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Effect of concentrate feeding technology on nutrient digestibility in Latvian Dark-Head lambs

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Abstract. Research has been conducted to evaluate the effect of concentrate feeding technology on nutrient digestibility in Latvian Dark-Head lambs. Twenty-four purebred Latvian Dark-Head lambs (rams) were divided into three study groups (four lambs in each group). Concentrate was offered with different feeding technologies: group 1 – *ad libitum* once per day (ADL); group 2 – five times per day (5TD); group 3 – three times per day (3TD). Lamb live weight at the start of research was 24.6 kg (ADL), 24.1 kg (5TD) and 25.6 kg (3TD), the average age – 83 ± 1.4 days (ADL; $p < 0.05$), 75 ± 1.4 days (5TD) and 75 ± 1.6 days (3TD). Research data were collected over three periods and two repetitions during lamb fattening in July, August and September, 2019. During the data collection period lambs were transferred to cages with slatted wooden floor and a container with a grid under it. The highest concentrate intake in all data collection periods was found in ADL lambs (1.25 ± 0.106 kg – 1.75 ± 0.092 kg on average per lamb). Hay intake was not equal (90–350 g in average per lamb).The highest average faecal production was found in 3TD and 5TD lambs (F – 0.98 ± 0.102 kg (3TD), S – 1.13 ± 0.060 kg (5TD) and T – 0.99 ± 0.070 kg (5TD)).The least urinal production was found in 3TD lambs (0.24 ± 0.038 kg (F), 0.61 ± 0.078 kg (S) and 0.47 ± 0.033 kg (T)). Dry matter digestibility was 66.54–80.39%. Faecal consistency was soft for ADL and 5TD lambs and solid for 3TD lambs.

Key words: lamb fattening, digestibility, dry matter intake, faecal production, manure.

INTRODUCTION

It is useful to study the different processes in the forestomach (rumen, reticulum, omasum) of ruminants to improve the nutrient breakdown in ruminants and maximize their effect on wool, milk and meat production as well as for meeting animal energy requrements (Slavov, 2017).

Nutrient digestibility denotes the amount of nutrients (part of nutrient intake) used for animal needs and milk, meat and wool production (Spring, 2013). Numerous studies report impact of different factors (forage type and quality, animal breed and age, etc.) on nutrient digestibility and productivity of ruminants (Tripathi et al., 2007; Atkinson et al., 2010; Oguri et al., 2013; Gomes et al., 2014; Zhao & Yan, 2017; Pino et al., 2018; Valério Geron et al., 2019, etc.).

The most appropriate feed ration has been studied for years and scientists have come to the common conclusion that a feed ration with a higher concentrate content and a lower roughage content is best suited for intensive lamb finishing (NRC, 2007). No data can be found in literature regarding nutrient digestibility in lambs fed the same diet using different feeding technologies. Research results of nutrient digestibility using various feeding technologies could be useful for sheep breeders planning organization of their sheep flock feeding. It would also provide a possibility to determine the labour force necessary for sheep feeding to maximize their productivity.

The research has been conducted to evaluate the effect of concentrate feeding technology on nutrient digestibility in Latvian Dark-Head lambs.

MATERIALS AND METHODS

The research was carried out at the ram testing station 'Klimpas' of the association 'Latvian Sheep Breeders Association' located in Latvia (57.849789, 25.327707). Twenty-four purebred Latvian Dark-Head ram lambs were used (one born as a single lamb and others as twins or triplets) in two repetitions (twelve lambs in each repetition). In each repetition the lambs were divided into three trial groups (four) lambs per group. Concentrate was offered using different feeding technologies: group 1 – *ad libitum* once per day (ADL); group 2 – five times per day (5TD) and group 3 – three times per day (3TD). Concentrate daily ration was increased during fattening and offered once daily (ADL) or in equal rations daily (5TD and 3TD). Lambs were provided *ad libitum* fresh water and alfalfa hay throughout the research. Concentrate included maize, wheat, soy beans (genetically modified), barley, rapeseed cake, sunflower cake, beet chips, beet molasses, CaCO3, seed oil and premix of vitamins and minerals.

