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Relationship between temperature, temperature-humidity index and amount of food intake of Sheep

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KEYWORDS

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Food intake

Hot season

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Temperature-humidity index

ABSTRACT

This study aimed to identify the relationship between temperature, temperature-humidity index (THI), and the amount of dry matter food intake (DMI) by sheep. Twelve Phan Rang (Ninh Thuan province) sheep belonging to three age groups of 6, 9, and 12 months (4 heads of each age group) raised in Thua Thien Hue province were fed with natural grass for two seasons: hot season (April-August) and cold season (November-February). Daily temperature, humidity, and food intake were recorded. The results of the study revealed that temperature and THI were closely correlated ($P<0.05$) with the amount of food intake by sheep. When the temperature was in the range of 29.5°C to 32.5°C and increased by 1° C, the DMI of sheep decreased by 14.7 g/BW/day. When the value of THI was more than 28.5 and rose by 1°C, the DMI of sheep decreased by 16.2 g/BW/day.

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1 Introduction

Sheep are isothermal animals and adapted to ambient temperature conditions. In Vietnam, since the 18^{th} century, sheep were raised in the Southern Central Region and the practice continues until now. Marai et al. (2007) stated that when the ambient temperature is going down, sheep needs more energy to maintain their body temperature and increase their food intake. Previous studies showed that sheep dry matter intake (DMI) was significantly reduced when they suffered heat stress (Savage et al. 2008; Alhidary et al. 2012; Tadesse et al. 2019). According to Marai et al. (2007) and Tadesse et al. (2019), the free grazing time regime also has a significant effect on the DMI of sheep. When it experienced cool temperature (from 7:00 AM to 11:00 AM) the DMI reached a higher level and when the temperature rose from 11:00 to 19:00 it is going down. The influence of seasons on DMI and digestibility of sheep was also reported by various researchers (Kamalzadeh et al. 1997; Li et al. 2012; Goetsch and Johnson1999). The lower DMI of sheep in summer or dry season and the warm temperature was found to be lower than that in autumn (Goetsch and Johnson 1999) as compared to cold season or cold environment (Li et al. 2012). Food intake was not only affected by ambient temperature but it is also affected by humidity. Therefore, many researchers have been proposed to study the effect of the temperature-humidity index (THI) to assess the heat stress of sheep (Paim et al. 2012; Marai et al. 2009; McManus et al. 2008).

In recent years Phan Rang sheep have been raised on large scale in the Thua Thien Hue province. Climate difference between the two provinces does influence the sheep husbandry practices due to the corresponding impact on their food intake. Statistics showed that the weather indexes in Thua Thien Hue and Ninh Thuan provinces differ markedly, in which the annual rainfall in Thua Thien Hue is much higher than that of Ninh Thuan (3,877 vs. 1,687 mm/year), the air temperature is lower (24.7^{o}C compared to 27.4^{o}C), and the air humidity is higher (87.3% vs. 79%). However, no study has been carried out on the effect of climate on sheep husbandry performance in this area. Therefore, this experiment aimed to identify the influence of temperature and humidity on the food intake of Phan Rang sheep raised in Thua Thien Hue, and recommend suitable solutions for sheep farmers to better the efficiency in livestock production.

2 Materials and methodology

2.1 Study sites and animal samples

The experiment was conducted on 12 Phan Rang sheep (males and females) with the three age groups ranging from 6, 9 to12 months (4 sheep in each age group) bought from Ninh Thuan province and nurtured at Thuy, Livestock Research Center, University of Agriculture and Forestry, Hue University, Thua Thien Hue province. Before the experiment, Helmin and worms were removed from sheep by orally administering with 12 mg/1 kg BW albendazole (Han-Dertil-B, Hanvet).

2.2 Feeds, feeding, and composition

Sheep were fed with daily collected natural grasses, dried at 60^{o}C for 72 hours, and daily left over's were also collected and weighted to calculate daily dry matter intake

As per the National Research Council US (1981) the dietary composition of nature grass is as follows: DM = 20.5%; OM = 87.9%; CP% = 10.5; NDF = 60.1% and Total of Energy (3742 Kcal/kg, 12.1 % of Ash).

