Effects of roughage particle length on growth performance and physiological changes and heat tolerance of crossbred beef heifers (*Bos indicus*) in the tropics

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บทคัดย่อ

การทดลองนี้มีวัตถุประสงค์เพื่อศึกษาผลกระทบของความยาวของอนุภาคฟางข้าวและหญ้าสดแบบตัดสั้น ต่อสมรรถภาพการเจริญเติบโตของโคเนื้อจำนวน 10 ตัว (*Bos indicus*) เลี้ยงด้วยฟางข้าวและหญ้าสดที่เป็นรูปแบบตัดสั้น ผลการวิจัยได้กล่าวถึงการผลิตความร้อนเมื่อเลี้ยงโคเนื้อ ด้วยรูปแบบทางกายภาพที่แตกต่างกันของอาหารหยาบ จากผลการวิจัยแสดงให้เห็นว่าปริมาณอาหารที่กิน (DM) และการบริโภคน้ำไม่ได้รับอิทธิพลจากความยาวของอนุภาคอาหารหยาบที่ให้แก่โคเนื้อ (Chopped > Unchopped; P> 0.05) ความเข้มข้นของ cortisol และ TF3 ยังคงมีความสอดคล้องกัน (Unchopped> chopped; P> 0.05) แสดงให้เห็นว่าโคเนื้อมีความเครียดจากการกินอาหารที่มีอนุภาคยาว แต่ความร้อนที่ถูกสร้างขึ้นนั้นไม่มีผลต่อ ปริมาณอาหารหรือน้ำที่กินได้ของโคเนื้อ (P> 0.05) ถึงแม้ว่าอุณหภูมิทวารหนักและอุณหภูมิผิวหนังจะมีค่าสูง SknT (P <0.01) อีกทั้งยังไม่มีผลต่ออัตราการเจริญเติบโตของโคเนื้อ ADG (Unchopped <Chopped; P> 0.05) ดังนั้นผลการวิจัยของฮอร์โมนที่มีความแตกต่างกันในการทดลองครั้งนี้อาจเป็นผลจากความเครียดอื่นที่ไม่ใช่ความร้อนในการลดอนุภาคของอาหารหยาบ ซึ่งการลดอนุภาคอาหารหยาบแบบสับไม่ได้ช่วยให้โคเนื้อทนร้อนได้มากขึ้น

คำสำคัญ: ความร้อนเครียด, การเคี้ยว, ความยาวอนุภาค, กระบวนการสร้างความร้อนในการย่อยอาหาร

Abstract

An experiment was designed to investigate the effects of roughage particle length on the growth performance of cattle. Ten beef heifers (*Bos indicus*) were fed with chopped or long physical form (unchopped) rice straw or fresh grass. The results were discussed in terms of heat production when the animals were fed with different physical forms of roughage.

The results indicated that both roughage DM intake and water intake were not influenced by particle length (Chopped > Unchopped; P>0.05). Hormone concentration of

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both cortisol and TF3 remained consistent (Unchopped > chopped; P>0.05), indicating that the animal was being stressed by feeding on long unchopped roughage, but the heat that was generated had no effect on the animal. Finally, both RT (P > 0.05) and SknT (P < 0.01) of animals fed unchopped rice straw were higher than those animals that were fed the chopped straw – without affecting ADG (P > 0.05).

Therefore, while less heat was produced by masticating chopped feed particles, the differentce was not great enough to exert benefit to heat stressed cattle. Hence, the hormone results could have been exerted by stressors other than heat – that is, possibly emotional stress. It was concluded that chopping of roughage could not ameliorate heat stressed cattle.

Keywords: heat stress, chewing, particle length, thermogenesis

Introduction

Rice straw, a by-product from paddy cultivation, and poor quality roughage (Doyle et al., 1986) is traditionally fed to animalsduring periods of feed shortage. It does not, however, provide adequate nutrients for maintenance. Under experimental conditions as well as field conditions, it has been shown that buffaloes (Wanapat, Sriwattanasombat and Chanthai, 1984; Wongsrikeao and Wanapat, 1985), cattle (Mclennan, Wright, and Blight, 1981; Wanapat et al., 1982, 1984; Suriyajantratong and Wilaipon, 1985) and sheep (Vijchulata and Sanpote, 1982), fed straw alone lose weight. This is due to the low nutritional value of this highly lignified material (Sarnklong, et al., 2010). However, it can be utilized as a roughage component to prevent acidosis in concentrated feeding (González et al., 2012).