Lamb live weight at the start of research was 24.6 kg (ADL), 24.1 g (5TD) and 25.6 kg (3TD), average age – 83 ± 1.4 days (ADL; $p < 0.05$), 75 ± 1.4 days (5TD) and 75 ± 1.6 days (3TD). Lamb live weight was fixed at the beginning of the research and on last day of each data collection period. Electronic scales (accuracy ± 0.01) were used for lamb weighing.

Fattening were organized in two repetitions: 1) from June 15, 2019 to August 16, 2019 (R1); 2) from June 25, 2019 to September 13, 2019 (R2). Research data were collected within three periods (each for five days) and two repetitions within lamb fattening: period 1 (F) from July 1, 2019 to July 5, 2019 (R1) and from July 29, 2019 to August 2, 2019 (R2); period 2 (S) from July 22, 2019 to July 26, 2019 (R1) and from August 19, 2019 to August 23, 2019 (R2); period 3 (T) from August 12, 2019 to August 16, 2019 (R1) and from September 9, 2019 to September 13, 2019 (R2). Research data were compared between average results of each data collection period (F, S and T) in both repetitions.

During fattening lambs were kept on straw bedding in cages placed in an outdoor shed grouped the same way as in the data collection periods (four lambs per group). Cages were equipped with wooden ladder trough, drinkers and hopper trough. For data collection lambs were moved to cages additionally equipped with slatted wooden floor and a container with a riddle under it (Fig. 1). To calculate feed intake the feed refusals were subtracted from the feed offered on the previous day. The data collected about the cage on each data collection day were divided by four to obtain results per lamb (Table 4, 5, 7).

On the first day of fattening lambs were offered 4.00 kg of concentrate and 2.00 kg of hay per group, the amount of concentrate was increased by 160 g per group each subsequent day till concentrate refusals in trough remains under 10% from offered amount. The offered amount of concentrate remained unchanged when concentrate refusals exceeded 10% from offered amount. The quantity of hay offered remained unchanged.

On the first day of each data collection period only the offered alfalfa hay and concentrate amounts were registered per each cage. Every next day of each data collection period the offered alfalfa hay, feed refusals were weighed and faecal and urine production was collected and weighed additionally per each cage. The results were divided to four (number of lambs per cage) to calculate data of feed and dry matter intake and faecal and urinal production per lamb. Electronic scales (precision ± 0.005) were used for weighing of feed refusals, hay, concentrate, faecal and urine production. Faecal production was placed into a plastic container and kept in a refrigerator under temperatures up to 8 ^{0}C until delivery to laboratory. The general feed concentrate (1 kg), alfalfa hay (1 kg) and faecal (2 kg) samples were prepared on the last day of each data collection period.

Figure 1. Cages with slatted wooden floor and a container with a grid under it made for data collection (photo from the achieve of project participants): 1 – hopper trough for concentrate feeding in ADL group lambs; 2 – wooden ladder trough for hay; 3 – trough for concentrate feeding in 5TD and 3TD group lambs; 4 – drinker; 5 – slatted wooden floor; 6 – container with a grate for faecal and urine production.

Sample preparation was made in accordance with the standard LVS EN ISO 6498:2012. On the last day of each data collection period all the prepared samples were delivered to the Division of Agronomic analysis of Latvia University of Life Sciences and Technologies Research Laboratory of Biotechnology for making analyses of sample chemical composition. Standards or calculations were used for determination of sample chemical composition (Table 1, 2).

Table 1. Chemical components of faecal production and standards used

Chemical component, unit	Standards
Dry matter, %	LVS EN 13040:2008 8.1; 9-11
Nitrogen, % (in natural sample)	LVS EN 13654-1/NAC:2004
Ammonium-nitrogen (N/NH4), g kg^{-1}	*ГОСТ 26180-84, met.2
% of dry matter	
Crude fibre, %	*ISO 5498:1981
Fat, %	*ISO 6492:1999
Ash, %	*LVS EN 13039:2012
P, %	LVS ISO 6598:2001
K, %	LVS ISO 9964-3:2000
pH	LVS EN 13037:2012

* – unaccredited standard.

