Research Article

Influence of Different Variety and Wilting Treatment on the Nutritive Value of Whole Plant Sorghum Silage

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Abstract | Our objective was to investigate the effect of different variety and wilting treatment on silage quality and *in vitro* degradability of whole-plant sorghum. Three sorghum varieties (Numbu, Super 1 and Samurai 1) were ensiled either fresh or wilted and evaluated in a 2 x 3 factorial arrangement. Based on sensory evaluation, colour, smell and sensory index increased after wilting treatment ($P < 0.01$). Based on chemical quality, pH and NH_3-N values were lower in wilted groups than in unwilting sorghum silage ($P < 0.01$). Compared with non-wilted materials, higher dry-matter (DM) and organic-matter (OM) content were found in wilted materials ($P < 0.01$). Wilting did not affect crude protein (CP), ether extract (EE), neutral detergent fibre (NDF), acid detergent fibre (ADF), hemicellulose, cellulose, or non-fibre carbohydrate (NFC) content. Samurai 1 sorghum silage had the lowest NDF and ADF, both in non-wilted and wilted materials ($P < 0.05$). The interaction of wilting and different variety had a significant impact on NDF ($P < 0.05$), ADF, OM, and CP ($P < 0.01$). Wilting treatment had no significant impact on all aspects of *in vitro* degradability. In contrast, variety difference had a significant impact on *in vitro* degradability ($P < 0.01$). Results of the current study indicate that wilting treatment influences the sensory score and chemical quality of sorghum silage. There was no effect on nutrient composition or *in vitro* digestibility. The effect of different variety on the nutrient value of sorghum silage was more pronounced than the wilting variable.

Keywords | *In vitro* digestibility, Nutritive value, Silage, Sorghum, Variety

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INTRODUCTION

In recent years, sorghum plants have been cultivated as high-quality forage in Indonesia. Low forage production in the dry season and lack of fertile land in some areas in Indonesia are classic problems in the supply of forage (Sriagtula et al., 2017; Wahyono et al., 2019). Sorghum (*Sorghum bicolor* (L.) Moench) is a suitable forage source due its adaptive traits appropriate to marginal land. Sorghum plants are more tolerant to high temperature and drought environments than maize (Yucel and Erkan, 2020). Moreover, sorghum requires less fertilizer and has fewer soil preferences than maize. In Indonesia, sorghum is used for a variety of purposes, including human food, livestock feed, and bioethanol production. Numbu variety is a commonly grown forage type because of its high biomass production (Wahyono et al., 2019). Moreover, Super 1 sorghum, developed as a sweet sorghum variety, is also grown in Indonesia. Recently, the National Nuclear Energy Agency of Indonesia (BATAN) developed and released a new cultivar of sweet sorghum for ruminant forage, namely Samurai 1 (Wahyono et al., 2017). In the past few years, sweet sorghum has become considered suitable for silage production due to its high soluble carbohydrate content.

Some areas in Indonesia have a dry climate and low levels of rainfall and so need to apply silage technology to increase feed availability. Lyimo et al. (2016) reported that silage is one of the promising options for increasing forage availability, particularly in the dry season. Sorghum plants are high in nutrients, especially soluble carbohydrates, and thus are commonly used for silage production (Yucel and Erkan, 2020). We hypothesize that the variety of sorghum used will influence the chemical quality and nutrient value of sorghum silage. The evaluation of different cultivars of sorghum in silage form in relation to different purposes, such as grain, bioethanol production, forage, or dual-purpose, is required (Pinho et al., 2017). Previous studies have reported that the different sorghum varieties could lead to different product quality in the ensiling process (Junior et al., 2015; Neves et al., 2015; Yucel and Erkan, 2020). Different phenotypic traits of various sorghum cultivars might consequently modify the fermentation quality and nutritional value of silage (Perazzo et al., 2017). Moreover, Yucel and Erkan (2020) reported that sweet sorghum provides better quality for silage production due to its high soluble carbohydrate content, low buffering capacity, and high DM digestibility.

Pre-treatment of raw samples before ensiling also affects the quality of the silage produced. Dry-matter (DM) and soluble carbohydrate content significantly impact on silage quality (Gomes et al., 2017). As an example, wilting before ensiling results in better quality in taro silage compared with not wilting (Hung et al., 2020). Previous studies have demonstrated that wilting is recommended to increasing DM content (Lyimo et al., 2016), improve nutritional values of raw samples (Gomes et al., 2017), and depress clostridial fermentation in the silage process (Zheng et al., 2018). Overnight wilting also does not affect the content of C18:3n3 and C18:2n6 of plants (Liu et al., 2020). Conaghan et al. (2010) reported that rapid wilting before ensiling had been widely adopted in silage management as a means of increasing nutrient value. However, there is limited information on silage in Indonesia with regard to issues such as appropriate sorghum varieties and wilting methods for high nutritive value in silage. Therefore, the objective of this study is to investigate the effects of different varieties and wilting treatments on silage quality and *in vitro* degradability of whole-plant sorghum.

MATERIALS AND METHODS

Materials

Numbu, Super 1, and Samurai 1 sorghum varieties were planted in a laboratory field station, Research Center for Isotope and Radiation Application Technology, National Nuclear Energy Agency of Indonesia (BATAN) (Elevation: 38 m, 6°17'38.9" S; 106°46'28.8" E). Sorghum plants were harvested at hard-dough phase (± 115 days after sowing). All edible parts (stems, leaves and panicles) were separately chopped and then uniformly mixed to create a representative sample.

Experimental design

Three sorghum varieties were ensiled either fresh or wilted and evaluated in a 2 x 3 factorial arrangement. Each treatment had four replicates.

Sampling of raw sorghum

Before ensiling, representative samples were placed into individual paper bags, dried at 65°C for 48 h, and their dry-matter (DM) content determined. Dried samples were ground, passed through a 1 mm sieve and prepared for chemical analysis.

