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Original Paper

Digestibility of *NDF* and its effect on the level of rumen fermentation of carbohydrates

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The objective of this study, was to determinate the effects of digestibility of *NDF* of *TMR* on rumen fermentation characteristics and nutrient digestion, dairy cows were fed total mixed ration (*TMR*). We are measured *NDF* digestibility of *TMR* using *in situ* methods. Digestibility of *NDF* of *TMR* in our experiment range 26.8 to 48.2%. Digestibility of *NDF* of *TMR* did not alter VFA production but had effects on A : P ratio and production of acetate and propionate. Our results indicate that *TMR* with more d*NDF* may provide more favourable condition for nutrient digestion both in the rumen and in the total tract of dairy cows.

Keywords: rumen, fermentation, *NDF*, volatile fatty acids, digestibility of *NDF*

1. Introduction

Feeding of total mixed rations (*TMR*) in dairy cows resulted in increased milk production, through the optimization more balanced ration with a uniform rate of roughage and concentrate and increased DM intake. Increasing production efficiency with feeding *TMR* is associated with a constant intake of nutrients which is stabilized fermentation and rumen environment for growth of microflora, nitrogen utilization and production of microbial protein. Effects of *TMR* in comparison with conventional feeding system for the same intake of nutrients increased their utilization by 4% and milk production by 5% (Hutjens, 2002). The quantity and quality neutral detergent fibre (*NDF*) in *TMR* acts as a major factor affecting feed intake, rumination, passage and digestibility of nutrients to support production through stabilization of rumen function and healthy rumen environment (Chumpawadee and Pimp, 2009).

Digestibility of *NDF* is a good indicator for evaluation of the nutritional value of *TMR* for lactating dairy cows. Higher digestibility of *NDF* increases the rates and efficiency of rumen fermentation, which is stimulated by appetite of cows with higher intake of dry matter (Voelker et al., 2009). To maintain a healthy rumen environment of high producing dairy cows during early lactation is necessary to maintain the recommended amount of *NDF* in the range of 280 to 330 g kg-1 of dry matter (Varga, 2006). Digestibility of *NDF* is crucially influenced by the phase of vegetation and proportional representation of roughage. Digestibility of *NDF* in relation to the plants mature and chemical composition of the feed, structure and harvest, disruption of stalk and grinding of grains, according to the used hybrid maize (Hoffman and Shawer, 2009). Grasses are characterized by greater digestibility *NDF* compared to legumes. At high digestibility *NDF* of roughage increases dry matter intake and utilization of energy from ration, which promotes the synthesis of milk and reduces supply of grain. At low digestibility and lack of compensation of nutrients of *TMR* required amount of energy and nutrients for the synthesis of milk, which animals meet increasingly from body reserves with excessive weight loss and health disorders (Oba and Allen, 1999). The improved digestibility *NDF* of *TMR* helps to maintain rumen pH and to the proportion of acetic and propionic acid (A/P ratio) also contributes to stabilization of the conditions in the rumen of rumen function and improving e.g. higher fibrolytic enzyme activity.

The aim of study was to analyse ruminal digestibility of *NDF* in selected total mixed ration – *TMR* at peak lactation and determinate its impact on the level of rumen fermentation of carbohydrates.

2. Material and methods

2.1 Animals and *in situ* incubation

Parameters of rumen digestibility of neutral detergent fibre (*NDF*) in selected *TMR*s from 15 farms of high producing dairy cows were determined, using methods *in situ* (Ørskov and McDonald, 1979), where 5 g of sample of each feed was weighed into bags (10 × 20 cm, 53±10 µm pore size) and heat-sealed. Samples of each feedstuff were incubated in duplicate, in the rumen of each cow for 30 h. The *in situ* procedure was conducted using 3 non-lactating

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dairy cows (600 kg of body weight) fitted with rumen cannulas. Animals were fed *ad libitum* lactation diet (CP 15.0%, neutral detergent fibre 36.8%, and acid detergent fibre 25.3% of dry matter) composed of 53% forage and 47% of concentrate. After ruminal digestibility, bags were rinsed with cold water to remove particulate matter.

2.2 Analysis

Chemical analysis of nutrients in samples of *TMR*, and also in undigested food residue after rumen incubation were analyzed for dry mater, crude protein (CP), acid and neutral detergent fibre (*ADF*, *NDF*) and starch according to conventional methods (Committee regulation ES No. 152/2009 of 27. 1. 2009). Non-fibrous carbohydrates (*NFC*) was calculated by difference (100 - (*CP* + (*NDF* - *NDF bound protein*) + ash + ether extract)) and energy calculated by regression (Linn et al., 1989, NRC, 2001). The amount of *NDF* prior to incubation in the rumen and the amount of residue remaining is used for calculating the digestibility of *NDF*.