Table 2. Chemical components of forages and standards used

Chemical component, unit	Concentrate	Hay	Standards
Dry matter, %	indicated	indicated	for hay: LVS NE ISO 6498:2012, 7.5. for concentrate: ISO 6496:1999
% of dry matter			
Crude protein, %	indicated	indicated	LVS EN ISO 5983-2:2009
Bound protein, %	indicated	indicated	* Forage analysis, USA, met. 6:1993
Soluble protein, %	indicated	indicated	* Nor For method – 2006
Protected protein of crude protein, %	indicated	indicated	Calculation
Crude fibre, %	indicated	indicated	ISO 5498:1981
NDF, %	indicated	indicated	LVS EN ISO 16472:2006
ADF,%	indicated	indicated	LVS EN ISO 13906:2008
NEG, MJ kg^{-1}	indicated	indicated	TDN=88.9-(ADF*0.779) NEG=(TDN*0.01318)-0.459)*4.184/0.453
ME, MJ kg^{-1}	indicated	indicated	TDN=88.9-(ADF*0.779) ME(ruminant)=((TDN*0.2004)*(96-(0.202*CP)))*4.184/0.453/1000 (MJ kg^{-1})
Fat, %	indicated	not indicated	ISO 6492:1999
Ash, %	indicated	indicated	ISO 5984:2002/Cor 1:2005
Ca, %	indicated	indicated	LVS EN ISO 6869:2002
P, %	indicated	indicated	ISO 6491:1998
K, %	indicated	indicated	* LVS EN ISO6869:2002
Strach, %	indicated	not indicated	LVS EN ISO 10520:2001

* – unaccredited standard; NDF – Neutral Detergent Fibre, ADF – Acid Detergent Fibre; TDN – Total Digestible Nutrients; NEG – Net Energy used for Growth; ME – Metabolizable Energy.

Daily digested nutrient amount, faecal and urine production excreted into external environment per lamb during the data collection periods were calculated. Results of chemical component analysis of faeces, hay and concentrate were used for calculations of nutrient digestibility in purebred Latvian Dark-Head ram lambs.

Results were calculated using Microsoft Excel. Results obtained in this study are presented as mean values with the standard error of the mean and variation (CV). The results were compared among the data collection periods with *t-test* paired two samples for means. Significant differences between groups ($P < 0.05$) are marked with different letters of the alphabet in superscripts.

RESULTS AND DISCUSSION

Laboratory analysis of concentrate chemical components (Table 3) shows low variation in the amount of nutrients in samples, except for bound protein (CV 24.86%) and crude fibre (CV 9.84%). It could be explained by different proportion of nutrients used in concentrate production in different production batches to ensure the necessary amount of protein and crude fibre.

Table 3. Forage chemical content

Chemical component,	Concentrate		Hay	
unit	Mean	CV	Mean	CV
Dry matter, %	87.97 ± 0.051	0.13	87.60 ± 1.016	3.10
% of dry matter				
Crude protein, %	21.23 ± 0.067	0.70	9.60 ± 0.395	10.90
Bound protein, %	0.47 ± 0.052	24.86	0.60 ± 0.069	24.40
Soluble protein, %	4.30 ± 0.102	5.30	4.60 ± 0.260	11.40
Protected protein of crude protein, %	72.58 ± 0.369	1.14	30.30 ± 2.673	17.60
Crude fibre, %	5.22 ± 0.230	9.84	32.20 ± 1.146	9.40
NDF, %	15.11 ± 0.219	3.24	59.90 ± 1.633	7.20
ADF,%	7.22 ± 0.061	1.89	36.70 ± 0.951	6.90
NEG, $MJkg^{-1}$	5.90 ± 0.006	0.22	3.10 ± 0.089	7.60
ME, MJ kg^{-1}	14.14 ± 0.007	0.11	10.50 ± 0.134	3.40
Fat, %	3.43 ± 0.020	1.30	-	-
Ash, %	7.12 ± 0.017	0.54	5.50 ± 0.214	10.20
Ca, %	1.23 ± 0.015	2.78	0.50 ± 0.042	20.90
P, %	0.58 ± 0.011	4.10	0.20 ± 0.014	16.90
K, %	1.03 ± 0.013	2.79	1.40 ± 0.083	14.00
Starch, %	42.28 ± 0.196	1.04	-	-

NDF – Neutral Detergent Fibre, ADF – Acid Detergent Fibre; NEG – Net Energy used for Growth; ME – Metabolizable Energy.