The effects of rice straw particle size in the feed of ruminant animals have been reported (Gunun, Wanapat and Anantasook, 2013; Wang et al., 2011; Zhaoa et al., 2009; Shen, Ni and Sunstol, 1998) in several studies. Information on other feedstuff (i.e. barley straw, alfalfa forage, corn straw, and etc.) may not be easily applicable to rice straw because of differences in chemical composition and the physical form of the fibre (Mertens, 1997; Plaizier et al., 2008).

In tropical countries, cattle are often subjected to heat stress. In hot climates, extra heat load to animals should be avoided in an attempt to negate heat stress. Internal heat load comprises metabolic heat, which includes heat from fermentation, and heat from muscle movements including those from movement of muscles associated chewing and grazing (Virot et al., 2017). Characteristics of the food, such as moisture content and hardness, are known to influence the masticatory process. Food hardness is sensed during mastication and affects masticatory force, jaw muscle activity, and mandibular jaw movements (van der Bilt et al, 2006).

The energy cost of eating has been said to constitute an appreciable part of the extra maintenance requirement of the grazing animal (Osuji, 1971; Webster, 1972). The muscular activities of prehension and mastication, plus the secretory activities associated with feeding, are essential components contributing to this complexity. Therefore, the study of heat production associated with eating, especially its contributions to the total heat increment of an animal, may lead to a better understanding of the physiology of forage utilization. This is particularly so with regard to energy requirements and effects arising from the physical form of the diet on the productivity of ruminants. Cattle activities which involve muscle movement, including those associated with mastication and grazing, will cause thermogenesis (McDowell, 1972; Reece, 2015a; Reece, 2015b).

These extra muscular activities, might increase the maintenance energy requirements of animals. It is suggested that this increased requirement might be due to the energy cost of eating and the work of digestion done by the gut in handling bulky pasture-materials (Osuji, 1974).

Crop residues can be ground, soaked, pelleted or chopped to reduce particle size (Kumar et al., 2014). Furthermore, mechanically processed roughage is typically used in finishing diets to improve mixing characteristics and rumen digestibility. (Weiss et al., 2017).

Usually the straw is fed *ad libitum* in a long form when it is collected and stored, but some physical processing methods such as chopping or grinding may be applied to reduce wastage and to facilitate feeding. Chopping or grinding of rice straw does not alter the cell wall structure in such feeds. Rice straw is often fed with concentrates to dairy cattle (Gunun, Wanapat and Anantasook, 2013).

Roughage source (Gencoglu, and Turkmen, 2006) may have an effect on the chewing activity and rumen pH. Chewing activities involve muscle movements which generate heat (Frandson, Wilke and Fails, 2009; Reece, et al., 2015), which is also then loaded to the animal. Reduction in this activity should thus reduce heat load, heat stress. Zhaoa et al. (2009) reported that, in goats, there was a significant ($P < 0.05$) increase in chewing activity as particle length of dietary rice straw increased.

Heat stress usually leads to loss of production. As the animal receives heat from environment and from within its body, ameliorating heat stress could be achieved by lowering heat input from the environment and from within the animal's body (Khongdee, Sripoon and Vajrabukka, 2011); Vajrabukka, 1992). The latter could be done by lowering body activities as a result of lowering heat production from a diet via physical form manipulation and other activities.

Therefore, an experiment has been designed to investigate the effects of particle length of roughage {rice straw (RS) and grass (GR)} on growth performance and physiological changes of crossbred beef heifers (Hindu Brazil X Brahman) in the tropics

Method and materials

Animal: A herd of Hindu Brazil – Brahman cross (50% Hindu Brazil X 50% Brahman) was maintained at the Chainat College of Agriculture and Technology, Chainat Province (latitude 15° 16′ N, longitude 100° 06′ E and at 18 m above sea level). The study was carried out at the college for 157 days.

Ten beef heifers, approximately of 2 years of age (average weight = 240 kg,) were randomly selected from the above herd of cattle and used in the present experiment. They were divided randomly into two groups of equal size and assigned to treatments 1 and 2 for the Part I and Treatment 3 and 4 for the Part 2. Therefore, the experiment was divided into two parts: in Part I {the cattle were offered Chopped rice straw (RS_{chop}) and Unchopped rice straw (RS_{unchop})}; and in Part II the RS was switched over to grass (GR) and the cattle were then offered Chopped grass (GR_{chop}) and Unchopped grass (GR_{unchop}). The data was treated as a 2 X 2 experiment.