Preparation of silage

For ensiling process, all sorghum varieties were chopped manually using a machete into 20–30 mm particle sizes. All parts of the sorghum were prepared for ensiling in either fresh or wilted treatments. Wilting was achieved by spreading the chopped fresh sorghum for 12 h for use as low-moisture silage. About 300 g of raw material was ensiled in 24 sterile glass laboratory silos. Four replications were performed for each treatment. The silos were then stored at room temperature of 25°C in the laboratory for 30 days. At the end of the 30-day ensiling period, final silo weights were recorded and inspected for sensory evaluation. Some representative samples were also dried at 65°C for 48 h, ground, passed through a 1 mm sieve and analysed for chemical composition.

Sensory evaluation

The sensory scores (colour, smell and texture) of the silage samples were determined using methods developed by Jian et al. (2015). Smell and colour score indices were determined up to 15 points each, while texture indices were determined up to 10 points. Sensory quality was classified as follows: low grade (< 10 points), general (11–20 points), good (21–30 points) and excellent (31–40 points).

Chemical quality of silage

Wet silage samples of 20 g were blended for two minutes with 180 ml of distilled water using a kitchen blender (Cosmos CB-287, Cosmos) and then filtered through four layers of cheesecloth. Wet silage extract was then filtered through paper and left to stand for 10 minutes. An amount of 10 ml was collected to determine pH, total volatile fatty acids (TVFA; mM) (Kromann et al., 1967), ammonia (NH_3-N; mg/100 ml) (Conway 1951), and sugar content (% Brix). The pH and stem sugar content stem were measured using an HI-2211 pH meter (Hanna instruments®, USA) and an Atago Refractometer (Atago® Co, Japan), respectively. Determination of Fleigh value was calculated as follows:

$$Fleigh\ point = 220 + (2 \times \%DM - 15) - (40 \times pH)$$

Chemical analysis

The content of organic matter (OM), crude protein (CP) and ether extract (EE) of the silages and raw samples were measured by Association of Official Analytical Chemists method (AOAC, 2005). The content of non-fibre carbohydrate (NDF) and acid detergent fibre (ADF) were determined by ANKOM A200 fibre analyzer (ANKOM®, USA). The content of acid detergent lignin (ADL) was measured according to Van-Soest et al. (1991). Hemicellulose, cellulose and non-fibre carbohydrate (NFC) content were calculated using the equations described below.

$$Hemicellulose\ (\%) = NDF\ (\%) - ADF\ (\%)$$
$$Cellulose\ (\%) = ADF\ (\%) - ADL\ (\%)$$
$$NFC\ (\%) = OM\ (\%) - CP\ (\%) - NDF\ (\%) - EE\ (\%)$$

In vitro digestibility evaluation

In vitro digestibility was determined using the *in vitro* gas technique described by Menke et al. (1979). Solutions were prepared according to Menke and Steingass (1988) and rumen fluid was obtained from two cannulated Holstein bulls (approximate live weight 525 kg) grazing Napier grass combined with 3 kg/d of concentrate based on pollard, rice bran, soybean meal, mineral and vitamin mix. The 200 mg dry-silage and raw-sorghum samples were weighed with four replications into calibrated 100 ml glass syringes (Fortuna®, Labortechnik, Germany). Four syringes containing only rumen-buffer fluids were incubated as blank data. The rumen-buffer fluid (30 ml) was filled into each syringe followed by incubation in a water bath at 39°C. Total gas production was recorded before incubation (0) and at 3, 6, 9, 12, 24, 48 and 72 h after incubation. The kinetics of gas production were fitted to the model of Ørskov and McDonald (1979) using non-linear regression and the SPSS 22.0 software program, as follows:

$$p = a + b\,(1 - e^{-ct})$$

Where p represents cumulative gas production (ml), t represents incubation time (h), a represents gas production from the soluble fraction (ml/200 mg DM), b represents gas production from the insoluble fraction (ml/200 mg DM), and c represents rate of gas production (ml/h).

Total gas produced after 3 and 24 h of incubation was used to calculate the gas production caused by fermentation of the soluble (GPSF) and insoluble (GPNSF) fractions (Van-Gelder et al., 2005), respectively, as follows:

$$GPSF\ (ml) = (gas\ at\ 3\ h \times 0.99 \times 5) - 3$$
$$GPNSF(ml) = (1.02 \times (gas\ at\ 24\ h \times 5) - (gas\ at\ 3\ h \times 5)) + 2$$

In vitro OM digestibility (IVOMD) and metabolizable energy were calculated according to Menke et al. (1979) estimation from cumulative gas production at 24 h incubation (GP ml/200 mg DM), CP (% DM), and ash (% DM), as follows:

$$IVOMD\ (\%) = 14.88 + 0.889\ GP + 0.45\ CP + 0.0651\ ash$$

Amounts of 20 ml rumen-buffer from representative fluid samples were collected after 72 h incubation to determine pH, TVFA (mM) (Kromann et al., 1967), and NH_3-N (mg/100 ml) (Conway, 1951).

Statistical analysis

Statistics and analysis of data were treated by ANOVA and Duncan multiple range test performed using IBM SPSS Statistics 25 software. The interaction studies of sorghum variety and wilting treatment were analysed using GLM procedure.

RESULTS AND DISCUSSION

The nutrient and fibre content of whole-plant sorghum

Compared with fresh sorghum, overnight wilting increased the DM and OM content in whole-plant raw sorghum ($P < 0.01$) (Table 1). Except for EE, significant difference ($P < 0.01$) was observed for all content as influenced by different variety. Super 1 variety had the highest CP content ($P < 0.05$), both in fresh (7.02%) and wilted treatments (7.31%). Samurai 1 sorghum contained the lowest NDF, ADF and cellulose content ($P < 0.05$). Samurai 1 also had the highest NFC content ($P < 0.05$). There is a significant interaction between variety and wilting treatment in terms of CP, ADF ($P < 0.05$) and ADF ($P < 0.01$).

Table 1: The nutrient and fiber content of raw sorghum (% DM).