Hay was prepared at the ram testing station 'Klimpas' and preparation process was affected mainly by circumstances of external environment, for example – rain, soil composition or maturity stage. Weather conditions were not recorded during the preparation of the hay, but by comparing the mean nutrient values of hay used in the research and those shown in the summary of chemical analyses and digestibility of forages made in Latvia (Degola et al., 2016) it denotes late hay cutting. Beecher et al. (2018) study results indicate decreased dry matter digestibility of grass in its late maturity stage. It could impact the dry matter digestibility of hay prepared of grass in its late maturity stage as well. As a result the variation of chemical composition of hay was very high (from 3.40% to 24.40%). The lowest variation (3.40%) was fixed for metabolizable energy.

Daily mean concentrate and hay intake per lamb is shown in Table 4. The highest mean concentrate intake per lamb daily in all data collection periods was recorded in ADL lambs (F – 1.25 ± 0.106 kg, S – 1.58 ± 0.043 kg, T – 1.75 ± 0.092 kg). This could be explained by periods of lamb eating activity. A previous study showed that eating activity of lambs daily was increased: at 02:00–02:59, 08:00–09:59 and 19:00–20:59 (Šenfelde & Kairiša, 2018). The lambs of the ADL group were able to start consuming the desired amount of concentrate in the morning and throughout the day. Although the daily amount of concentrate offered was the same for all groups, at the morning lambs in group 5TD and 3TD received concentrate only partly of daily norm. Thus, in the first half of the day, lambs of group 5TD and 3TD could only consume concentrates partly from the whole daily norm, not as much they wants. Previous researches of 50% Romanov and 50% Dorper crossbred lamb fattening with concentrate using an automatic feeding station showed the concentrate daily intake of 1.13 kg in the first fattening period, 1.50 kg in the middle of fattening and 1.40 kg in the last fattening period (Šenfelde & Kairiša, 2018). Lambs in mentioned research was in the same age and live weight at the start of the research. In the first and second fattening periods it is similar to ADL lambs, but at the end of fattening it is similar to 5TD and 3TD lambs.

Table 4. Daily mean concentrate and hay intake per lamb, kg

Data collection period	Concentrate			Hay		
	ADL	5TD	3TD	ADL	5TD	3TD
F	1.25 ± 0.106^{a}	0.65 ± 0.160^{b}	0.71 ± 0.133^{b}	0.13 ± 0.027^{a}	0.22 ± 0.024^{b}	0.35 ± 0.034^{c}
S	1.58 ± 0.043^{a}	1.11 ± 0.129^{b}	1.26 ± 0.096^{b}	0.13 ± 0.034^{a}	0.27 ± 0.027^{b}	0.23 ± 0.032^{b}
T	1.75 ± 0.092^{a}	1.50 ± 0.019^{b}	1.48 ± 0.032^{b}	0.09 ± 0.010^{a}	0.14 ± 0.033^{ab}	0.14 ± 0.015^{b}

$^{a, b, c}$ – data with different superscripts are significantly different, $P \leq 0.05$.

In the first data collection period significant differences ($P < 0.05$) were found in 5TD (0.65 ± 0.160 kg) and 3TD (0.71 ± 0.133) lambs compared to ADL (1.25 ± 0.106).

Overall in all data collection periods between all groups there was a varied daily hay intake (from 90 g to 350 g per lamb). ADL lambs had the lowest daily hay intake in all data collection periods (F – 0.13 ± 0.027 kg, S – 0.13 ± 0.034 kg and T – 0.09 ± 0.010 kg). Allen (1997) indicates that ruminants require roughage in their diets to maximize productivity and to maintain health by sustaining a stable environment in the rumen. But also, other researches have to be taken into consideration that increasing dietary roughage in feedlot diets decreases dry mater digestibility (Hales et al., 2014). The results of the research indicate that the hay intake by lambs was in the amount necessary to ensure the functioning of the digestive tract.

Ma et al. (2014) study has shown that increasing the share of concentrates in the ration, and thus the share of dry matter in concentrates, improves the digestibility of total dry matter. These results agree with the results obtained in this study (Table 5, 8). Due to the fact that the undigested amount of dry matter is excreted from the animal's body in the form of faeces, the amount of faeces decreases as the digestibility of dry matter increases. In this study, this is evidenced by the data obtained where the ADL group has the highest dry matter intake (1.10–1.54 kg per lamb daily; Table 5), the highest digestibility (79.63–80.39%; Table 8) and the lowest faecal excretion (0.70–0.94 kg per lamb daily; Table 7).