Treatment:

Treatment 1 Five crossbred beef heifers were maintained in an open shed (5 × 10 m) and were offered with RS_{chop}.

Treatment 2 Another five crossbred beef heifers similar to the above group of cattle were maintained in an open shed (5 × 10 m), similar to treatment 1, but were offered with RS_{unchop}.

Treatment 3 Five crossbred beef heifers were kept in the same housing as for Treatments 1 and 2 and were offered with GR_{chop}.

Treatment 4 Five crossbred beef heifers were kept in the same housing as for Treatments 1 and 2 and were offered with GR_{unchop}.

A period of 14 days was allowed for adaptation, and all animals were injected with Ivermac® subcutaneously at 14 days prior to the commencement of the experiment. Roughage and concentrates (Table 1) were used in the present experiment. The animals were group fed twice daily. While the roughage was fed *ad libitum*, the amount of concentrate (commercially produced) offered to the animals was don in accordance with NRC (2001). Water was available to the animals at all times. The feed was analysed (Van Soest et al., 1991; AOAC, 2000) and shown in Table 1.

Animal housing: The animal housing was a free-stall type of open shed, orientated along East–West direction and with the front facing North. The animal house was fitted with a corrugated galvanized iron roof and had a highest height point of 4 m above the ground with a slope of 0.375 m/m.

Eqiupment: Thermometers (mercury in glass) comprising Wet and Dry Bulb thermometer Shanghai Yilian Control Temperature Apparatus Factory, Yangpu, Shanghai, China (Mainland)] and Black Globe thermometer (BG, Somparn, 2004), were placed at each pen both inside (middle of the pen) and outside (2 m) away from the animal house at a height of 160 cm above floor i.e. beyond the reach of the animals. The values of the Black Globe thermometer, WB, DB, THI and shed temperatures from both Inside and Outside shed were collected daily at 08:00, 14:00 and 17:00 h. The inside temperatures were collected from the underside of the roofs using an Infrared Thermometer (Infrared Thermometer Model ST-660, Sentry Optronics Corps., China).

The caluculation for temperature humidity index (THI) is determined using Armstrong's (1994) formula as follows:-

$THI = T_{db} + 0.36(T_{dp}) + 41.2$

T_{db} = dry bulb temperature (^{o}C)

T_{dp} = dew point temperature (^{o}C).

Blood Sampling: Blood samples were drawn from the coccygeal vein at weekly intervals. They were then transferred to a laboratory where they were spun with a centrifuge at 3000 rev/min to separate the serum, which was then stored at -20^{O}C for further analyses. The blood serum samples were analyzed for Cortisol and Free Triiodotyronine (FT_3) at the Hormones Laboratory, Faculty of Medicine, Chulalongkon University using Elecsys 2010/1010 (Roche, Mannheim, Germany) to detect FT_3 and (Siemens Medical Solutions Diagnostics, Erlangen, Germany) to measure cortisol.

Statistical Analysis: Statistical analysis: the experiment was of Completely Randomized Design (CRD) and used ANOVA to find the difference between RS, GR, Chopped and Unchopped (Steel and Torrie, 1980; Duncan, 1955).

T-test was used PROC TTEST (SAS, 2000) to find the difference between treatment and mean values. These are shown with ± SD (Standard Deviation).

Results And Discussion

Scince the heifers were housed at all times during the experimental period, the results of Temperature Humidity Index (Table 1; THI) revealed that they were subjected to heat stress during the later part of a day (14:00 – 17:00 pm.) especially during an early afternoon, when the THI value of outside shed was significantly (P<0.01) higher than that of the inside shed. Therefore, it can be seen (Table 1) that roof effectively protected (P<0.01) the cattle from solar radiation. The results indicated that both groups of heifers were exposed to heat stress during day time, with those under the animal house being stressed more during the experimental periods.

Table 1. Temperature Humidity Index (Mean±SD) measured at 8:00 am., 14:00 and 17:00 pm. under inside (IS) and outside (OS) of the sheds.

Time	IS±SD	OS±SD	P value
08:00	71.73±3.39	72.29±3.49	0.4421
14:00	81.13±3.56^{b}	86.73±3.39^{a}	<0.0001
17:00	79.36±2.81^{b}	80.80±2.91^{a}	0.0015

a, b – Means within a row with different superscripts are highly significantly different (P<0.01).

