

## The effect of paddy straw and concentrate containing green tea dust on performance and nutrient digestibility in feedlot lambs

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Received: 04.09.2019 • Accepted/Published Online: 23.03.2020 • Final Version: 02.06.2020

**Abstract:** The utilization of low-input paddy straw hay (PSH) for fattening lambs should be incorporated with a high-quality concentrate (HQC) in which green tea dust (GTD) rich in tannins can be added as a natural feed additive. Completely randomized design was used to compare 5 doses of GTD inclusions (dry matter, DM basis) at 0% (GTD-0), 0.5% (GTD-0.5), 1% (GTD-1), 1.5% (GTD-1.5), and 2% (GTD-2) in an HQC as the main diet of PSH-fed fattening lambs on average daily gain (ADG, g/head/day), dry matter intake (DMI, g/head/day), and nutrient digestibility (%) using 6 replicates. The results showed that GTD-1.5 resulted in higher ( $P < 0.05$ ) ADG for the lambs compared with GTD-0 as a control diet during 69 days of a feeding trial, while GTD-0.5, GTD-1, and GTD-2 provided a nonsignificant increase in ADG for the lambs in comparison with GTD-0. There was no difference ( $P > 0.05$ ) in nutrient digestibility of the lambs for all GTD treatments, but GTD-1.5 resulted in better nutrient digestibility. Proper GTD inclusion in an HQC and PSH-based diet can therefore increase the performance of fattening lambs without any harmful effects on feed consumption and nutrient digestibility. GTD inclusion in an HQC as the main diet of feedlot lambs is recommended at 1.5%.

**Key words:** paddy straw hay, concentrate, green tea dust, fattening lambs

### 1. Introduction

Sheep and goat farming are the 2 major occupations of farmers in rural areas of Indonesia [1]. However, large conversion of grazing land into plantations, housing, and industries, especially on Java Island, have significantly decreased the availability of high-quality forage for ruminants. This has created a difficult situation for farmers since feed availability is a key expenditure, contributing to about 80% of total daily costs in animal production [2]. It seems that only low-quality forage such as paddy straw hay (PSH) is still widely available and is relatively affordable since the majority of Indonesians eat rice as a main staple. Unfortunately, PSH is less palatable, nutritious, and not easily digested by rumen microbes since it contains large amounts of lignin and silica [3–5]. Nevertheless, PSH can be a good source of dietary fiber required by ruminants to reduce the risk of digestive disorders such as acidosis and bloating during intensive fattening [6]. High-quality concentrate (HQC) supplementation is likely to be necessary to improve the quality of a PSH-based diet to meet the targeted nutrient requirements of ruminants, especially in feedlot situations [7,8]. Ramdani et al. [9] reported that adding green tea leaves (GTL) might improve

the utilization of PSH in ruminants since GTL has higher protein and energy but lower lignin contents in comparison with PSH, leading to higher *in vitro* digestibility and gas production of GTL. Ramdani et al. [10] also reported that GTL contained various micro and macrominerals, as well as secondary plant metabolites such as phenolic tannins. GTLs contain 20.4% total tannins [9], and the majority of its tannins are catechin derivatives [11]. The beneficial effects of tannins as natural additives in ruminant diets have been thoroughly discussed [9,10]. During the GTL-making process in the factory, green tea dust (GTD) was also produced as a nongrade byproduct. However, there is limited information about GTD and its utilization as an additive in ruminant diets. Therefore, the objective of this study was to test the effect of different doses of GTD inclusions (0, 0.5, 1, 1.5, and 2%) in an HQC diet on the performance and nutrient digestibility of PSH-fed fattening lambs.