Table 5. Daily mean dry matter intake from concentrate and hay per lamb, kg

Data collection period	Concentrate			Hay		
	ADL	5TD	3TD	ADL	5TD	3TD
F	1.10 ± 0.093[a]	0.56 ± 0.141[b]	0.63 ± 0.117[b]	0.11 ± 0.024[a]	0.19 ± 0.021[b]	0.31 ± 0.030[c]
S	1.39 ± 0.038[a]	0.98 ± 0.113[b]	1.11 ± 0.085[b]	0.11 ± 0.030[a]	0.23 ± 0.023[b]	0.20 ± 0.028[b]
T	1.54 ± 0.081[a]	1.32 ± 0.016[b]	1.30 ± 0.028[b]	0.08 ± 0.009[a]	0.12 ± 0.029[b]	0.13 ± 0.013[b]

[a, b, c] – data with different superscripts are significantly different, $P \leq 0.05$.

Chemical components of faecal production (Table 6) indicate higher nutrient content (g kg^{-1}) at the end of fattening for all groups, except for fat (ADL and 3TD), dry matter (3TD), crude fibre (3TD) and ashes (3TD). The live weight gain by data collection periods is not analyzed in this article, but the increased nutrient content in the faecal production in the last data collecting period (T) could be explained by the fact that the lamb live weight was already close to the maximum in the second data collection period (S) and the nutrient necessity for weight gain decreases in forward.

Table 6. Chemical components of faecal production, g kg^{-1} of natural sample

Nutrients	ADL			5TD			3TD		
	F	S	T	F	S	T	F	S	T
Dry matter	238.5 ± 27.04	306.0 ± 30.66	317.2 ± 18.63	227.9 ± 25.36	347.8 ± 20.42	340.3 ± 22.37	321.9 ± 27.10	369.0 ± 24.57	287.5 ± 23.87
Nitrogen	8.3 ± 1.09	11.2 ± 1.13	12.6 ± 0.78	6.6 ± 0.91	11.4 ± 0.81	13.6 ± 0.95	9.7 ± 1.28	12.7 ± 0.74	13.2 ± 1.10
Crude fibre	50.3 ± 5.21	69.38 ± 7.20	81.8 ± 5.70	57.7 ± 6.49	91.7 ± 4.28	81.38 ± 5.14	86.5 ± 7.73	89.9 ± 4.44	69.48 ± 5.77
Fat	8.5 ± 0.74	8.7 ± 1.05	6.0 ± 0.34	5.9 ± 0.51	6.5 ± 0.28	6.1 ± 0.40	7.3 ± 0.59	7.4 ± 0.56	6.5 ± 0.54
Ash	39.0 ± 4.88	49.9 ± 5.91	50.3 ± 2.86	35.0 ± 3.78	47.57 ± 4.82	56.0 ± 3.81	43.7 ± 3.41	54.0 ± 5.82	42.3 ± 3.51
P	2.9 ± 0.31	4.1 ± 0.40	5.0 ± 0.29	2.4 ± 0.34	3.5 ± 0.37	4.9 ± 0.32	3.0 ± 0.30	4.8 ± 0.68	3.7 ± 0.31
K	2.6 ± 0.29	3.5 ± 0.42	3.0 ± 0.26	2.6 ± 0.32	3.9 ± 0.22	3.5 ± 0.21	3.7 ± 0.39	4.1 ± 0.21	4.1 ± 0.34
N/NH_4	1.5 ± 0.24	2.5 ± 0.22	3.1 ± 0.24	1.4 ± 0.33	2.6 ± 0.10	3.0 ± 0.29	2.2 ± 0.41	2.9 ± 0.11	4.3 ± 0.36

The highest daily faecal production (Table 7) per lamb was recorded for 5TD and 3TD lambs (F – 0.98 ± 0.102 kg (3TD), S – 1.13 ± 0.060 kg (5TD) and T – 0.99 ± 0.070 kg (5TD)). The lowest urine production was recorded for 3TD lambs in all data collection periods (F–0.24 ± 0.038 kg, S – 0.61 ± 0.078 kg and T – 0.47 ± 0.033 kg).