Table 2. Feed compositions of rice straw (*Oryza sativa*), mixed grass and concentrates.

	Rice Straw	Mixed Grass	Concentrates
Moisture(%)	7.04	7.8	7.63
Protein (%)	5.26	7.92	18.83
Lipid (%)	1.21	2.4	4.83
Ash (%)	13.72	9.73	11.74
Total fibre (%)	30.91	26.55	9.16
NDF (%)	69.08	61.97	31.31
ADF (%)	48.1	34.93	18.48
Ca (%)	0.22	0.4	1.38
P (%)	0.01	0.24	0.98
NaCl (%)	0.25	NA	0.45

Muscle movements and heat production

Since any muscle movement always creates heat (Nowack et al., 2017; Poole and Erickson, 2015; Reece, 2015b), this amount of heat may contribute to the heat load to the body. During feeding, there are also head movements and chewing.

Results (Table 3) revealed that both the number of bites and number of chews, when fed on long (Unchopped) roughages, were significantly (P<0.01) higher than when fed on Chopped roughages, i.e. there was significantly higher muscle movement when feeding on long roughage. There was no significant (P > 0.05) difference in both bite and chew frequencies between RS and GR. There was a highly significant (P<0.01) interaction between physical form and roughage type. It was therefore observed that heat was being generated more significantly when the animals fed on long roughage particle particles.

Dry matter Intake

The results on DM intake of RS and GR showed, on the one hand, that cattle fed with either rice straw or grass (pangola) exhibited similar DM intake (Pilajun, Thummasaeng and Wanapat, 2016), but on the other hand, the results of the present study showed that DM intake of RS of the cattle was significantly (P<0.01) lower than that of the cattle that were offered GR. There was no statistical difference (P>0.05) between the DM intake of Chopped and Unchopped roughages (RS + GR). There was no interaction between the physical form and Roughage Type. The preference for hay versus straw could be related to hedonic characteristics (Webb et al., 2014). The results indicated that roughage DM intake was not influenced by particle length (Table 4 A, B). This was in consistent with the findings of Woodford, Jorgensen and Barrington (1986) and Zhaoa et al. (2009) who showed that in cattle and in goats, rice straw intake was not affected by the particle size.

Water Intake (litres/hd/d)

When the cattle were fed with Roughages (Table 4A) i.e. RS and Grass– it was found that water intake of the RS fed cattle was significantly (P<0.01) higher than the water intake of GR fed cattle. A contributing factor could be tha the GR offered had a higher moisture content (see Table 2).

There was no statistical difference (P>0.05) between the water intake of cattle fed Chopped and those fed Unchopped roughages (RS + GR), and hence, there was no significant difference in the corresponding DMI. There was also no interaction between physical form-water intake and Roughage Type-water intake. As water and dry matter intake are positively related, animals that drink less water will also have less dry matter intake (Knapp and Robinson,1954; Macfarlane and Howard, 1972; Silanikove, 1985).

Cortisol (ug%)

When the cattle were fed with Roughages (Table 5A) i.e. RS and Grass, it was found that blood Cortisol (ug%) of the RS fed cattle tended (P<0.0814) to be statistically lower than the blood Cortisol (ug%) of GR fed cattle. There was no statistical difference (P>0.05) between the Cortisol (ug%) of cattle fed Chopped and those fed Unchopped roughages (RS + GR). There was no interaction between physical form-Cortisol (ug%) and Roughage Cortisol (ug%).

Triiodothyronine {TF_3 (pg/ml)}

When the cattle were fed with Roughages (Table 6A) i.e. RS and Grass, it was found that blood TF_3 of the RS fed cattle was not statistically (P>0.05) different from the blood TF_3 of GR fed cattle. There was no statistical difference (P>0.05) between the TF_3 of cattle fed Chopped and those fed Unchopped roughages (RS + GR). There was no interaction between physical form- TF_3 and Roughage TF_3. The results indicated that the animals were not stressed by feeding on different physical forms of roughage.

Table 3. Number of bite/h. and chew/h. DMI, Water Intake, Cortisol, TF3, RT, SknT and ADG of cattle fed chopped or unchopped rice straws or grass.

