THE INFLUENCE OF FIBER PARTICLE SIZE ON BODY PERFORMANCE, FEED INTAKEAND DIGESTIBILITY OFEGYPTIAN BUFFALO HEIFER

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Abstract

This work was done to investigate the influence of fiber particle size through physically effective neutral detergent fiber (peNDF) of mixed ration on feed intake, nutrients digestibility, and performance of Egypt ianbuffalo (*Bubalusbubalis*) heifers. Fifteen animals within experiment were divided into 3 groups (5 per each). Buffalo heifers were allotted to one of variant three diets; G1 (high peNDF content), G2 (moderate content), then G3 (low content), where we made them by mixing feed at variable times (5, 15, and 25 minutes). By multiplying aportion of TMR remainon a 1.18 mm-sieve screen of standard Penn State Particle Separator by NDF portion, we could determine peNDF contents, where they were 29.84%, 28.59%, and 26.59% for the G1, G2, and G3 TMRs, respectively. Feed intake amount was constant with different peNDF amount in TMRs. The better body weight gain observed with G1 group than in G2 and G3 groups ($p<0.05$), where both groups did not differ. The feed efficiency has a negative relation with peNDF content (G1: 6.4, G2: 7.35, and G3: 9.48 kg/kg), while peNDF content of rations has a linear relation with digestibility of ration nutrients, besides chewing time($p<0.05$). Finally, we could conclude that the peNDF amount of ration should be taken in consideration to improve animal performance, feed utilization, and general health in buffalo heifers.

Keywords: Physically Effective Fiber, feed utilization, Buffalo Heifer

Introduction

In our country, buffalo is preferable dairy animal for most Egyptian people and produce milk that is favorable by the Egyptian. Decreasing the digestion problem of cattle considers the main idea for recent research. The effective ruminal ecosystem, the better performance and health we have. Buffaloes have many physiological differences from cattle, especially in digestive system, where rumen movements and its liquor amount, besides digestibility in buffaloes are better than in cattle, also buffaloes have less feed intake, less eating time, and decrease passage rate as a result to higher digestibility(Mandal et al., 2003).Although, the digestibility results of Bhatia et al. (1998) were variable between cattle and buffaloes. Bhatia et al., (1992)found that the buffaloes are higher (5-7 folds) in proteolytic and amylolytic bacterial than cattle. Wanapat, (2001)reported that buffaloes' rumen acidity was lower than that of cattle, which was explained by a better rumen ecosystem. The low digestible forages consider the main diet constituents for dry animals and heifers, where it has low NDF digestibility. These animals require low energy, so NDF with low digestibility recommended for its nutrition. To get the advantage of NDF feed by animals, it is important to determineits quality and peNDF to reach with the feed intake to maximum levels (Jane, 2008).

The main feed constituent used by buffaloe heifers is fiber that not digested by digestive enzyme but need a microbial enzymes that present in rumen (Mertens, 1988). In ruminants the digestibility of fiber must be evaluated to ensure a proper performance. The rumen has developed ecosystem that efficiently digest fiber. Consequently, to have a better performance and reducing the incidence of disorders related to fiber intake, ruminant animal needs appropriate feed intake, available energy, beside proper amount of fiber in the diet. Thus, determining appropriate dietary fiber requirements for buffalois crucial for performance, because roughage and forages have low digestion coefficient and available energy than other ingredients. Fiber reduction to minimum levels is often required for high-lactating cow and beef (Mertens, 1997). The definition of peNDF is the proportion of neutral detergent fiber (NDF) that is needed for proper rumination and keeps effective consistency of ruminal content(Mertens, 1997). The chewing response could be predicted by using peNDF system (Grant and Colenbrander, 1990).

Poppi et al., (1981) documented that chewing and rumination are stimulated by the presence of 1.18 mm feed particles that resist passage from rumen. The DM digestibility is related positively to digestible portion of nutrients including fiber also digestion rate of fiber, whereas digestibility is negatively related to fiber escaping rate from rumen and the rate of transformation from long non-escapable fiber to short escapable fiber. So digestibility decreases with the reduction of particle length that increases escaping rate from rumen fiber matt. Finally, fiber particle size recommended being one effective parameter in diet formulation to ruminants to ensure take a benefits of rumen ecosystem (Mertens, 1997).