2.3 Housing and management

Sheep were numbered for tracking and captured individually in each cage whose dimension was 0.8 x1.5 m. All cages were placed on floors leveled approximately 0.2 m higher than the ground, with holes in the floor for manure collection. The barn has enough windows to ensure ventilation systems on top. In each cage, there is a trough for roughage, a trough for fine food, and drinking water. All sheep were kept in cages throughout the examination time and only left for free grazing once at weekends when no data is collected.

2.4 Data and variables

For collecting the data regarding the barn's temperature and humidity of the study area an automatic Hygro - Thermometer (France) was used at the following time points: 1:00; 4:00; 7:00; 10:00; 13:00; 16:00; 19:00 and 22:00 on consecutive days in both seasons. The hygro-thermometer was placed at a height similar to that of an adult sheep, which is 0.8 m from the ground and 0.6 m from the barn floor. The daily recording of THI at different times of the day during the experiment was calculated using the formula of Marai et al. (2000): $THI = T^{o}C – [(0,31 – 0,31*RH/100)(T^{o}C - 14,4)]$, in which T ^{o}C; air temperature ^{o}C; RH: air humidity (%).

Daily food intake was collected at 5 meals (7:00, 9:00, 13:00, 16:00, and 21:00 h) and the amount of food to be fed was 3% (DM) of the sheep weight; while daily left over's were also collected and weighted to calculate daily dry matter intake. Sheep were weighed at the beginning of each stage and the average weight in each stage, which served to calculate the intake per mass weight.

2.5 Data analysis

Data were recorded by Microsoft Excel and processed using descriptive statistics and analysis of variance (ANOVA) through the model (GLM) on Minitab version 15.10 (2010). Nonlinear regression analysis was carried out by using the following quadratic equation: Y = ax2 + bx + c; where Y is the amount of food intake (g DM/kg BW); x: is temperature or THI, according to the method by Tadesse et al. (2019.

3 Results

3.1 Variables (temperature, humidity, and THI)

The results of the study showed the variation in temperature, humidity, and THI at 8 timelines of the day (1:00, 4:00, 7:00, 10:00, 13:00, 16:00, 19:00, and 22:00, consecutively) during two seasons i.e. hot season (HS) and cold season (CS) and are illustrated in Figure 1. Results of the study revealed that the temperature and THI of the cages in the cold and hot seasons tended to fluctuate according to the general rule, which is “the lowest value was reported from 1 to 4 o’clock and increased gradually later on”. These parameters reached the maximum at 13 o’clock, and then gradually decreased until 22 o’clock. Further, trends of humidity changes are antipodes with temperature and THI, and it reached the peak from 1 to 4 o’clock and decreased gradually, later on, these results correspond with Tadesse et al. (2019). The temperature was lowest between 22:00 and 4:00 of the following day, with an average of 21.1^{o}C in CS and 27.9^{o}C in HS. The highest temperature was at 13 o'clock and at this time, the average temperature was reported to be 26.70°C in the cold season and 35°C in the hot season. The difference in temperature during the cold season was greater than in the hot season, which was realized in the early morning at 7 o’clock with a temperature of 9^{o}C of the hot season, and 13:00 o’clock of the cold season. Results of three hotter months (June to August) of the summer season showed that the amount of food intake has been changed by the time (Table 1). Further, food intake frequency results of cold seasons 3 months (from December to February of the following year) also showed that there is an effect of temperature and humidity food intake (Table 2). An average of THI also indicated different values between hot and cold season and a food intake (Table 3), and suggested the impact of temperature stress on the sheep food intake.

Table 1 Fluctuation of the temperature and humidity in the hot season (n= Fn)

Humidity (%)		< 50	50 - 60	61 - 70	71 - 75	76 - 80	81 - 90	91 - 100	Total
Temperature (^{0}C)	24						2		2
	25					1	4		5
	26					3	14	5	22
	27				6	13	31		50
	28			6	8	29	60		103
	29			9	27	49	20		105
	30			13	21	19	8		61
	31		1	29	9	4	3		46
	32		6	24	5	2			37
	33	1	14	39	1				55
	34	3	18	12	3	3			39
	35	4	41	14	2	1			62
	36	7	18						25
	37	9	7	1					17
	38								
	39			1					1
	40								
	Total	24	105	148	82	124	142	5	630