Analysis of VFA and metabolic transformation of carbohydrates: Samples of rumen content intended for analysis of fermentative and synthesizing capacity of the rumen were taken 4–6 hours after morning feeding by stomach canulas and stabilised by thymol for conservation of sample. Samples of rumen fluid were strained through 4-layer of gauze, centrifuged 25 min and diluted 1 : 50. VFA in the rumen content were determined in a two-capillary isotachophoretic analyser EA100 (VILLA LABECO, Slovak Republic). The pH of the rumen content was determined potentiometrically with portable electronic pH-meter (JP SELECTA, Spain).

Each parameter was presented by its average (x), standard deviation (SD), respectively.

3. Results and discussion

3.1 The nutrient composition of analyzed samples of *TMR* for dairy cows at peak lactation

Level of rumen fermentation is affected by the amount, type, structure and proportions of carbohydrates in the ration of dairy cows. The concentration of VFA in the rumen at any given time reflects the balance between the rate of production and rate of loss. The nutrient composition of samples of *TMR* for cows 60–90 days after calving is summarized in Table. 1. The nutrient composition of *TMR* is evaluated by comparing the nutrient content of the ration (*TMR*) with the recommended nutrient by production phases for dairy cows on farms in our conditions.

Analysed content of *NDF* in *TMR* was variable with an average of 341.1±27.6 g kg^{-1} of dry matter (DM) and individual variations from 279.6 g kg^{-1} DM to 393.2 g kg^{-1} DM in *TMR*. National Research Council (2001) recommends *NDF* concentration to be maintained at 28–30% of dietary DM with at least 75% from forage for the *NDF* requirement. The upper limit of this recommended range it was increased in 53% samples of *TMR*, individually on 8 selected farms.

The analysis of neutral detergent fiber (*NDF*) in tested *TMR*s for cows at the peak of lactation summarized in table 2 and divided in average value by recommended and increased values. Analyzed values of *TMR* with *NDF* over 33% against reference value have an average content of *NDF* 361.4±17.4 g kg^{-1} DM and digestibility of *NDF* on average 35.9±6.5%. Analyzed values of *NDF* directly correlated with forage quality and their vegetation phase of harvest and reduced dry matter intake, as shown by the lower digestibility of *NDF*. At standardized by *NDF* (28–33%) in the samples analyzed *TMR* for the first phase of lactation, the mean amount of *NDF* 318.0±16.9 g kg^{-1} DM and digestible *NDF* on average 40.0±5.4%.

The efficiency of the use of *NDF* in the group with a standard amount of *NDF* on average 318.0±16.9 g kg-1 DM and with a higher proportion of *NFC* 415.1±20.6 g kg-1 DM showed level of rumen fermentation on medium level (VFA 116.72 mmols l^{-1}, acetate (A) 61.13±2.9% and propionate (P) 25.63±2.7%) with a ratio A:P (2.47 : 1) tend to favor propionate. In *TMR* with high contents of *NDF* on average 361.4±17.4 g kg^{-1} DM and a lower of *NFC* 367.5±23.1 g kg^{-1} DM showed a similar level of rumen

Table 1 Chemical analysis of nutrients in total mixed ration – *TMR* in g kg dry matter

Markers	$x_{min} - x_{max}$	x±s.d.
Ratio forage(F) : Concentrate (C)	42 : 58–64 : 36	53 : 47
***NDF* in g kg DM**	279.6–393.2	341.1±27.6
Digestibility *NDF* in %	26.8–48.2	37.7±6.4
NDF*d* in g kg DM	96.5–157.6	128.1±19.4
***ADF* in g kg DM**	168.6–265.7	208.7±29.3
***NFC* in g kg DM**	332.5–442.6	389.7±32.4
Starch in g kg DM	217.4–363.1	276.6±39.4
NDF*/*NFC	0.63–1.11	0.89±0.1

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Table 2 *NDF* and rumen fermentation of dairy cows at peak lactation – represented by *NDF*

Markers	*x*±s.d.	*NDF* 28–33%	*NDF* >33%
***NDF* in g kg**	341.1±27.6	**318.0±16.9**	**361.4±17.4**
Digestiblity of *NDF* in %	37.7±6.4	40.0±5.4 126.7±18.2	35.9±6.5
***NDF*d g kg**	128.1±19.4	**303.2±39.9**	129.1 ±20.2
Starch g kg	276.6±39.4	415.1±20.6	**256.6±24.2**
***NFC* in g kg**	389.7±32.4	**188.1±16.2**	367.5±23.1
***ADF* in g kg**	208.7±29.3	0.76±0.1	**226.7±26.2**
NDF*/*NFC	0.89±0.1	6.23±0.2	0.99±0.1
pH	6.28±0.3	116.72±10.9	6.31±0.3
∑ VFA in mmol l	116.62±16.2	61.13±2.9	116.53±19.6
Acetate in %	61.55±3.3	25.63±2.7	61.93±3.5
Propionate in %	25.06±3.2	2.47± 0.4	24.56±3.4
Ratio A : P	2.56±0.5	**22.14±5.4**	2.64±0.5
NH_3 in mg 100ml	20.62±6.5	–	**19.28±7.1**