There are many ways that are recommended to determine feed particle size, where PSPS (standard separator) is now considered a simple quick tool and field method for ruminant farm to determine the feeds particle length (Lammers et al., 1996). The peNDF>1.18was defined as the result of multiplying of fraction of feed DMremains over a 1.18-mm sieve by NDF portion of feed (Mertens (1997). However, the information about the physical effective fiber of diet is rare in Egyptian ruminant farms. Therefore, a precise evaluation of TMR is important to buffalo production progress

The main purpose of this work was to evaluate the influence fiber particle length (size)on buffalo heifer´s performance, feed intake, nutrients digestibility, and ingestive daily activities.

Materials and Methods

Buffalo heifer and diets

Egyptian buffalo (*Bubalusbubalis*) heifers with average weight420± 14 kg and age 18 month, were observed to evaluate the influence of fiber particle length of feed on amount intake, digestion process, and Ingestive daily activities time. Buffaloe heifers within the experiment were randomly separated into three groups (5 per each). Heifers were placed in separateyards and were fed TMR *ad libitum* twice a day at morning and evening. Animals have clean water and trace mineral blocks along the experiment period. The experimental period consisted of adaption period (14 days) then experimental period (14 days). The raising procedures were agreed with the regulation of nutrition and clinical nutrition Dept. Faculty of Vet. Med. Sohag University.

Table 1: diet ingredients and chemical composition of diet TMR.

Item	Basal-diet
Ingredients, % of DM	
Wheat straw	33.13
Corn (ground)	22.22
Wheat bran	13.33
Sunflower meal	11.11
Cottonseed meal	8.89
Molasses	11.06
Vitamin-mineral supplement[1]	0.25
Chemical compositions, % of DM	
CP	14.7±0.2
NDF	39.2±1.12
ADF	33.2±1.41
NFC	39.4±1.20

EE	2.5±0.09
Ash	4.2±0.1
NEl[2], Mcal/kg of DM	1.54
NEg[2], Mcal/kg of DM	0.94

[a, b, c]Averagesat each row with different subscripts differ ($P < 0.05$).
[1]Vitamin-mineral supplement: Cover the dairy requirements of trace mineral and vitamins according to **NRC, (2001).**
[3]NEl and NEg were calculated according to **NRC, (2001).**

Each group was allotted to one of three diets, that have same composition, but fiber size portion was differing. The different portions of fiber size were obtained by three variable times of mixing diets TMR, 5, 15 and 25 minutes for G1, G2 and G3 groups, respectively. The diets of the experiment have same composition and chemical analysis (Table 1). The TMR was formulated according the requirements reported by Bulbul. (2010).

Feed samples were collected weekly, and the amounts of feed remains after feeding were weighed daily to estimate feed intake and nutrient digestibility along the experiment period. According to AOAC, (2002)feed samples were manipulated for chemical analysis and dried for two daysat 65°C. Feed particle size portions of experimental diet TMR were estimated with standard PSPS (19, 8 and 1.18 mm and a pan sieves) (Lammers et al., 1996), where the physically effective factors (pef) and peNDF1.18 were estimated (Kononoff and Heinrichs, 2003a and Mertens, 1988).

Nutrient digestibility and chewing time

The apparent digestibility of nutrients was carried out between days 15 and 28 of experiment. Fecal samples collection carried out rapidly after egestion, where samples were totally mixed, dried and ground before further analysis to obtain digestion coefficient, and digestibility.

Ingestive daily activities (eating, rumination and chewing times) were observed continuously for 48 h for all groups. According to TeimouriYansari and Primohammadi (2009), **e**ating and rumination behaviors were observed at five minutes intervals, where each one was supposed to last for the whole interval time. A rumination period was 5 min of rumination activity at least, followed by 5 min without rumination activity.

Eating rate was estimated as this equation = feed intake (kg/day)/ time of eating (h/day). Ruminating efficiency was estimated as this equation = feed intake (kg/day)/ time of rumination (h/day). Chewing efficiency was estimated as this equation = feed intake (kg/day)/ total chewing time.

The acidity of rumen liquor (pH) was estimated with portable pH meter at different time interval during 12h after feeding.