Fn = Number of appeared frequency in amount changes

Table 2 Fluctuation of the temperature and humidity in the hot season (n= Fn)

	Humidity (%)	< 50	50 - 60	61 - 70	71 - 75	76 - 80	81 - 90	91 - 100	Total
Temperature (^{0}C)	16							1	1
	17						3	13	16
	18						5	19	24
	19						2	34	36
	20						5	33	38
	21						19	25	44
	22			1	2	2	19	31	55
	23				2	1	22	27	52
	24			2	1	3	22	10	38
	25				1	5	22	12	40
	26			3		5	19	1	28
	27			2	2	9	7		20
	28			2	4	1	3		10
	29			4	7	1			12
	30		1	6	1		1		9
	31			5	1				6
	32		2	3					5
	33		4	4					8
	34	1	1						2
	Total	1	8	32	21	27	149	206	444

Fn = Number of appeared frequency in amount changes

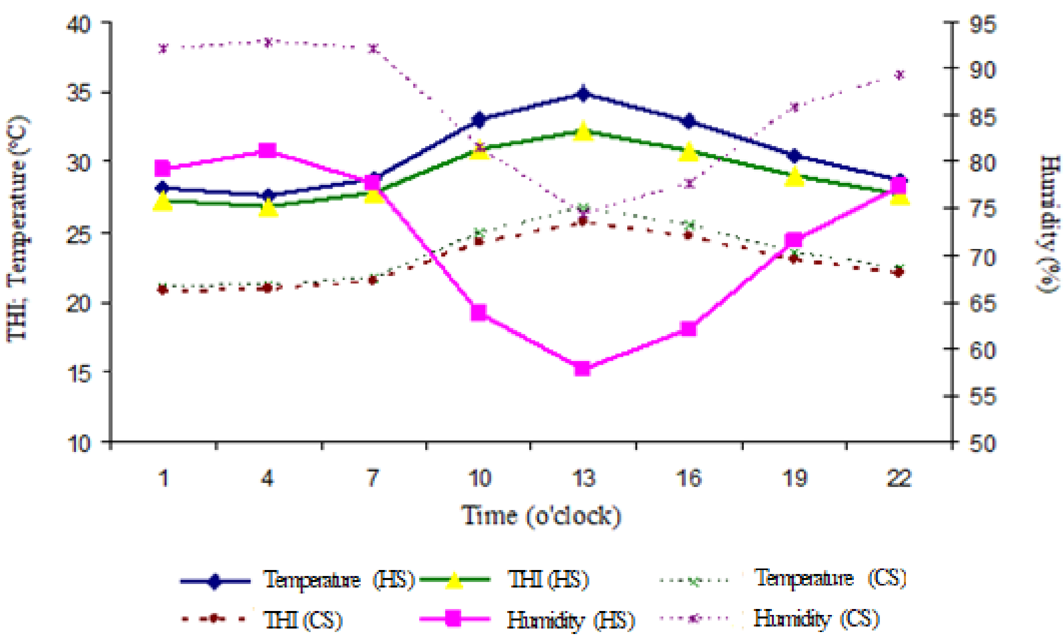

Figure 1 Variation in temperature, humidity, and THI in seasons

Table 3 Frequency of THI occurrence at predetermined hours daily in the hot and cold seasons (n = Fn)

Hour in a day	Hot season				Cold season			
	≤ 22.2	22.3 – 25.6	25.7 – 28.5	> 28.5	≤ 22.2	22.3 – 25.6	25.7 – 28.5	> 28.5
1		5	75	4	43	16	1	-
4		8	73	-	40	19	1	-
7		2	69	16	34	20	6	-
10		-	9	78	14	20	19	7
13		-	-	83	11	20	17	12
16		1	6	73	18	17	18	7
19		1	25	58	28	20	11	1
22		1	63	18	31	23	6	-
Total		18	320	330	219	155	79	27