### 2. Materials and methods

#### 2.1. Animals

Thirty growing male lambs (of Priangan breed, Decree of Indonesian Agricultural Minister No. 300/Kpts/

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SR.120/5/2017) with an average body weight  $20.01 \pm 2.41$  kg were used for this experiment. The experimental animals were divided into 5 different groups. Each lamb was randomly placed in an individual pen (1.5-m long  $\times$  0.8-m wide  $\times$  0.9-m high) separated by wood panels through which each of them had visual and part-physical contact. Each lamb was then subjected to an adaptation period of 14 days and fed 300 g of HQC and ad libitum PSH and clean water. During adaptation, each lamb was sheared, cleaned, given anthelmintic orally (Kalbazen-SG), and injected with B complex vitamins (B-Sanplex) at prescribed doses. During the experiment, 400 g of HQC was initially offered to each lamb and increased gradually up to 600 g.

## 2.2. Diet preparation and animal feeding

Paddy straw was prepared in the form of PSH. Fresh straw was chopped (5–10 cm long) using a chopper machine and dried under the sun for 3–5 days. An HQC was made using the following ingredients: pollard (35%), bran pollard (15%), copra meal (27%), corn gluten feed (20.9%), calcium (Ca) (2%), and mixed minerals (0.1%). GTD was obtained from a tea-processing factory located in Soreang district in West Java. The chemical compositions of the feed materials were determined, and these are presented in Table 1. During the experiment, each lamb was given a diet consisting of 70% HQC and 30% PSH. This diet was based on dry matter which had already been formulated to meet the nutrient requirements of tropical lambs to obtain an average daily gain (ADG) of about 100 g/head/day according to Paul et al. [12] at a 3% dry-matter intake requirement from lamb's body weight. Meanwhile, GTD treatments were included in the HQC at 0% (GTD-0), 0.5% (GTD-0.5), 1% (GTD-1), 1.5% (GTD-1.5), and 2% (GTD-2). All lambs were fed 3 times daily: halved PSH in the morning, full HQC at noon, and other halved PSH in late afternoon. All HQC mixtures were consumed and finished by each lamb but not PSH, and each refusal of PSH was weighed daily before morning feeding.

## 2.3. Data collection and measurements

Daily intake of PSH and HQC were calculated by the difference between the corresponding of offered and refused PSH and HQC in grams of dry matter (DM). The lambs were weighed at day 0, 35, and 69 using a digital weighing scale. After 69 days of the feeding trial, the lambs continued to be subjected to nutrient digestibility measurements. The daily collection of feed samples was continued as previously described, while total feces was collected daily from each lamb in zipped synthetic bags marked for each lamb. A separate bag was attached to the rear of each lamb by using appropriate sheep harnesses. All lambs were adapted to these bags for 2 days during which the bags were emptied to discard the feces. From day 3 onwards, the total feces from each lamb was

**Table 1.** Mean chemical contents (DM % or otherwise stated, n = 2) of feed materials.

Contents	PSH	HQC	GTD
Dry matter (% sample)	89.4	93.6	98.1
Crude ash	13.3	23.3	16.7
Crude protein	4.88	14.2	20.1
Crude fiber	36.7	10.9	17.2
Ether extract	3.56	7.53	2.53
Nitrogen free extract	41.5	44.1	43.5
Total digestible nutrients	53.6	78.0	63.0
Calcium	0.26	0.72	0.56
Phosphor	0.49	0.50	0.55
Total phenols	1.24	0.58	25.6
Total tannins	0.22	0.18	23.0

DM: dry matter; PSH: paddy straw hay; HQC: high quality concentrate; GTD: green tea dust; n: number of replicates.

collected, weighed, and 10% was retained daily for 6 days. The retained samples were dried daily at 60 °C. The dried subsamples of feces from the 6 day collection period, alongside the feed offered and refused samples of each treatment, were pooled and ground to pass through a 1-mm sieve in a sample hammer mill. These ground samples were then subjected to various nutrient analyses. These analyses were then used to estimate each nutrient digestibility by calculating the difference between total nutrient intake from the diets and total nutrients out in the feces on a DM basis. The estimated values were then expressed as a percentage of digestibility.