Table 7. Daily faecal and urine production per lamb, kg

Data collection period	Faecal production			Urine production		
	ADL	5TD	3TD	ADL	5TD	3TD
F	0.70 ± 0.078^{a}	0.74 ± 0.079^{ab}	0.98 ± 0.102^{b}	0.61 ± 0.138^{a}	0.29 ± 0.021^{b}	0.24 ± 0.038^{b}
S	0.94 ± 0.063^{a}	1.13 ± 0.060^{b}	1.09 ± 0.048^{ab}	0.86 ± 0.116^{a}	0.66 ± 0.112^{ab}	0.61 ± 0.078^{b}
T	0.91 ± 0.073^{a}	0.99 ± 0.070^{a}	0.91 ± 0.076^{a}	0.75 ± 0.077^{a}	0.88 ± 0.070^{a}	0.47 ± 0.033^{b}

$^{a, b, c}$ – data with different superscripts are significantly different, $P \leq 0.05$.

Dry matter digestability of forages (Table 8) was 76.63% – 80.39% (ADL), 66.54% – 76.08% (5TD) and 66.91% – 80.23% (3TD). A lower dry matter digestibility during the S data collection period is observed in all groups. The other studies indicate similar or lower dry matter digestibility results in other sheep breeds. Zhao et al. (2015) indicate 79% dry matter digestibility in Highlander and Texel crossbred lambs for fattening fed *ad libitum* perennial ryegrass (*Lolium perenne*) and 0.5 kg concentrate once daily. Dry matter digestibility in Suffolk purebred lambs fed twice daily with hay and corns ground to particle size from 1 to 3 mm was in the range of 62–65% (Vranic et al., 2017). Dry matter average digestibility in Dorper and thin-tailed Han cross-bred ram lambs fed *ad libitum* mixed diet was 63% (fed twice daily; Ma et al., 2019), 58% (fed once daily; Deng et al., 2012) and 59% (fed once daily; Xu et al., 2015).

Table 8. Nutrient digestibility, %

Nutrients	ADL			5TD			3TD		
	F	S	T	F	S	T	F	S	T
Dry matter	80.29	79.63	80.39	75.96	66.54	76.08	71.40	66.91	80.23
Nitrogen	78.73	77.05	76.46	77.17	63.19	70.57	70.30	62.53	71.69
Crude fibre	44.25	37.94	22.59	44.00	27.70	18.65	39.80	25.09	30.93
Fat	77.72	81.61	88.69	77.30	76.33	86.95	73.92	76.34	86.65
Ash	53.77	52.33	55.71	45.75	31.40	45.23	41.93	28.01	58.43
P	55.93	51.56	46.36	50.12	34.91	52.30	45.24	18.12	54.64
K	80.07	77.55	81.86	74.84	67.31	79.41	70.64	67.37	71.99

The results of this research indicated crude fibre digestibility decrease in all groups during the fattening, while digestibility of nitrogen in the all fattening period decreased in ADL and 5TD lambs. In 5TD and 3TD lambs the lowest nitrogen digestibility was in second period when data were collected.

Nutrient digestibility (Table 8) for 3TD lambs compared with 5TD lambs was higher at the end of fattening (T), except for fat and K.

CONCLUSIONS

Intensive fattening of lambs fed with concentrate offered in a hopper trough ensures low labour necessity and lambs have *ad libitum* access to feed that results in high concentrate and low hay intake. The best dry matter and nitrogen digestibility was in ADL group. The team of authors prefer feeding with *ad libitum* access to forage for lamb fattening. Faecal consistency was soft and extra bedding was necessary.

Low concentrate intake at each feeding time was ensured by feeding lambs five times daily; low hay intake was registered as well. Average dry matter digestibility was not significantly different ($P > 0.05$) and low nutrient content in faecal production was found. 5TD lambs had soft faecal consistency and high urine production.

Lamb fattening by feeding them three times daily resulted in lowest dry matter and nitrogen digestibility in the first data collection period. But compared to the other groups, in the third data collection period dry matter and nitrogen digestibility in 3TD lambs were average. Faecal consistency was solid, visually lambs were dry and clean. Low labour was necessary and hay intake was significantly different ($P < 0.05$) in the first data collection period.

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