Fn = Number of appeared frequency in amount changes

3.2 Relationship between temperature and feed intake

The relationship between the temperature and food intake of sheep have been represented in Figure 2, this suggested a correlation between the amount of food intake and the barn temperature, as follows: Y1 = -0,0874x12 + 3,0284x1 + 23,861 (R2 = 0.81; P = 0.001), where Y1: amount of food intake (gDM/kg BW/day); x1: temperature (0C). According to Tadesse et al. (2019), the R2 value is more important than the P-value when using regression analysis. When calculating the amount of food intake of sheep at every 0.5^{o}C temperature difference, it was reported that when the temperature was equal to or higher than 22.5^{o}C, the average amount of food intake of sheep was 49.3 gDM/kg BW/day (100%). With the increase of temperature, the amount of food intake of sheep tended to decrease, but not much. Further, when the temperature was in the range of 22.5^{o}C to 29.5^{o}C, the amount of food intake of sheep decreased approximately 9.2 gDM/BW/day, and overall 18.7% reductions were reported as compared to equal to or lower than 22.5^{o}C. Remarkably, when the temperature increased >29.5^{o}C, the food intake dropped by approximately 11.6 gDM/BW/day and showed a decrease of 23.5% compared to the temperature ≤ 22.5^{o}C (P<0.05) (Table 4).

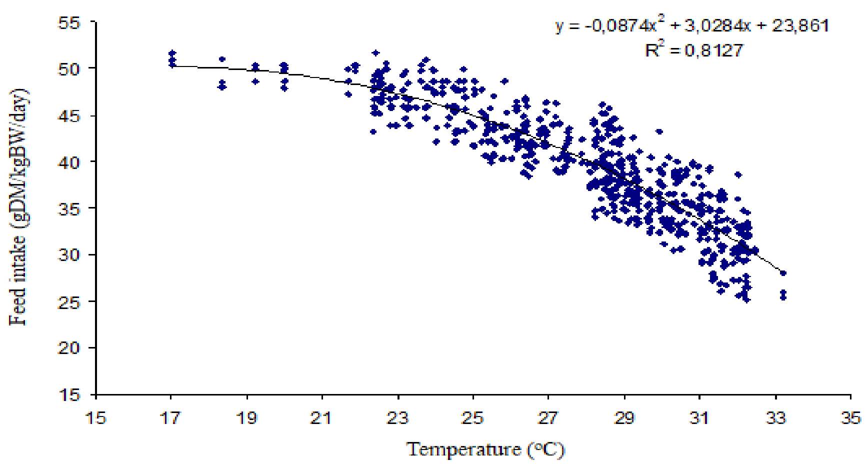

Figure 2 The relationship between barn temperature and food intake of sheep

Table 4 Temperature milestones affecting feed intake

Temperature (^{0}C)	Food intake (gDM/BW/day)	
	Fluctuation range	M ± SEM
≤ 22.5	47.6 – 51.0	49.3^{a*} ± 0.98
22.6 – 26.3	42.7 – 47.4	45.2^{b} ± 0.85
26.4 – 29.5	36.8 – 42.9	40.1^{c} ± 0.98
> 29.5	26.4 – 36.1	37.7^{d} ± 0.91

*Data with different exponents in the same column are significantly different (P<0.05)