## 2.4. Chemical analyses

All ground feed and feces samples were analyzed in duplicate using the standard methods of the Association of Official Analytical Collaboration (AOAC) [13] to determine DM, crude protein (CP), crude ash (CA), ether extract (EE) and crude fiber (CF) as described in Ramdani et al. [10]. A similar method from AOAC [13] was also used to determine Ca and phosphor (P) based on spectrophotometer analysis. Meanwhile, total phenols (TP) and total tannins (TT) were analyzed using the Folin-Ciocalteu method, as described in Makkar [14], with tannic acid (Sigma Aldrich, Singapore) as the reference standard. All chemical contents were express as percentage DM except DM was expressed as a percentage fresh sample. Nitrogen-free extract (NFE) was calculated using the following equation:  $NFE = 100 - (CA + CP + CF + EE)$ . Total digestible nutrients (TDN) for HQC was predicted using the equation as follows:  $TDN = 70.6 + (0.259 \times CP) + (1.01 \times EE) - (0.76 \times CF) + (0.0991 \times$

NFE), while TDN for PSH and GTD were estimated using the following equation:  $TDN = (-26.685) + (1.334 \times CF) + (6.598 \times EE) + (1.423 \times NFE) + (0.967 \times CP) - (0.002 \times (CF^2)) - (0.67 \times (EE^2)) - (0.024 \times (CF \times NFE)) - (0.055 \times (EE \times NFE)) - (0.146 \times (CF \times CP)) + (0.039 \times ((CF^2) \times CP))$  [15].

### 2.5. Statistical analyses

Each chemical content of the feed materials was calculated as an average from duplicate analysis ( $n = 2$ ), whereas completely randomized design was used to compare 5 different GTD treatments (GTD-0, GTD-0.5, GTD-1, GTD-1.5, and GTD-2) on ADG, DMI, and nutrient digestibility of feedlot lambs using 6 replicates ( $n = 6$ ). The data were statistically analyzed using one-way ANOVA in MINITAB 16 statistical software, in which Tukey's test was applied to compare means. Statistical significance was assumed at  $P < 0.05$ . The residual data were analyzed for normality by passing the Anderson–Darling normality test at  $P > 0.05$ .

### 3. Results

Table 1 presents the chemical contents of PSH, HQC, and GTD of feed materials used in this experiment. PSH could be categorized as low-quality forage as it had the lowest CP and TDN but the highest CF contents in comparison with GTD and HQC. Based on nutritive values, GTD utilization

as a natural feed additive in a PSH-based diet not only has the potential to increase tannins but also to improve CP contents.

Table 2 shows the effect of GTD inclusions in an HQC at 0% (GTD-0), 0.5% (GTD-0.5), 1.5% (GTD-1), and 2% (GTD-2) of PSH-fed fattening lambs on ADG and DMI at day 35 and day 69 of the feeding trial. At 35 days, GTD-treated lambs had a similar ( $P > 0.05$ ) ADG but lower ( $P < 0.01$ ) total DMI than those fed without GTD, where all GTD-treated lambs consumed significantly lower PSH. Later, GTD inclusions increased the ( $P < 0.05$ ) ADG of the lambs at day 69, although they had a similar ( $P > 0.05$ ) total DMI. Fattening lambs fed a diet containing GTD-1.5 had a greater ( $P < 0.05$ ) ADG than those fed without GTD.

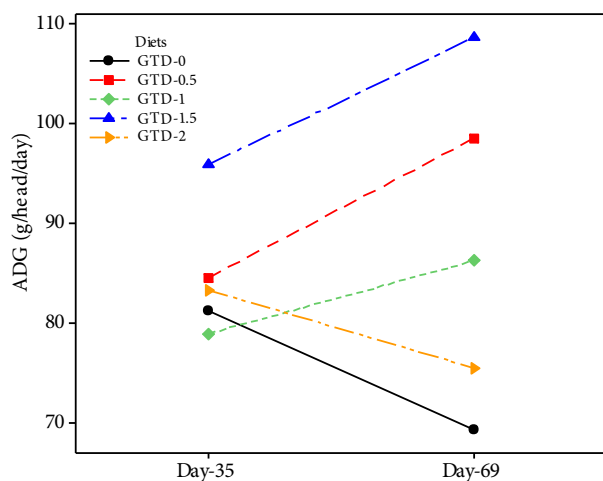
Figure 1 illustrates the means of ADG of experimental feedlot lambs between day 35 and day 69. GTD-fed lambs receiving up to GTD-1.5 could maintain increased ADGs between day 35 and day 69, but lambs fed without GTD inclusion and lambs fed GTD-2 were likely to decrease ADGs during the same time period. Figure 2 outlines the means of total DMI of experimental feedlot lambs between day 35 and day 69. All GTD-fed lambs had increased DMI, but lambs without GTD treatment had decreased DMI.