Table 3 Digestibility of *NDF* and rumen fermentation *TMR* for dairy cows at peak lactation

Markers	x±s.d.	Digest. *NDF* >40%	Digest. *NDF*<40%
***NDF* g kg**	341.1±27.6	**325.7±23.3**	**351.5±25.4**
Diges. *NDF* %	37.7±6.4	**43.8±2.9**	**33.1±4.0**
***NDF*d g kg**	128.1±19.4	142.6±14.3	117.2±15.1
Starch g kg	276.6±39.4	281.6±34.9	272.8±42.8
***NFC* g kg**	389.7±32.4	399.2±35.6	383.4±28.3
***ADF* g kg**	208.7±29.3	190.5±14.0	220.8±30.6
NDF*/*NFC	0.89±0.1	0.83±0.1	0.94±0.1
pH	6.28±0.3	**6.14±0.2**	**6.37±0.3**
∑ VFA mmol l	116.6±16.2	**118.38±10.7**	**115.45±18.9**
Acetate %	61.55±3.3	**59.5±3.8**	**62.93±1.8**
Propionate %	25.06±3.2	**29.48±3.1**	**24.11±2.9**
Ratio A : P	2.56±0.5	**2.35±0.4**	**2.71±0.4**
NH3 mg 100ml	20.62±6.5	20.4±5.5	20.76±7.1

fermentation, while it has been shift in the ratio A : P with an average of 2.64±0.5 : 1. Analysis and management of rumen fermentation by evaluation of the amount and proportion produced VFA is directly dependent on the level of fermentation in relationship to carbohydrate composition of *TMR* respectively *NDF* digestibility of the ration. The proportions of the dominant VFA produced in the rumen vary with diets, microbial growth rates, levels of feeding, and ruminal pH (López et al., 2000). High-forage diets result in the production of greater amounts of acetate and butyrate, while high starch diets result in the production of greater proportions of propionate, although acetate is still the dominant VFA (Beever and Mould, 2000). While the rumen microflora transforms 43–46% of fermentable carbohydrate of diets to the creation of VFA, which provide 80% of energy needs for the animal.

3.2 Digestibility of *NDF* – *TMR* and rumen fermentation of dairy cows in peak of lactation

The Analysis of digestibility of *NDF* was et experimental conditions determined by the method *in situ* at 30 h of incubation in 15 tested samples of *TMR*s with different levels of structural (*NDF* and ADF) and non-fibrous (*NFC*) carbohydrates for dairy cows at peak lactation stage. Results of digestibility of *NDF* in *TMR* a showed significant

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difference and values ranged from 26.8 to 48.2%. Analyzed samples of *TMR* were divided by digestibility of *NDF* with level over and below 40%, because no samples didn't reach 50% digestibility of *NDF*. The *TMR*s (n = 6) with digestibility of *NDF* over 40% was confirmed on average 43.8±2.9%, where ruminal digestibility of *NDF* ranged from 40.2 to 48.2% and analyzed content of *NDF* on average 325.7±23.3 g kg^{-1} of dry matter. Effect of digestibility of *NDF* on level of rumen fermentation is in average values summarized in Table 3. In the group of 9 samples *TMR* with digestibility of *NDF* below 40% was mean 33.1±4.0% and individually digestibility of *NDF* ranged from 26.8 to 39.3% and analyzed content of *NDF* on average 351.5±25.4 g kg^{-1} DM. Increased *NDF* degradability increases the energy density of diets and stimulates microbial N production (Oba and Allen, 2000).

The comparison of level of rumen fermentation of carbohydrates by the digestibility of *NDF* showed differences in concentration of rumen acetate and propionate and their ration (A : P), and the pH of the rumen. A higher digestibility of *NDF* effected level of rumen fermentation of a carbohydrate, it is more intensive with the pH 6.14± 0.2, acetate 59.5±3.8%, propionate 29.5±3.1% and ratio A : P 2.35±0.4 : 1 compared to rumen fermentations with lower digestibility of *NDF* pH 6.37±0.3, acetate 62.9±1.8%, propionate 24.1±2.9% with a ratio A : P 2.71±0.4 : 1. The ruminal pH of cattle fed a predominantly forage diet is generally higher, in the range of 6.2–7.0, than those fed diets with greater proportions of concentrates, in the range of 5.5–6.5 (Kolver and de Veth, 2002). The relative concentration of the individual acids is influenced most by concentration, digestibility, and fragility of forage *NDF* (Allen et al., 2009).

4. Conclusions

The composition of analysed *TMR* for high production cows showed the increased content of *NDF* and limited digestibility of *NDF* in the first stage of lactation with a negative impact on the level of rumen fermentation and dry matter intake. Calculated and confirmed the capacity of dry matter intake required to secure the energy supply in high-production dairy cows increasing the concentration of non-fibrous carbohydrates and starch to an extent that exceeds the physiologically tolerated concentration and results in acidification rumen environment.

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