Statistical analysis

The influence of the study was analyzed by one-way analysis of variance with the Excel program procedure (Microsoft Office, 2010). At observation of significant difference in the analysis, Bonferroni Correction (Bonferroni Post Hoc Test) was applied to determine significance ($p<0.05$) among groups and means were separated.

RESULTS

Feed composition and particle length portion distribution

All diets of the three groups have the same chemical analysis, as they have the same ingredients proportions (Table 1), whereas the mixing times only different. Mixing time was the only variable parameters that cause significant distribution of fiber particle size portions. On the 19-mm sieve layer, the remained amount of feed particles decreased with increasing period time of mixing diet TMR (G1: 14.88%, G2: 5.9%, and G3: 1.85%). The remained feed particle proportion on the 1.18-mmsieve and pan were directly related (($p<0.05$) with increased mixing time period, (G 1: 38.4%, 23.89%, G 2: 39.35%, 27.1% and G 3: 42.31% , 32.19%). The amount of peNDF>1.18mm of diet TMR has a negative linear relation with increasing mixing time, where there were29.84%, 28.59% and 26.59% for G 1, G 2 and G 3, respectively ($p<0.05$).

Intake, live body weight gain, and digestibility

Feed DM intakes (kg/d)were11±0.09; 11.33±0.09; 11.37±0.15 for G 1;G2; G3, respectively, where G2 and G3 have not a significant difference between each other. The NDF and peNDF intake amounts were not impacted (Table 2). The amounts of excretion (kg/d)were 3.33±0.02, 3.82±0.02, and 4.05±0.06for G1, G2, and G3, respectively,($p<0.05$).

There are significant differences between groups in daily live bodyweight gain (ADG), where ADG of G1 was higher than G2 and G3, (1.72, 1.54 and 1.2 kg, respectively). The increasing portion of peNDF content of feed accompanied with decreased feed conversion ratio (6.4, 7.35, and 9.48 in G1, G2, and G3, respectively), (Table 4).

Group 1 (G1) have a higher DM digestibility ($p<0.05$) than G2 and G3 (Table 3). When peNDF content increased, all nutrients digestion was significantly impacted except for ether extract and NFCwere not affected. The digestion of crude protein (CP), NDF, and ADF in G1was significantly better than G2, that followed byG3.

Ingestive daily activities (eating, rumination and chewing times)

These activities have direct linear relationship with peNDF content ($p<0.05$) (Table 4), where the increased amount of peNDF resulted in increased times of rumination and chewing activities, however eating time of G2 and G3 not affected. There were an inverse relationship between peNDF content and rate of eating, chewing and ruminating efficiency, where were lower peNDF content significantly increase che wing, ruminating efficiency and eating rate.

Rumen acidity

Rumen pH has a negative relationship with amount of peNDF, where it was more acidic with decrease peNDF and vice versa.

Table 2: Particle size portion of diet TMRwith different mixing times. (physical characteristics).

Item	Groups		
	G1	G2	G3
Particle size portion (amountremain on each sieve) (% of DM)			
19 mm	14.88±0.65 a	5.9±0.19 b	1.85±0.11 c
8 mm	22.83±0.71 b	27.65±0.32 a	23.65±0.44 b
1.18 mm	38.4±0.37	39.35±0.12	42.31±0.13
Pan	23.89±1.06 c	27.1±0.24 b	32.19±0.13 a
Physical effective factor			
$Pef_{>8}$ [1]	37.71±1.35	33.55±0.28	25.50±0.34
$Pef_{>1.18}$ [1]	76.11±1.06 a	72.94±0.48 b	67.83±0.15 c
Physical effective NDF, % of DM[1]			
$peNDF_{>8}$	14.78±0.53	13.15±0.11	10±0.13
$peNDF_{>1.18}$	29.84±0.42	28.59±0.19	26.59±0.06

[a, b, c] Averages at each row with different subscripts differ ($P < 0.05$).

[1]$pef_{>8}$ = estimated as DM proportion remained on 8 mmsieves of the standard Penn State particle separator, $pef_{>1.18}$ = estimated as DM proportion remained on 1.18 mm sieves of the standard separator, The peNDF was estimated by multiplying NDF content by portion on each pef sieve.

Table 3: Feed intake, andnutrients digestibility for buffalo heifers allotted to diet TMR with different mixing times.

