H. B. Chen, Z. Z. Zhao, L. Zhu, dan T. Yi, "Oolong tea: A critical review of processing methods, chemical composition, health effects, and risk," *Crit. Rev. Food Sci. Nutr*. 58,**17**, 2957–2980, (2018), doi: 10.1080/10408398.2017.1347556.
7. E. W. C. Chan, E. Y. Soh, P. P. Tie, dan Y. P. Law, "Antioxidant and antibacterial properties of green, black, and herbal teas of Camellia sinensis," *Pharmacognosy Res*. 3, **4**, 266–272, (2011), doi: 10.4103/0974-8490.89748.
8. M. Kondo, Y. Hirano, K. Kita, A. Jayanegara, dan H. O. Yokota, "Fermentation characteristics, tannin contents and in vitro ruminal degradation of green tea and black tea by-products ensiled at different temperatures," *Asian-Australasian J. Anim. Sci.*, 27, **7**, 937–945, (2014), doi: 10.5713/ajas.2013.13387.
9. J. Guyader, M. Eugène, M. Doreau, D. P. Morgavi, C. Gérard, dan C. Martin, "Tea saponin reduced methanogenesis in vitro but increased methane yield in lactating dairy cows," *J. Dairy Sci.* 100, **3**, 1845–1855, (2017), doi: 10.3168/jds.2016-11644.
10. X. Zhu, L. Tao, H. Liu, dan G. Yang, "Effects of fermented feed on growth performance, immune organ indices, serum biochemical parameters, cecal odorous

compound production, and the microbiota community in broilers," *Poult. Sci.*102, **6**, 102629, 2023, doi: 10.1016/j.psj.2023.102629.

11. P. K. Tahuk, G. F. Bira, dan H. Taga, "Physical Characteristics Analysis of Complete Silage Made of Sorghum Forage, King Grass and Natural Grass," *IOP Conf. Ser. Earth Environ. Sci.*, 465, **1**, (2020), doi: 10.1088/1755-1315/465/1/012022.
12. F. A. Rajab dan S. Chuzaemi, "The Quality of Dwarf Elephant Grass (Pennisetum purpureum cv . Mott) Silage Using Fresh Rumen Content Inokulan and Carbohydrate Source Additives with Different Incubation Time. 5, **4**, 201–204, (2020).
13. M. F. Ikhwan, W. Mansor, Z. I. Khan, M. K. A. Mahmood, A. Bujang, dan K. Haddadi, "Pearson Correlation and Multiple Correlation Analyses of the Animal Fat S-Parameter," *TEM J.* 13, **1**, 155–160, (2024), doi: 10.18421/TEM131-15.
14. V. S. P. Chaturvedula dan I. Prakash, "The aroma, taste, color and bioactive constituents of tea," *J. Med. Plants Res.* 5, **11**, 2110–2124, (2011).
15. J. Q. Wang *et al.*, "Study on the color effects of (-)-epigallocatechin-3-gallate under different pH and temperatures in a model beverage system," *Food Control*. 139, 109112, (2022), doi: 10.1016/j.foodcont.2022.109112.
16. K. Teshome, "Effect of tea processing methods on biochemical composition and sensory quality of black tea (Camellia sinensis (L.) O. Kuntze): A review," *J. Hortic. For.* 11, **6**, 84–95, (2019), doi: 10.5897/JHF2019.0588.
17. W. S. Wati, Mashudi, dan A. Irsyammawati, "Kualitas silase rumput odot (Pennisetum purpureum CV . Mott) pada waktu inkubasi yang berbeda," *J. Nutr. Ternak Trop.* 1, **1**, 45–53, (2018).
18. R. A. Edwards, "Animal nutrition," *Nature.* 111. **2793**, 651, 1923, doi: 10.1038/111651a0.
19. H. Lin, S. Lin, M. K. Awasthi, Y. Wang, dan P. Xu, "Exploring the bacterial community and fermentation characteristics during silage fermentation of abandoned fresh tea leaves," *Chemosphere*. **283**, June, 131234, (2021), doi: 10.1016/j.chemosphere.2021.131234.
20. O. İ. Leri, "Turkish Journal of Range and Forage Science Silage Quality of Second Forage Pea at Different Plant Densities and Cereal Mixtures. 1, **2**, 35–45, (2020).
21. M. Czernicka, G. Zaguła, M. Bajcar, B. Saletnik, dan C. Puchalski, "Study of nutritional value of dried tea leaves and infusions of black, green and white teas from Chinese plantations," *Rocz. Panstw. Zakl. Hig*. 68, **3**, 237–245, (2017).
22. R. Balasooriya, M. Kooragoda, dan P. Jayawardhane, "Comparative analysis on physical and chemical characteristics of commercially manufactured/ processed green tea in Sri Lanka," *Int. J. Food Sci. Nutr. www.foodsciencejournal.com*. **4**, July, 43–47, (2019), doi: 10.13140/RG.2.2.11002.85441.
23. A. Sudheer Babu, C. Rama Krishna, S. Raju, K. Vijay, dan A. Suresh Nayak, "Evaluation of tea waste or tea residue, orange peels and pigeon pea pods for proximate composition, fodder quality and digestibility parameters," *Pharma Innov. J.* 11, **11**, 1441–1445, (2022), [Daring]. Tersedia pada: https://doi.org/10.1007/978-981-13-8660-2_3
24. A. Susilowati, Iqbal Khoiruddin Syahida, Istnaini Novi Wahyuningsih, dan Evi Nindyawati, "Uji Parameter Mutu, Nilai Gizi, Dan Aktivitas Antioksidan Berbagai Produk Teh Celup (Teh Putih, Teh Kuning, Teh Hijau, Dan Teh Oolong)," *Med. Sains J. Ilm. Kefarmasian*. 8, **2**, 649–656, (2023), doi: 10.37874/ms.v8i2.670.