Items	Variety	DM	OM	CP	EE	NDF	ADF	ADL	Hemi	Cellu	NFC
Fresh	Numbu	22.04± 0.89[a]	87.51± 0.29[bc]	6.95± 0.26[b]	3.40± 1.06	65.28± 1.30[bc]	37.80± 1.42[b]	7.97± 0.59[a]	27.48± 0.19[b]	29.83± 1.42[b]	11.89± 0.79[b]
	Super 1	27.78± 1.82[a]	86.04± 1.14[a]	7.02± 0.25[bc]	3.96± 1.03	66.53± 0.86[cd]	40.59± 1.14[c]	9.96± 0.87[b]	25.94± 0.43[a]	30.63± 0.60[b]	8.53± 2.37[a]
	Samurai 1	34.93± 3.29[b]	88.41± 0.66[cd]	6.25± 0.27[a]	3.94± 1.14	63.23± 1.36[ab]	33.60± 0.88[a]	8.64± 0.86[ab]	29.64± 0.62[c]	24.96± 0.82[a]	14.98± 2.52[c]
Wilting	Numbu	36.95± 2.59[b]	89.00± 0.71[d]	6.25± 0.24[a]	4.07± 0.71	68.62± 0.96[d]	40.71± 0.99[c]	9.75± 1.91[ab]	27.90± 0.73[b]	30.96± 2.27[b]	10.06± 1.18[ab]
	Super 1	41.96± 8.33[b]	86.72± 0.17[ab]	7.31± 0.08[c]	3.39± 1.41	66.03± 1.74[c]	39.95± 0.52[c]	9.91± 1.26[b]	26.08± 1.45[a]	30.03± 1.02[b]	10.00± 0.38[ab]
	Samurai 1	56.83± 8.25[c]	88.65± 0.09[d]	6.74± 0.31[b]	4.35± 0.63	62.42± 1.89[a]	32.67± 1.51[a]	8.26± 0.85[ab]	29.75± 0.41[c]	24.41± 1.16[a]	15.14± 1.84[c]
Wilting		**	**	NS	NS	NS	NS	NS	NS	NS	NS
Variety		**	**	**	NS	**	**	*	**	**	**
Wilting x Variety		NS	NS	**	NS	*	**	NS	NS	NS	NS

Dry matter (DM); organic matter (OM); crude protein (CP); ether extract (EE); neutral detergent fiber (NDF); acid detergent fiber (ADF); acid detergent lignin (ADL); hemicellulose (hemi); cellulose (cellu); non fiber carbodydrate (NFC)

Table 2: The sensory score of sorghum silage.

Items	Variety	Index score			Total score	Grade
		Color	Smell	Texture		
Fresh	Numbu	10.84±0.52[a]	10.55±0.37[a]	7.68±0.27[a]	29.06±0.78[a]	good
	Super 1	11.15±0.55[a]	11.43±0.76[b]	7.93±0.22[a]	30.50±1.08[b]	good
	Samurai 1	11.19±0.17[a]	11.50±0.37[b]	7.95±0.13[a]	30.64±0.40[b]	good
Wilting	Numbu	12.21±0.77[b]	12.40±0.26[cd]	8.88±0.26[c]	33.48±1.09[c]	excelence
	Super 1	11.13±0.16[a]	11.79±0.28[bc]	8.33±0.26[b]	31.24±0.48[b]	excelence
	Samurai 1	12.09±0.31[b]	12.55±0.24[d]	8.55±0.13[bc]	33.19±0.37[c]	excelence
Wilting		**	**	**	**	
Variety		NS	*	NS	*	
Wilting x Variety		*	**	**	**	

Different superscript in the same column mean significant difference ($P<0.05$); * mean $P<0.05$; ** mean $P<0.01$; NS mean non-significant

Sensory evaluation of sorghum silage

After wilting, all of the sensory scores of sorghum silage were significantly increased (Table 2). The colour, smell and sensory index all increased after wilting treatment ($P < 0.01$). Overnight wilting also increased the grade score from good to excellent. Sorghum variety affected the smell index score ($P < 0.05$). There was a significant interaction between variety and wilting treatment for colour ($P < 0.05$), smell and texture index scores ($P < 0.01$).

Chemical quality of whole-plant sorghum silage

The interaction of wilting treatment and variety significantly influenced pH and NH_3-N concentration ($P < 0.01$) but did not influence Brix, TVFA and Fleigh value (Table 3). Except for TVFA production, wilting treatment and different variety influenced the chemical quality of whole-plant sorghum silage. The pH value was lower in the wilting treatment groups than in the unwilted sorghum silage ($P < 0.01$). Furthermore, overnight wilting also increased Fleigh value ($P < 0.01$). Samurai 1 wilted sorghum silage had the highest Brix and Fleigh values ($P < 0.05$).

The nutrient and fibre content of whole-plant sorghum silage

As shown in Table 4, compared with non-wilted materials, higher DM and OM content were found in wilted materials ($P < 0.01$). However, wilting treatment did not affect CP, EE, NDF, ADF, hemicellulose, cellulose and NFC content. In contrast, variety significantly influenced nutrient and fibre composition of whole-plant sorghum silage ($P < 0.01$), except for EE content. Samurai 1 sorghum silage had the lowest NDF and ADF content, both in non-wilted and wilted materials ($P < 0.05$). The NFC content in Samurai 1 silage was also significantly higher than that of Numbu and Super 1 varieties ($P < 0.05$). The interaction of wilting and different varieties had significant impact on NDF ($P < 0.05$), ADF, OM and CP ($P < 0.01$) content.

Table 3: The chemical quality of sorghum silage.

Items	Variety	pH	NH_3-N (mg/100ml)	Brix (%)	TVFA (mM)	Fleigh
Fresh	Numbu	4.65±0.06[c]	1.43±0.26[bc]	0.78±0.09[a]	75.91±19.09	63.65±2.27[a]
	Super 1	4.92±0.02[d]	2.02±0.11[d]	0.88±0.05[a]	75.91±12.76	63.87±3.88[b]
	Samurai 1	4.87±0.06[d]	1.65±0.31[c]	0.98±0.05[a]	59.49±9.77	76.48±11.81[ab]
Wilting	Numbu	4.24±0.11[a]	1.26±0.14[b]	0.95±0.31[a]	59.49±16.58	100.39±7.16[cd]
	Super 1	4.50±0.06[b]	1.29±0.29[b]	0.95±0.10[a]	68.73±13.14	89.38±7.51[bc]
	Samurai 1	4.75±0.10[c]	0.63±0.03[a]	1.38±0.36[b]	57.44±6.70	112.12±14.10[d]
Wilting		**	**	*	NS	**
Variety		**	**	*	NS	**
Wilting x Variety		**	**	NS	NS	NS

N ammonia (NH_3-N); total volatile fatty acids (TVFA). Different superscript in the same column mean significant difference (P<0.05); * mean P<0.05; ** mean P<0.01; NS mean non-significant.