Table 3 shows the means of nutrient digestibility for GTD inclusions in an HQC diet at 0% (GTD-0), 0.5%

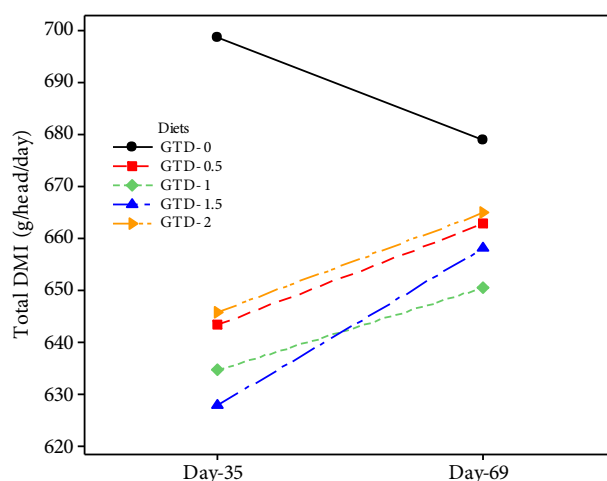
**Table 2.** Mean ( $n = 6$ ) weight (kg/head), ADG (g/head/day), and DMI (g DM/head/day) of feedlot lambs during the feeding trials, together with SEM and significances.

Measures	GTD-0	GTD-0.5	GTD-1	GTD-1.5	GTD-2	SEM	P
Weight							
Day 0	20.5	18.7	20.9	19.7	20.4	1.15	0.648
Day 35	23.4	21.7	23.6	23.1	23.3	1.12	0.699
Day 69	25.3	25.5	26.8	27.2	25.6	1.02	0.571
ADG							
Day 35	81.2	84.6	79.0	95.9	83.3	17.2	0.963
Day 69	69.4 <sup>b</sup>	98.5 <sup>ab</sup>	86.3 <sup>ab</sup>	108.6 <sup>a</sup>	75.5 <sup>ab</sup>	8.32	0.011
Total DMI							
Day 35	698.7 <sup>a</sup>	643.5 <sup>b</sup>	634.8 <sup>c</sup>	628.0 <sup>b</sup>	646.0 <sup>b</sup>	13.68	0.006
PSH	257.4 <sup>a</sup>	202.2 <sup>b</sup>	193.5 <sup>b</sup>	186.7 <sup>b</sup>	204.7 <sup>b</sup>	13.68	0.006
HQC	441.3	441.3	441.3	441.3	441.3	n/a	n/a
Day 69	679.1	662.9	650.6	658.2	665.1	14.13	0.657
PSH	185.3	169.1	156.8	164.4	171.3	14.14	0.657
HQC	494.8	493.8	494.8	493.8	493.8	n/a	n/a

Mean values were significantly different at  $P < 0.05$ ; n: number of replicates; SEM: standard error of mean; ADG: average daily gain; DMI: dry matter intake; PSH: paddy straw hay; HQC: high quality concentrate; GTD-0: green tea dust in an HQC at 0%; GTD-0.5: green tea dust in an HQC at 0.5%; GTD-1: green tea dust in an HQC at 1%; GTD-1.5: green tea dust in an HQC at 1.5%; GTD-2: green tea dust in an HQC at 2%; n/a: not available.