Item	Groups		
	G1	G2	G3
Intake, kg/d			
DM	11±0.09 b	11.33±0.09a	11.37 ±0.15a
CP	1.62±0.01	1.67±0.01	1.67±0.02
EE	0.28±0.01	0.28±0.01	0.28±0.02
NFC	4.33±0.03	4.47±0.04	4.48±0.06
NDF	4.31±0.03	4.44±0.04	4.46±0.6
ADF	3.65±0.03	3.76±0.03	3.77±0.05
peNDF > 8	1.63±0.07	1.49±0.02	1.14±0.03
peNDF > 1.18	3.28±0.06	3.24±0.04	3.02±0.04
Fecal excretion (kg/d)	3.63±0.02 c	3.82±0.02 b	4.05±0.06 a
Digestibility, %			
DM	67.028±0.4	66.264± 0.14	64.390±0.99
NDF	41.529±1.04	40.092±0.4	36.442±2.3
ADF	30.962±1.23	29.266±0.49	24.956±2.76
CP	62.25±0.18 a	62.40±0.1 a	60.41 ±0.7b
NFC	98.0±0.03	97.5±0.04	97.1±0.06
EE	90.33±1.3	90.18±0.2	90.56±0.06

$^{a, b, c}$Averagesat each row with different subscripts differ (P < 0.05).
G1:5, G2: 15, and G3: 25 minutes.
[1]pef$_{>8}$ = estimated as DM proportion remained on 8 mm sieves of the standard Penn State particle separator,pef$_{>1.18}$ = estimated as DM proportion remained on 1.18 mm sieves of the standard separator.

Table 4. The influence of peNDF portion on body weight and FCRfor buffalo heifers allotted to diet TMR with different mixing times.

Item	Groups		
	G1	G2	G3
BW, kg	471.6±7.54	466.2±5.7	456±3.1
Live body weight gain (ADG)(kg/d)	1.72±0.24	1.54±0.15	1.2±0.09
Cumulative weight gain	51.6±4.5	46.2±2.4	36±1.9
Feed conversion ratio (DMI/ADG) (kg/kg)	6.40	7.35	9.48

G1:5, G2: 15, and G3: 25 minutes.
$^{a, b, c}$Averagesat each row with different subscripts differ (P < 0.05).

Table 5. The influence of peNDF content on ingestive daily activities (eating, rumination and chewing times) of buffaloe heifers allotted to TMR mixed for three different times

Item	Groups		
	G1	G2	G3
		min	
Total chewing time	651±6.89 a	608±9 b	564±5.3 c
Eating time	245.67±4.04 a	221.67±2.06 b	221.67±3.21 b
Ruminating time	405.33±5.51 a	386.33±6.03 b	242.33±2.52 c
		-------------------- kg/h ------------------	
Eating rate	2.69±0.05 c	3.07±0.04 b	3.08±0.02 a
Ruminating efficiency	1.63±0.02 c	1.76±0.02 b	1.99±0.03 a
Chewing efficiency	1.01±0.01c	1.12±0.01 b	1.21±0.01 a

$^{a, b, c}$Averagesat each row with different subscripts differ (P < 0.05).
G1:5, G2: 15, and G3: 25 minutes.

Table 6. The influence of peNDF content on rumen pH of buffaloe heifers allotted to TMR mixed for three different times

Item (h)	Groups		
	G1	G2	G3
After feeding			
0.5	7.08 ±0.002a	7.06 ±0.003b	7.02±0.002 c
3	6.59±0.001a	6.53±0.003b	6.5±0.002 c
6	6.45±0.004a	6.18±0.002b	6.08±0.003 c
12	7.12±0.005a	6.61±0.004b	6.46±0.001 c

a, b, c Averagesat each row with different subscripts differ ($P < 0.05$).
G1:5, G2: 15, and G3: 25 minutes.

DISCUSSION

The fiber physical characters in diet, including length, are critical parameter in reduction ruminal acidosis. The current study revealed that peNDF amounts of diets TMR were inversely related to mixing time, where the more mixing time, the less peNDF portion. The higher values of peNDF>1.18 of diet TMR (29.84%, 28.59%, and 26.59% for G1, G2, and G3) in this work than recorded by either Mertens (1997)(19- 21%) or Einarson et al. (2004)(18.9-21.2%), that was due to higher NDF percentage (39.2%) and the diet composition differ from their study, also we should record that they work on cows not buffalos that have a superior digestion of fiber than cows.