Table 4: The nutrient and fiber content of sorghum silage (% DM).

Items	Variety	DM	OM	CP	EE	NDF	ADF	ADL	Hemi	Cellu	NFC
Fresh	Numbu	22.32± 1.74[a]	87.60± 0.18[c]	6.97± 0.29[c]	2.99± 0.61[ab]	68.23± 2.08[c]	41.85± 1.74[b]	5.51± 1.66[ab]	26.38± 1.33[b]	36.34± 2.79[c]	9.41± 1.74[ab]
	Super 1	27.78± 0.35[b]	83.78± 0.35[a]	6.03± 0.16[ab]	3.38± 1.09[abc]	67.60± 0.99[c]	43.01± 0.85[b]	7.32± 1.13[ab]	24.59± 0.44[a]	35.69± 1.31[bc]	6.77± 1.59[a]
	Samurai 1	30.65± 0.28[b]	87.97± 0.28[c]	6.29± 0.01[ab]	3.39± 0.39[abc]	62.79± 1.24[a]	34.80± 0.72[a]	5.45± 3.09[ab]	27.99± 1.04[cd]	29.35± 3.03[a]	15.49± 1.26[d]
Wilting	Numbu	32.39± 0.36[b]	88.46± 0.36[d]	5.97± 0.05[a]	2.81± 1.19[a]	69.12± 2.37[c]	42.39± 1.55[b]	5.71± 1.56[ab]	26.73± 1.05[bc]	36.68± 2.57[c]	10.56± 2.95[bc]
	Super 1	32.24± 0.31[b]	86.40± 0.31[b]	6.26± 0.75[ab]	4.15± 0.39[bc]	66.40± 2.29[bc]	43.02± 1.80[b]	7.83± 3.18[b]	23.38± 0.68[a]	35.19± 3.16[bc]	9.59± 2.45[ab]
	Samurai 1	48.46± 0.07[c]	88.60± 0.07[d]	6.54± 0.23[bc]	4.64± 0.81[c]	63.89± 2.91[ab]	35.57± 1.75[a]	3.93± 1.25[a]	28.31± 1.23[d]	31.64± 2.35[ab]	13.53± 2.22[cd]
Wilting		**	**	NS	NS	NS	NS	NS	NS	NS	NS
Variety		**	**	**	NS	**	**	*	**	**	**
Wilting x Variety		NS	**	**	NS	*	**	NS	NS	NS	NS

Dry matter (DM); organic matter (OM); crude protein (CP); ether extract (EE); neutral detergent fiber (NDF); acid detergent fiber (ADF); acid detergent lignin (ADL); hemicellulose (hemi); cellulose (cellu); non fiber carbodydrate (NFC). Different superscript in the same column mean significant difference (P<0.05); * mean P<0.05; ** mean P<0.01; NS mean non-significant.

The *in vitro* degradability of whole-plant sorghum silage

The effect of ensiling on cumulative gas production after nine hours of incubation was significant (P < 0.01). Wilting treatments had no significant impact on all *in vitro* gas production parameters (Table 5). In contrast, variety differences had a significant impact on *in vitro* gas production (P < 0.01). Except for gas production rate (*c*), the interaction of wilted and different variety had a significant impact on all *in vitro* gas production parameters (P < 0.01). Fresh Samurai 1 and wilted Numbu sorghum had the greatest gas production (*a+b*) value (P < 0.05). As shown in Table 6, ensiling and different varieties had a significant effect on TVFA and IVOMD (P < 0.01). The ensiling process tended to decrease IVOMD in sorghum forage. In the ensiled groups, the Samurai 1 variety had the highest IVOMD values (P < 0.05).

Overnight wilting increases DM content both in conventional and sweet sorghum. In this study, the DM content of whole-plant sorghum was about 36.95–56.83% after wilting. Silage materials are often wilted to above 30% DM content before ensiling to reduce the chance of clostridial fermentation (Zheng et al., 2018). The increase in DM content after wilting was similar as reported by Oliveira et al. (2018), Agarussi et al. (2019) and Liu et al. (2020) in studies on elephant grass, alfalfa and whole-plant oats, respectively. The moisture of raw material was decreased after wilting treatments and at the same time soluble carbohydrate content was relatively improved (Jian et al., 2015). Agarussi et al. (2019) reported that the wilting process also increased lactic acid bacteria (LAB)

Table 5: The *in vitro* gas production characteristics of sorghum silage.