**Figure 1.** Mean ( $n = 6$ ) average daily gain (ADG, g/head/day) of experimental feedlot lambs fed a diet containing green tea dust in a high quality concentrate at 0% (GTD-0), 0.5% (GTD-0.5), 1% (GTD-1), 1.5% (GTD-1.5), and 2% (GTD-2) between day 35 and day 69.



**Figure 2.** Mean ( $n = 6$ ) total dry matter intake (DMI, g/head/day) of experimental feedlot lambs fed a diet containing green tea dust in a high quality concentrate at 0% (GTD-0), 0.5% (GTD-0.5), 1% (GTD-1), 1.5% (GTD-1.5), and 2% (GTD-2) between day 35 and day 69.

**Table 3.** Mean ( $n = 6$ ) nutrient digestibility (%) of lambs during digestibility trials, together with SEM and significances.

Digestibility	GTD-0	GTD-0.5	GTD-1	GTD-1.5	GTD-2	SEM	P
DM	71.3	70.4	73.2	80.0	73.8	3.41	0.305
CP	75.2	70.5	74.2	81.6	75.9	3.36	0.233
CF	55.5	63.5	63.2	69.4	63.7	5.04	0.391
EE	82.4	82.8	83.4	88.3	85.8	2.56	0.426
TDN	62.8	61.4	61.3	71.6	68.0	3.59	0.175
Ca	37.5	36.4	31.3	58.3	44.2	8.52	0.224

Mean values were not significantly different at  $P > 0.05$ ;  $n$ : number of replicates; SEM: standard error of mean; DM: dry matter; CP: crude protein; CF: crude fiber; EE: ether extract; TDN: total digestible nutrients; Ca: calcium; GTD-0: green tea dust in a high quality concentrate (HQC) at 0%; GTD-0.5: green tea dust in an HQC at 0.5%; GTD-1: green tea dust in an HQC at 1%; GTD-1.5: green tea dust in an HQC at 1.5%; GTD-2: green tea dust in an HQC at 2%.

(GTD-0.5), 1.5% (GTD-1), and 2% (GTD-2) of PSH-fed lambs that were all not different ( $P > 0.05$ ). However, lambs fed GTD-1.5 were likely to have better nutrient digestibility on average than those fed other GTD treatments.

#### 4. Discussion

During fattening, lambs cannot be fed solely by low-input PSH to avoid a lack of nutrient intake. PSH is categorized as low-quality forage in terms of nutrient content, palatability, and digestibility. Ramdani et al. [9] reported that the quality of PSH was similar to wheat straw and barley straw hay, which have low protein and

energy content but which are high in fiber fractions such as NDF, ADF, and lignin. PSH is not only high in lignin but also silica, making it less digestible in the rumen [3–5]. Conversely, an HQC diet is high in protein and energy but low in fiber content, resulting in faster digestibility in the rumen compared with forages [8]. Therefore, HQC supplementation is necessary to improve a PSH-based diet to meet the nutrient requirements of lambs during the fattening period. It is quite difficult to set a targeted ADG of fattening lambs above 100 g/head/day without HQC supplementation [7,12]. In fact, the averaged ADG of each group of lambs during the 69-day feeding trial was under

the target of 100 g/head/day, except for lambs with GTD-1.5 treatment that could reach ADG of 108.6 g/head/day.

Although PSH has poor nutritive value, it can be a good source of fiber in the diet of ruminants. In feedlot situations, dietary fiber is essential to reduce the incidence of metabolic disorders such as acidosis and bloat since it stimulates chewing activity, saliva production, and the increase of pH [6].