Oh et al. (2016)found that peNDF content had no influence on DM and NDF intakes, that are changed in our study where decrease peNDF increase DM and NDF intakes. Yang and Beauchemin, (2006) reported that lactating cows suffer from ruminal acidosis have the ability to pickedup long particles offeed by selection, that happened when peNDF intake was lower than recommended values. Some other studies reported that feed and NDF intakes notaffected by reduction of peNDF (Calberry et al., 2003;Soita et al., 2000).We found from previous researches that physical characters of feed and ingredient and nutrient composition could be used for regulation of feed intake (DM)of lactating cows(Allen, 1997, Mousa et al. 2017),besides the relation between peNDF content and the forage/concentrate ratio also regulate intake, and affect ingestive behavior according to digestion and escaping rate from rumen.

Allen, (1997) found that higher feed intake are recorded with the greater passage rate of feed particles from rumen as a result of lower peNDF amount in feed. Also Einarson et al., (2004) found somewhat minor improvement of feed intake (DM)in lactating cows that are attributed to decreased amount of peNDF portion in diet and reported in animals allotted to coarse forage (42%) with (58%) concentrated diet, where length of fiber was 19 mm.

In current study, ADG weights of G1buffalo heifers were significantly improved than that of G2, whileG3 was the lowest weights among groups. We reported that peNDF portion have a strong effect on feed conversion ratio that was improved with the presence of high peNDF portion (6.4, 7.35, and 9.48kg/kg).

The dietary peNDF content has a direct relationship with nutrients digestibility such as CP, NFC, NDF and ADF (Table 3), where these findings are supported by previous workson lactating cows (Yang et al., 2002; Schwab et al., 2003;Mousa et al., 2017).The forage particle length affects fibrous carbohydrate digestibility (NDF and ADF), that also affected by the amount of peNDF>1.18mm portion in the diet. In this research we found the acidity of rumen liquor increase with decrease digestibility and affects on both rumen performance (fermentation) and animal performance (FCR), these result was confirmed by the result of Azizi et al. (2007) who work on male buffaloes.

There is no doubt that the fine particles of the diet always have a rapidrate of passage from contents of rumen, so reduction of digestibility is recorded. Decreasing the peNDF portion of dietresult in exposing more surface area to ruminal microfona and microflora activities, that lead to accelerate digestion, whereas fine particle escape from rumen and decrease digestibility. Besides, reduction of coarse particles are also happened with animal mastication, consequently we could exclude the impact of feed particle size(length), but the onset of introduction of peNDF has the effect of the reduction of digestibility and rumen pH, also Michalet-Doreau et al. (2002)found that during mastication the feed particle size are decreased.

The time of animal eating was reduced with peNDF amount reduction, while the eating time was similar for G2 and G3, but the rumination time has a linear relationship with peNDFportion ($p<0.05$), as they both increased or decreased with each other. Beauchemin et al. (2003) results are in agreed with ours. The heifers can efficiently decrease particles length through increasing their chewing rate. The sefacts are recorded previously by Brouk and Belyea (1993),who reported similar time for chewing, but a higher rate of chewing with lactating cows allotted to long hay particle length, while Kononoff and Heinrichs, (2003) found higher time of chewing and rate accompanied with the feeding of long forage particle length.

In the present work, higher dietary peNDF content lead to increase total chewing time and increase rumination time Regardless of eating time.

The daily gain we recorded was higher than reported by Bulbul. (2010) review, that explained with compensatory growth due the delay in growth related to age(NRC, 2001), besides Bulbul, (2010) reported the requirements and growth of the buffaloes in Asia not in Egypt, whereas the TMR was formulated according its reported requirements but the feed intake was higher by 132.5%, 136.5% and 1.37% for G1, G2 and G3 respectively, according to the higher DMI he reported (8.3 kg), in body weight 400-500kg, with growth rate 1kg.

Finally we could conclude that, the Physical characteristics of diets are important to have a proper ingestive activity, and improve animal performance. Thus a higher peNDF mighten hance growth performance of buffalo heifers, improve feed conversion ratio and digestibility, besides decreasing the cost of feeding. The values of peNDF determine fiber effectiveness and consider as indicator for ruminal ecosystem potential of the diet.

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