Item	Variety	Comulative gas production (ml/200 mg DM)							Gas kinetics			
		3	6	9	12	24	48	72	a+b	c	GPSF	GPNSF
Raw material												
Fresh	Numbu	6.74±0.28^{ab}	11.16±0.68^{bc}	15.80±0.88^{bc}	19.17±0.91^{bc}	36.72±1.85^{def}	49.96±2.30^{cde}	53.92±2.51^{cde}	58.15±2.91^{b}	0.040±0.002^{bcd}	30.36±1.38^{ab}	154.89±8.20^{c}
	Super 1	5.28±0.43^{a}	9.16±0.59^{ab}	13.62±0.29^{ab}	16.90±0.60^{ab}	33.46±1.40^{abc}	47.20±2.21^{bc}	51.19±2.15^{abc}	56.02±2.54^{ab}	0.037±0.001^{abc}	23.14±2.11^{a}	145.73±7.88^{bc}
	Samurai 1	10.08±1.09^{d}	15.77±1.19^{e}	21.35±1.33^{f}	25.26±1.32^{f}	42.93±0.94^{h}	55.62±0.96^{g}	59.65±0.98^{g}	62.60±0.87^{d}	0.045±0.001^{e}	46.89±5.40^{d}	169.55±1.75^{d}
Wilting	Numbu	8.61±1.03^{cd}	14.03±1.66^{cd}	19.33±1.63^{ef}	22.98±1.72^{ef}	41.59±1.30^{gh}	55.38±1.84^{fg}	59.27±2.05^{g}	63.10±2.16^{d}	0.042±0.001^{de}	39.60±5.11^{cd}	170.24±1.96^{d}
	Super 1	5.13±0.53^{a}	8.74±0.53^{a}	13.52±0.32^{ab}	17.26±0.33^{ab}	34.52±1.07^{bcd}	48.16±1.22^{bcd}	52.01±1.25^{bcd}	56.60±1.23^{ab}	0.039±0.001^{bcd}	22.39±2.63^{a}	151.87±4.46^{c}
	Samurai 1	8.74±0.60^{cd}	14.18±1.01^{de}	19.14±0.87^{de}	22.92±1.05^{ef}	39.10±3.08^{efg}	52.70±1.29^{ef}	56.36±1.09^{ef}	59.19±2.55^{bc}	0.041±0.005^{cde}	40.28±2.96^{cd}	156.83±14.42^{c}
Silage												
Fresh	Numbu	6.40±-.69^{ab}	10.82±1.27^{ab}	15.25±1.40^{bc}	18.85±1.49^{bc}	36.66±1.98^{def}	50.16±1.80^{de}	54.35±2.03^{de}	58.88±1.95^{bc}	0.039±0.002^{bcd}	28.69±342^{ab}	156.32±7.69^{c}
	Super 1	5.71±0.80^{a}	9.20±0.74^{ab}	12.81±0.73^{a}	16.19±0.74^{a}	30.87±0.71^{a}	44.38±0.60^{a}	48.69±0.23^{a}	54.16±0.66^{a}	0.03bcd4±0.002^{a}	25.26±3.96^{a}	130.32±5.29^{a}
	Samurai 1	8.96±1.73^{cd}	14.63±2.19^{de}	18.99±1.90^{de}	22.41±2.32^{de}	39.28±2.09^{fg}	53.44±1.72^{fg}	57.21±1.49^{fg}	61.49±1.31^{cd}	0.040±0.002^{bcd}	41.36±8.57^{cd}	156.63±4.43^{c}
Wilting	Numbu	6.42±2.31^{ab}	11.20±2.90^{bc}	15.27±2.98^{bc}	18.77±3.54^{bc}	36.00±3.83^{cde}	50.20±2.96^{de}	54.16±3.14^{cde}	59.08±2.64^{bc}	0.038±0.003^{abcd}	28.78±11.43^{ab}	152.88±7.84^{c}
	Super 1	5.86±0.30^{a}	9.96±1.11^{ab}	13.72±1.27^{ab}	16.88±1.26^{ab}	32.12±1.96^{ab}	46.20±1.46^{ab}	50.77±1.56^{ab}	56.45±1.38^{ab}	0.034±0.003^{a}	26.03±1.48^{a}	135.92±9.24^{ab}
	Samurai 1	7.89±0.26^{bc}	13.08±0.66^{cd}	17.08±0.92^{cd}	20.26±1.34^{cd}	36.41±1.47^{cdef}	49.72±1.79^{cd}	53.73±2.29^{cde}	58.01±2.28^{b}	0.037±0.005^{ab}	36.08±1.30^{bc}	147.42±6.79^{c}
Ensiling		NS	NS	**	**	**	**	**	*	**	NS	**
Wilting		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Variety		**	**	**	**	**	**	**	**	**	**	**
Ensiling x wilting		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Ensiling x variety		*	NS	NS	NS	NS	NS	NS	NS	NS	*	NS
Wilting x variety		*	*	**	**	**	**	**	**	NS	*	**
Ensiling x wilting x variety		NS	NS	NS	NS	NS	*	*	NS	NS	NS	NS

Dry matter (DM); optimum gas production (a+b); the rate of gas production (c); the gas production caused by fermentation of the soluble (GPSF) and insoluble fraction (GPNSF). Different superscript in the same column mean significant difference (P<0.05); * mean P<0.05; ** mean P<0.01; NS mean non-significant.

Table 6: The *in vitro* rumen fermentation characteristics of sorghum silage.

Item	variety	pH	NH_3-N	TVFA	IVOMD
			mg/100 ml	mM	%
Raw material					
Fresh	Numbu	6.60±0.22[abc]	3.86±0.42	40.00±7.01[ab]	51.46±1.74[cd]
	Super 1	6.71±0.09[bc]	3.95±0.43	66.67±5.16[de]	48.69±1.23[abc]
	Samurai 1	6.58±0.14[ab]	3.58±0.66	43.08±8.54[ab]	56.61±0.93[f]
Wilting	Numbu	6.55±0.14[ab]	3.65±0.24	46.16±3.93[abc]	55.39±1.04[ef]
	Super 1	6.52±0.10[ab]	3.69±0.20	40.00±9.10[ab]	49.72±0.99[bc]
	Samurai 1	6.41±0.13[a]	3.94±0.20	37.95±7.77[a]	53.41±2.62[de]
Silage					
Fresh	Numbu	6.63±0.03[bc]	3.37±0.35	69.24±5.89[e]	51.42±1.86[cd]
	Super 1	6.61±0.12[bc]	3.91±0.40	50.26±9.10[abc]	46.09±0.68[a]
	Samurai 1	6.62±0.08[bc]	3.44±0.55	51.29±5.30[bc]	53.41±1.87[de]
Wilting	Numbu	6.79±0.06[c]	3.63±0.23	64.11±12.01[de]	50.33±3.38[c]
	Super 1	6.60±0.07[abc]	3.60±0.21	56.42±7.01[cd]	47.14±1.85[ab]
	Samurai 1	6.66±0.13[bc]	3.72±0.24	49.24±7.49[abc]	50.93±1.39[cd]
Ensiling		**	NS	**	**
Wilting		NS	NS	NS	NS
Variety		NS	NS	**	**
Ensiling x wilting		**	NS	NS	NS
Ensiling x variety		NS	NS	**	NS
Wilting x variety		NS	NS	NS	**
Ensiling x wilting x variety		NS	NS	**	NS

N ammonia (NH_3-N); total volatile fatty acids (TVFA); *in vitro* organic matter digestibility (IVOMD). Different superscript in the same column mean significant difference (P<0.05); * mean P<0.05; ** mean P<0.01; NS mean non-significant.

from 5.28 log cfu/g to 6.88 log cfu/g. Silage quality could be improved after the raw material was wilted by several mechanisms: (1) reduced moisture content; (2) improved soluble carbohydrate content; (3) increased LAB activity; and (4) reduced pH value (Jian et al., 2015; Lyimo et al., 2016). Samurai 1 variety had the lowest fibre fraction content and the greatest NFC content, reflecting its characteristics as a sweet sorghum particularly used in the bioethanol industry (Wahyono et al., 2017). Sweet sorghum varieties are suitable materials for silage due to their rich fermentable sugar compounds which facilitate lactic acid fermentation (Yucel and Erkan, 2020).