GTD and GTL as natural feed additives might have similar nutritive values and both functions to improve the quality of a PSH-based ruminant diet because GTD is part of GTL but is rejected due to its smaller particle size. Ramdani et al. [9] reported that GTL contained higher CP (24.0 vs. 6.04%) and metabolizable energy (7.08 vs. 4.01 MJ/kg) but a lower lignin (3.76 vs. 59.8%) content compared to PSH, resulting in higher *in vitro* digestibility and gas production for GTL. Ramdani et al. [10] reported that GTL contained about 20.4% tannins, and the majority of its tannins were catechin derivatives [10]. Nasehi et al. [16] reported that green tea waste from tea drying factories had 16.3% CP and 12.2% tannins, which is considerably high for a waste product. Although GTD had lower CP (20.1 vs. 24.0%), it had slightly greater tannin (23.0 vs. 20.4%) content compared with GTL in the study of Ramdani et al. [10]. This confirms that GTD can also be categorized as source of CP and tannins.

Po et al. [17] reported that tannin supplementation in a ruminant diet resulted in reduced feed intake due to its bitter taste, while Méndez-Ortiz et al. [18] concluded that tannin intake had no significant impact on the DMI and ADG of sheep. However, the current study showed that the inclusion of a GTD-1.5 treatment in a feedlot sheep diet significantly increased ADG during the 69-day feeding trial without reducing feed intake. This suggests that a PSH-based diet can be improved with a proper dose of GTD inclusion without any detrimental effect on feed consumption. It seems that GTD-fed lambs adjusted to GTD-1.5 maintained increased ADGs from the beginning to the end of the feeding trial, but lambs fed without GTD were likely to have decreased ADG. Decreased ADG on lambs without GTD inclusion from day 35 to day 69 was followed by a reduced total DMI in the same lambs. Moreover, GTD inclusion greater than GTD-1.5 is not recommended since experimental lambs on GTD-2 tended to have decreased ADG during the 69-day feeding trial, although their DMIs were not negatively affected.

GTD is rich in tannins and tannins can decrease the solubility and rumen degradability of most leaf proteins because of their protein binding properties [19,20], leading to decreased protein digestibility and  $\text{NH}_3$  output in the

rumen [19–21]. However, GTD utilization in this current *in vivo* study did not have any negative impact on protein digestibility, and it was likely to be increased at GTD-1.5 instead. This can be the sign that bounded protein was not effectively degraded in the rumen but available as a bypass protein to be absorbed in the small intestine [19–21].

It is quite clear that GTD inclusion could improve the performance of fattening lambs without any detrimental effect on feed intake and nutrient digestibility. Increased performance might occur because of improved protein utilization in the digestive gut as explained in the above discussion. In addition, GTD-fed lambs adjusted to GTD-1.5 maintained an improved ADG and DMI from the beginning to the end of the feeding trial but not those without GTD inclusion, which showed a decrease in ADG and DMI.

Besides feeding and digestibility trials, further research should address the potential of the multiple benefits of tea tannins in GTD on disease prevention [22–24], methane mitigation [25–28], and improved beneficial fatty acids in meat via altered rumen biohydrogenation [29–31]. If these multiple advantages of tannin-rich GTD as a nongrade GTL product in tea processing factories can be scientifically proven, this can be an additional, natural, and alternative additive to replace antibiotic growth promoters that have been banned in the European Union since 2003 (EC Regulation No. 1831/2003) and in Indonesia since 2017 (Indonesian Ministry of Agriculture Regulation, No. 14/2017).

In conclusion, PSH can be used as a source of dietary fiber for fattening lambs, but its utilization should be incorporated with an HQC. A proper dose of GTD inclusion as source of CP and tannins into an HQC- and PSH-based diet can increase the performance of fattening lambs via improved protein utilization and vitality without any disadvantageous effects on feed consumption and nutrient digestibility. The recommended dose of GTD inclusion is 1.5% in an HQC as the main diet of feedlot lambs.

#### **Acknowledgement**

The authors would like to thank Universitas Padjadjaran for funding this research through the RKDU-HIU grant scheme, contract no. 1793/UN6.J/LT/2018.

#### **Informed Consent**

The manuscript is a research article from an *in vivo* experiment using growing lambs under normal intensive fattening situations without any stressful treatment to the animals.



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