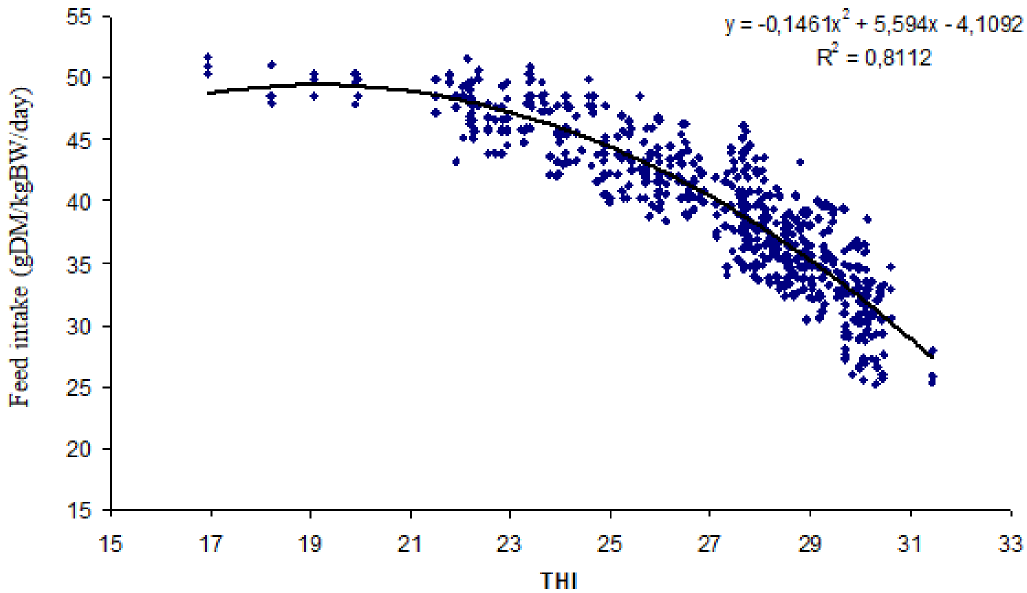

Figure 3 The relationship between THI cage and food intake of sheep

Table 5 THI milestones affecting feed intake

THI	Food intake (g DM/BW/day)	
	Fluctuation range	M ± SE
≤ 22.5	48.0 – 51.0	$49.11^{a*} \pm 0.75$
22.6 – 26.3	46.1 – 47.7	$46.78^{ab} \pm 1.15$
26.4 – 29.5	43.6 – 47.6	$45.15^{b} \pm 0.81$
> 29.5	39.3 – 42.6	$41.09^{c} \pm 0.81$
≤ 22.5	26.4 – 36.0	$32.27^{d} \pm 0.81$

*Data with different exponents in the same column are significantly different (P < 0.05)

3.3 Relationship between THI and feed intake

The relationship between the THI and food intake of sheep is illustrated in Figure 3 and it showed a correlation between THI and food intake of sheep as the following equation: Y2 = -0,1461x22 + 5,594x2 - 4,1092; R2 = 0,81; P = 0,001; where Y2: the amount of food intake (g DM/kg BW/day); x2: THI.

The calculation of the THI value showed that when the THI was ≤ 22.2°C, the average food intake of sheep was 49.11 gDM/kg BW/day (100 %). Further, when the THI was > 22.2 - 25.6°C, the amount of food intake of sheep was not significantly different (P > 0.05) but with the increase to temperature from 25.6 - 28.5°C increased the rate of THI which slightly decreased the rate of sheep food intake (approximately 8.02 gDM/BW/day), it was showing overall 16.3 %, reduction as compared to the THI at ≤22.2°C. Similarly, when the temperature range between >28.5 - 31.5°C, THI was also increased and the food intake of sheep decreased remarkably, with an average reduction of 16.84 gDM/BW/day and it was approximately 34.3% less as compared to THI ≤22.2°C (P< 0.05) (Table 5). Further, with the increase of THI value from>28.5 - 31.5°C and for every increase of 1°C, the food intake of sheep decreased by 6.1 - 15.2 g/DM/BW/day (compared to THI ≤ 22.2°C). Specifically, when THI increased from 28.5 - 29.5°C, 29.5 - 30.5°C, and 30.5 - 31.5°C, food intake decreased by 11.4, 17.6, and 19.6 gDM/BW/day respectively.

4 Discussions

According to Srikandakumar et al. (2003), at a temperature of 32°C and 65% of humidity, sheep started to suffer from heat stress. Under conditions of high ambient humidity and low temperature, the mechanism of heat loss through the skin does not work, so the sheep must increase the respiratory rate to expel heat (Srikandakumar et al. 2003; McManus et al. 2008; Alhidary et al. 2012). Thus, it is noteworthy that in hot seasons, although the temperature is high, the frequency of occurrence of high humidity levels accounts for a large proportion. Thua Thien Hue Province, where the air contains a large amount of water vapor, is one of the regions with the highest air humidity in Vietnam. In the cold seasons, high air humidity (> 80 %) accounted for a large proportion (79.95 % of the total measuring hours) and was predominantly associated with low air temperatures (< 27 0C). High air humidity combined with low air temperature can cause cold stress in sheep. Thus, in the cold seasons, high humidity (> 80 %) accounted for a large proportion. In winter, Thua Thien Hue province experiences prolonged drizzles and northeast monsoons causing quite high humidity.