Sensory evaluation is commonly used mainly by smallholders as an alternative way to determine the nutritive value of silage (Bretschneider et al., 2015). Despite Numbu and Samurai 1 varieties having higher total sensory score values than Super 1, all varieties were in the excellent category after wilting treatment. In the present study, overnight wilting improved all of the sensory scores, in line with most previous results. Lyimo et al. (2016) reported that wilted fodder grass had higher sensory scores than unwilted fodder grass. Fermentation and sensory quality of naked oats and alfalfa silage were significantly increased after overnight wilting (Jian et al., 2015). The difference in sensory score might be due to the difference in soluble carbohydrate availability, as used as an energy source for LAB fermentation and to increase DM content of silage (Rajabi et al., 2017). Higher scores for smell, colour and texture might have been due to increased concentration of DM and soluble carbohydrate content having led to a better fermentation process (Lyimo et al., 2016).

The pH values of sorghum silage in this study were about 4.24–4.92 while another recent study found the pH values of sweet sorghum as varying between 3.21–3.82 (Yucel and Erkan, 2020). The differences between these findings might be due to differences in ensiling times and microbial starter additions. We assume that the ensiling process in our study was aerobically unstable and that this would have affected inhibition of the fermentation process, as represented by a pH value above 4. However, this assumption needs to be further investigated. The variation of pH values in sorghum silage is considerably affected by levels of soluble carbohydrate, which in turn influence the development of LAB and cause pH reduction (Fernandes et al., 2020). After wilting, NH_3-N concentration in sorghum silage tends to decrease. This might be influenced by the higher DM content of wilted raw materials. High DM content in silage produces lower levels of NH_3-N (Vendramini et al., 2016). The reduction of NH_3-N concentration in wilted silage indicates that the decomposition of amino acids and protein has decreased (Jian et al., 2015). The decrease of proteolysis might be due to reduced moisture created by the wilting process, which in turn provides better conditions for fermentation (Lyimo et al., 2016). Wilting creates a more rapid fall in pH value, thus lowering proteolysis and deamination (Zheng et al., 2018). The greatest Brix value found in Samurai 1 represents either the high soluble carbohydrate contained in this variety (Wahyono et al., 2017) or that the ensiling process did not run perfectly due to soluble carbohydrate not having been maximally utilized by LAB. This is reflected by silage pH of above 4. This result might be due to the absence of LAB addition at the beginning of the ensiling process. The use of LAB inoculant is necessary to avoid poor ensiling (Borreani et al., 2009). According to the Fleigh point scale, the sorghum silage quality increased with wilting treatment before ensiling. Fleigh scale increased from good to very good. This might be due to the lower pH value in the wilted treatments than in unwilted materials. Wang et al. (2018) highlight that pH is an important indicator determining the quality of silage.

Overnight wilting increases DM and OM content of sorghum silage. This fact can be explained by the low moisture of the raw material leading to improved fermentation (Gomes et al., 2017). Organic content and microbial population are significantly increased by wilting (Wang et al., 2018). Wilting treatment did not affect the CP content or cell wall constituents (NDF, ADF, hemicellulose, cellulose, and ADL). A similar result was found by Jian et al. (2015) and Feng et al. (2019), these studies highlighting that wilting treatment did not influence the CP, NDF, and ADF content of naked oats, alfalfa and sweet sorghum silage, respectively. Furthermore, overnight wilting could lead to the raw materials containing high DM content, thus improving soluble carbohydrate availability.

Conversely, Liu et al. (2020) reported that overnight wilting increases NDF and ADF content due to epiphytic microbes (e.g. aerobic bacteria and yeasts) consuming increased soluble carbohydrates, thus increasing structural carbohydrate concentration. The lack of change in fibre fraction after wilting and ensiling also represents a suboptimal fermentation process. This is reflected in the pH value, which is above 4 (Table 3). Junior et al. (2015) demonstrated that the average pH value of sorghum silage was 3.64, and so pH values higher than 4 indicate the growth of undesirable microorganisms. In this case, the addition of LAB is necessary to improve the quality of silage products (Wang et al., 2018; Weinberg et al., 2010). Contradictory results were also demonstrated by Lymo et al. (2016) and Hung et al. (2020). The concentration of CP content of wilted taro (*Colocasia esculenta*) was higher than in taro silage made from fresh material (Hung et al., 2020). This difference might be due to different levels of protein solubility in the raw materials and the duration of ensiling. The differences in sorghum variety influence the composition of cell wall fractions in sorghum silage. Super 1 and Samurai 1 tends to produce a relatively low fibre fraction compared to Numbu. Sweet sorghum with its high soluble carbohydrate content is more suitable for silage production (Junior et al., 2015; Yucel and Erkan, 2020).

In vitro gas production and rumen fermentation represent nutrient quality and level of digestibility of feed materials (Wahyono et al., 2019, 2021). Wilting treatment had no significant impact on any of the degradability parameters as reflected by non-significant differences in CP, EE, NDF and ADF content. Differences in *in vitro* degradability characteristics are influenced by ADF and NFC content (Jayanegara et al., 2009; Wahyono et al., 2019). The volume of *in vitro* cumulative gases depends on the content of fibrous fractions and soluble carbohydrates, as well as on their total degradability (Oliveira et al., 2018). It is interesting to note that the IVOMD value of sorghum silages tends to be lower than non-silaged sorghum. Junior et al. (2015) demonstrated that the more digestible a sorghum variety is, the greater the loss of quality after the ensiling process, especially if the ensiling process does not proceed effectively.