		Physical			Roughage			Physical X Roughage
		Chop	Long	P	RS	GR	P	P
Bite	Bite/h.	16.68 ± 4.20[b]	21.15 ± 3.68[a]	P < 0.0001	18.35 ± 4.34	19.48 ± 3.54	P < 0.8315	P < 0.0001
Chew	Chew/h.	266.55 ± 96.09[b]	312.86 ± 75.04[a]	P < 0.0001	290.94 ± 96.28	288.47 ± 74.85	P < 0.8315	P < 0.0001
DM Intake	(kg/hd/d)	12.34 ± 0.90	13.19 ± 3.27	P < 0.5398	6.49 ± 3.57[b]	6.66 ± 0.04[a]	P < 0.0001	P < 0.1392
Water Intake	/L/hd/d	60.73 ± 3.07	60.14 ± 3.63	P < 0.5398	65.25 ± 2.88[a]	55.62 ± 3.66[b]	P < 0.0001	P < 0.1392
Cortisol	(ug%)	2.3141 ± 0.6796	2.3562 ± 0.6254	P < 0.9141	2.2895 ± 0.7115	2.3808 ± 0.5935	P < 0.0814	P < 1.0000
TF3	(pg/ml)	3.3848 ± 0.4608	3.4414 ± 0.5244	P < 0.8374	3.3103 ± 0.5238	3.5765 ± 0.4613	P < 0.2553	P < 0.8150
RT	(0C)	39.94 + 0.06[x]	39.88 + 0.09[y]	P < 0.0303	39.88 + 0.10[b]	39.95 + 0.05[a]	P < 0.0059	P < 0.1005
SknT	(0C)	36.55 + 0.80[a]	35.16 + 0.71[b]	P < 0.0001	35.91 + 0.57	35.81 + 0.95	P < 0.6466	P < 0.2526
ADG	Kg/d	0.403 ± 0.098	0.373 ± 0.107	P < 0.5285	0.402 ± 0.100	0.373 ± 0.107	P < 0.5290	P < 0.5284

a, b Means with different superscripts within a row are significantly different (P< 0.01).

x, y Means with different superscripts within a row are significantly different (P< 0.05).

Rectal and Skin Temperature (^{O}C)

It was found that there was no statistical significance between Rectal Temperature (RT) of cattle fed chopped or unchopped roughages and there was no statistical significance between Rectal Temperature (RT) of cattle fed RS or GR, i.e. both physical form of roughage and type of roughage have no influence on RT.

Skin Temperature (^{O}C)

It was found that SknT of cattle fed chopped was significantly (P<0.01) higher than those of fed unchopped RS. Therefore, the SknT was negatively affected by particle length reduction. Furthermore, the SknT was not affected by roughage type.

Therefore, chopping roughage has raised both RT but not in a way that is statistically significant (P > 0.05) and raised SknT significantly (P < 0.01). Both RT and SknT were not affected by roughage types.

Growth Rate (kg/d)

When the cattle were fed with Roughages (Table 8A) i.e. RS and Grass, it was found that Average Daily Rate of Gain (ADG; kg/d) of the RS fed cattle was not statistically (P>0.05) different from the ADG of GR fed cattle. There was no statistical difference (P>0.05) between the ADG of cattle fed Chopped and those fed Unchopped roughages (RS + GR). There was no interaction between physical form-ADG and Roughage-ADG. Results (Table 3) showed that there was significantly higher feeding activity associated with unchopped roughages. This indicatged greater amounts of heat production while grazing on unchopped roughage. No significant interaction (Physical form X Roughage Type) was consistently found thoughout the experiments.

The present study did not measure heat produced directly from those muscles associated with mastication. Therefore, the amount of heat produced may have drawn its effects as a result of heat stress on the animal.

Conclusion

In conclusion, the heifers preferred grass more than RS, and this could have contributed to the dryness of the RS, as they tried to drink more when taking in RS. As previously noted, roughage DM intake was not influenced by particle length (Unchopped > chopped {P>0.05). Water intake was no different between masticating unchopped and chopped roughages. Hormonal concentration of both cortisol and TF_3 remained consistent (Unchopped > chopped {P>0.05}). Furthermore, both RT (P > 0.05) and SknT (P < 0.01) of unchopped fed cattle were higher than that of their chopped fed counterparts i.e. ADG Unchopped < Chopped (P > 0.05).

Therefore, while less heat was produced by masticating shorter feed particles, the difference was not great enough to exert benefit to heat stressed cattle. Hence, the hormonal results could have been exerted by stressors other than heat, and may possibly be attributed to emotional stress. It was concluded that chopping of roughage could not ameliorate heat stressed cattle.

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