When THI rises, body temperature (Srikandakumar et al. 2003; Marai et al. 2007; 2009; Alhidary et al. 2012), respiratory rate (Srikandakumar et al. 2003; Marai et al. 2007; Savage et al. 2008; Alhidary et al. 2012), and skin temperature of the sheep found increases (Bhatta et al. 2005; McManus et al. 2008; Marai et al. 2009), and this temperature rise reduced the food intake (Marai et al. 2007; Savage et al. 2008; Alhidary et al. 2012). This point is worth noting when raising sheep in hot seasons in Thua Thien Hue, where high air humidity accounted for a large proportion of time in both hot and cold seasons. These results suggested that during the hot seasons when the temperature and the humidity were both reported high, it could cause stress in sheep. These weather features are very different from those of Ninh Thuan province and other localities across the country where sheep are raised (Table 3). At temperatures of >29.5 - 32.5°C, for every 1°C increase, the amount of food consumed by sheep decreased by 12.2 - 17.2 g/DM/BW/day. Specifically, when the temperature increased from 29.5 - 30.5, 30.5 - 31.5, and 31.5 - 32.5°C, the amount of food intake decreased by 12.2, 14.7, and 17.2 gDM/BW/day, respectively. The results of this study are consistent with previous studies by Ames and Brink (1977) and Keyserlingk and Mathison (1993).

According to Ames and Brink (1977), when the temperature was in the range of 5 – 30°C, the food intake of sheep did not change but when the temperature was < 5°C, the amount of food intake increased; and when the temperature was > 30°C, the amount of food intake decreased. Similarly, Keyserlingk and Mathison (1993) reported that when the temperature is in the range of 5 – 21°C, there was no influence on the food intake of sheep. According to Alhidary et al. (2012), when the environment temperature exceeded 30°C, heat stress occurred, resulting in a decreased DMI of sheep. The dry matter intake of Merino sheep (Australia) at room temperature of 16 – 24°C was 1008 g/day (3.33% BW) and it reduced 234 g/day (23.2 %) and reported 774 g/day (2.65 % BW) at 28 – 38°C (Alhidary et al. 2012). Similarly, Savage et al. (2008) reported that the DMI of sheep at room temperature of 20°C was 1,578 g/head/day (3% BW) and at a temperature of 30 – 40°C was decreased to 1,136 g/day (2.4% BW).

Other authors stated that when sheep expose a high ambient load heat, they will lose energy to maintain a stable body temperature, leading to an increased respiratory rate, water intake, and reduced food intake (Alhidary et al. 2012; Savage et al. 2008; Marai et al. 2007). However, sheep are less sensitive to heat stress than other cattle under the same environmental conditions. In addition, water shortages, unbalanced diets, and undernutrition conditions increase the heat stress in sheep (Marai et al. 2007). Studies have shown that the food intake of sheep is significantly reduced in high-temperature environments (Marai et al. 2007; Savage et al. 2008; Alhidary et al. 2012). Other studies have proven similar results, which showed higher food intake in autumn than in summer (Goetsch and Johnson 1999), higher food intake was reported in cold environments as compared to the warm environments (Li et al. 2012), and lower food intake was reported in the hot-humid and hot-dry environments as compared to the cold-dry and cold-humid environments (Guerrini 1981). According to Pluske et al. (2010), the environmental temperature during the year affects the amount of food intake of sheep. Thus, the results of this experiment are completely consistent with the above studies.

Conclusions and Recommendations

Temperature and THI were strongly correlated ($P < 0.05$) with the food intake. In the condition of temperature which was in the range of 29.5 - 32.5°C, for every 1°C increased, the sheep food intake decreased by 14.7 gDM/BW/day and the THI value was > 28.5. For every increase of 1°C value, the food intake of sheep decreased by 16.2 gDM/BW/day.

The natural conditions of Thua Thien Hue province (700 km north to Binh Thuan province) can be suitable for the application of sheep housing and farmers can raise these animals with adaptation to increase the efficiency of householders' income.

Ethics approval and consent to participate

All animals and samples were applied as per the international, national, regional, and institutional guidelines for animal care and rules in Vietnam. The approved animal slaughter license number is HU VN 0004.

Conflict of Interest

The authors report no conflict of interest

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Authors' contributions

All authors discussed and designed the experiments. Bui Van Loi, Nguyen Xuan Ba, Le Duc Ngoan, and Nguyen Quang Linh conducted the main experiments and data analysis. All authors wrote, read, and agreed on the final manuscript.

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