CONCLUSIONS AND RECOMMENDATION

Wilting treatment influences the sensory score and chemical quality of sorghum silage. However, there is no effect on nutrient composition or *in vitro* digestibility. The effect of different varieties on the nutrient value of sorghum silage is more pronounced than the wilting variable. There is a significant interaction between variety and wilting treatment on sensory score and *in vitro* degradability. For good silage quality, wilted sweet sorghum is the choice of best material. Further studies are necessary to determine the nutrient value of whole-plant sorghum silage after LAB addition with a longer ensiling period.

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NOVELTY STATEMENT

Our results focused on the interaction between wilting treatment and sorghum varieties, and their effect on silage quality. Our findings report that there is an interaction between variety and wilting treatment on sensory score and *in vitro* degradability. Furthermore, our study introduces two varieties of local sweet sorghum from Indonesia as raw material for silage (Super 1 and Samurai 1). Our results shows that overnight wilted sweet sorghum produces high quality silage.

AUTHOR'S CONTRIBUTION

Teguh Wahyono designed the experiments, collected the data, wrote the first-draft and revised the manuscript. Wijaya Murti Indriatama, Setiawan Martono and Slamet Widodo prepared raw sample, performed chemical analyses and *in vitro* measurements. Widhi Kurniawan and Wahidin Teguh Sasongko checked data and revised the article draft. Muhamad Nasir Rofiq supervised the experiments and revised the article draft.

Conflict of interest

The authors have declared no conflict of interest.

REFERENCES

Agarussi MCN, Pereira OG, da Silva VP, Leandro ES, Ribeiro KG, Santos SA (2019). Fermentative profile and lactic acid bacterial dynamics in non-wilted and wilted alfalfa silage in tropical conditions. Mol. Biol. Rep., 46: 451–460. https://doi.org/10.1007/s11033-018-4494-z

AOAC (2005). Official Method of Analysis. Maryland: Association of Official Analytical Chemists.

Borreani G, Chion AR, Colombini S, Odoardi M, Paoletti R, Tabacco E (2009). Fermentative profiles of field pea (*Pisum sativum*), faba bean (*Vicia faba*) and white lupin (*Lupinus albus*) silages as affected by wilting and inoculation. Anim. Feed Sci. Technol., 151: 316–323. https://doi.org/10.1016/j.anifeedsci.2009.01.020

Bretschneider G, Mattera J, Cuatrin A, Arias D, Wanzenried R (2015). Effect of ensiling a total mixed ration on feed quality for cattle in smallholder dairy farms. Arch. Med. Vet., 47: 225–229. https://doi.org/10.4067/S0301-732X2015000200015

Conaghan P, O'Kiely P, O'Mara FP (2010). Conservation characteristics of wilted perennial ryegrass silage made using biological or chemical additives. J. Dairy Sci., 93: 628–643. https://doi.org/10.3168/jds.2008-1815

Conway EJ (1951). Microdiffusion Analysis and Volumetric Error, 3rd Ed. London: Crosby Lockwood and Sons Ltd.

Feng T, Tang H, Yang W, Tong L, Shi L, Niu X, Shen Y (2019). Effects of wilting and mixing straws on fermentation quality and nutrients preservation of sweet sorghum silage. J. Nanjing Agric. Univ., 42: 352–357.

Fernandes T, Paula EM, Sultana H, Ferraretto LF (2020). Short communication: Influence of sorghum cultivar, ensiling storage length, and microbial inoculation on fermentation profile, N fractions, ruminal *in situ* starch disappearance and aerobic stability of whole-plant sorghum silage. Anim. Feed Sci. Technol., 266. https://doi.org/10.1016/j.anifeedsci.2020.114535

Gomes RDS, Almeida JCD, Carneiro JDC, Azevedo FHV, Lista FN, Elyas ACW, Oliveira TSD (2017). Impacto da adição de polpa citríca e do emurchecimento na qualidade da silagem de capim-elefante. Bioscience, 33: 675–684. (in Portugese, English abstract).

Hung LT, Lan LTT, Thu NTA, Thiet N, Mo TTH, Nhan NTH, Ngu NT (2020). Effects of wilting and rice bran supplementation on the quality of taro (*Colocasia esculenta*) leaf and petiole silage. Livest. Res. Rural Dev., 32: 12041.

Jayanegara A, Sofyan A, Makkar HPS, Becker K (2009). Kinetika produksi gas, kecernaan bahan organik dan produksi gas metana *in vitro* pada hay dan jerami yang disuplementasi hijauan mengandung tanin. Trop. Anim. Sci. J., 32: 120–129. (in Bahasa, English abstract).

Jian G, Cuijun Y, Guihe L (2015). Nutritional evaluation of fresh and wilted mixed silage of naked oats (*Avena nuda*) and alfalfa (*Medicago sativa*). Int. J. Agric. Biol., 17: 761–766. https://doi.org/10.17957/IJAB/14.0003

Junior MAPO, Retore M, Manarelli DM, Souza FBD, Ledesma LLM, Orrico ACA (2015). Forage potential and silage quality of four varieties of saccharine sorghum. Pesqui. Agropecu. Bras., 50: 1201–1207. https://doi.org/10.1590/S0100-204X2015001200010

Kromann RP, Meyer JH, Stielau WJ (1967). Steam distillation of volatile fatty acids in rumen ingesta. J. Dairy Sci., 50: 73–76. https://doi.org/10.3168/jds.S0022-0302(67)87356-9

Liu QH, Wu JX, Dong ZH, Wang SR, Shao T (2020). Effects of overnight wilting and additives on the fatty acid profile, α-tocopherol and β-carotene of whole plant oat silages. Anim. Feed Sci. Technol., 260. https://doi.org/10.1016/j.anifeedsci.2019.114370

Lyimo BJ, Mtengeti EJ, Urio NA, Ndemanisho EE (2016). Effect of fodder grass species, wilting and ensiled amount in shopping plastic bags on silage quality. Livest. Res. Rural Dev., 28: 3597.

Menke KH, Raab L, Salewski A, Steingass H, Fritz D, Schneider W (1979). The estimation of the digestibility and metabolizable energy content of ruminant feedingstuffs from the gas production when they are incubated with rumen liquor *in vitro*. J. Agric. Sci. Cambridge, 93: 217–222. https://doi.org/10.1017/S0021859600086305

Menke KH, Steingass H (1988). Estimation of the energetic feed value obtained from chemical analysis and gas production using rumen fluid. Anim. Res. Dev., 28: 7–55.

Neves ALA, Santos RD, Pereira LGR, Oliveira GF, Scherer CB, Verneque RS, McAllister T (2015). Agronomic characteristics, silage quality, intake and digestibility of five new brazilian sorghum cultivars. J. Agric. Sci., 153: 371–380. https://doi.org/10.1017/S002185961400063X

Oliveira BS, Pereira LGR, Azevêdo JAG, Rodrigues JAS, Velasco FO, Neves ALA, Maurício RM, Verneque RDS, dos Santos RD (2018). Silage quality of six sorghum cultivars for sheep. Pesqui. Agropecu. Bras., 53: 256–264. https://doi.org/10.1590/s0100-204x2018000200015

Ørskov ER, Mcdonald I (1979). The estimation of protein degradability in the rumen from incubation measurements weighted according to rate of passage. J. Agric. Sci. Cambridge, 92: 499–503. https://doi.org/10.1017/

S0021859600063048

Ozturk D, Kizilsimsek M, Kamalak A, Canbolat O, Ozkan CO (2006). Effects of ensiling alfalfa with whole-crop maize on the chemical composition and nutritive value of silage mixtures. Asian-Austral. J. Anim. Sci., 19: 526–532. https://doi.org/10.5713/ajas.2006.526

Perazzo AF, Carvalho GGP, Santos EM, Bezerra HFC, Silva TC, Pereira GA, Ramos RCS, Rodrigues JAS (2017). Agronomic evaluation of sorghum hybrids for silage production cultivated in semiarid conditions. Front. Plant Sci., 8: 1–8. https://doi.org/10.3389/fpls.2017.01088

Pinho RMA, Santos EM, de Oliveira JS, Perazzo AF, de Sousa WH, de Farias Ramos JP, de Carvalho GGP, Pereira GA (2017). Performance of confined sheep fed diets based on silages of different sorghum cultivars. Rev. Bras. Saude Prod. Anim., 18: 454–464. https://doi.org/10.1590/s1519-99402017000300006

Rajabi R, Tahmasbi R, Dayani O, Khezri A (2017). Chemical composition of alfalfa silage with waste date and its feeding effect on ruminal fermentation characteristics and microbial protein synthesis in sheep. J. Anim. Physiol. Anim. Nutr., 101: 466–474. https://doi.org/10.1111/jpn.12563

Sriagtula R, Karti PDMH, Abdullah L, Supriyanto, Astuti DA (2017). Nutrient changes and *in vitro* digestibility in generative stage of M10-BMR sorghum mutant lines. Trop. Anim. Sci. J., 40: 111–117. https://doi.org/10.5398/medpet.2017.40.2.111

Van Gelder AH, Hetta M, Rodrigues MAM, De Boever JL, Den Hartigh H, Rymer C, Van Oostrum M, Van Kaathoven R, Cone JW (2005). Ranking of *in vitro* fermentability of 20 feedstuffs with an automated gas production technique: results of a ring test. Anim. Feed Sci. Technol., 124: 243–253. https://doi.org/10.1016/j.anifeedsci.2005.04.044

Van Soest PJ, Robertson JB, Lewis BA (1991). Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. J. Dairy Sci., 74: 3583–3597. https://doi.org/10.3168/jds.S0022-0302(91)78551-2

Vendramini JMB, Aguiar AD, Adesogan AT, Sollenberger LE, Alves E, Galzerano L, Salvo P, Valente AL, Arriola KG, Ma ZX, Oliveira FCL (2016). Effects of genotype, wilting, and additives on the nutritive value and fermentation of bermudagrass silage. J. Anim. Sci., 94: 3061–3071. https://doi.org/10.2527/jas.2016-0306

Wahyono T, Lelananingtyas N, Sihono (2017). Effects of gamma irradiation on ruminal degradation of Samurai 1 sweet sorghum bagasse. Atom Indonesia, 43: 35–39. https://doi.org/10.17146/aij.2017.620

Wahyono T, Sasongko WT, Sugoro I, Firsoni (2021). Nutrient value and digestibility variation of five rice straw cultivars in Indonesia as ruminant roughage. Adv. Anim. Vet. Sci., 9: 73–81. https://doi.org/10.17582/journal.aavs/2021/9.1.73.81

Wahyono T, Sugoro I, Jayanegara A, Wiryawan KG, Astuti DA (2019). Nutrient profile and *in vitro* degradability of new promising mutant lines sorghum as forage in Indonesia. Adv. Anim. Vet. Sci., 7: 810–818. https://doi.org/10.17582/journal.aavs/2019/7.9.810.818

Wang Y, Wang C, Zhou W, Yang FY, Chen XY, Zhang Q (2018). Effects of wilting and *Lactobacillus plantarum* addition on the fermentation quality and microbial community of *Moringa oleifera* leaf silage. Front. Microbiol., 9: 1–8. https://doi.org/10.3389/fmicb.2018.01817

Weinberg ZG, Khanal P, Yildiz C, Chen Y, Arieli A (2010). Effects of stage of maturity at harvest, wilting and LAB inoculant on aerobic stability of wheat silages. Anim. Feed Sci. Technol., 158: 29–35. https://doi.org/10.1016/j.anifeedsci.2010.03.006

Yucel C, Erkan ME (2020). Evaluation of forage yield and silage quality of sweet sorghum in the Eastern Mediterranean region. J. Anim. Plant Sci., 30: 923–930. https://doi.org/10.36899/JAPS.2020.4.0108

Zheng M, Niu D, Zuo S, Mao P, Meng L, Xu C (2018). The effect of cultivar, wilting and storage period on fermentation and the clostridial community of alfalfa silage. Ital. J. Anim. Sci., 17: 336–346. https://doi.org/10.1080/1828051X.2017.1364984