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Forage quality and hygiene in automatic feeding systems for dairy cows

Automatic feeding systems (AFS), amongst other reasons, gain more and more importance due to their potential of saving labour and introducing flexible working hours in dairy farming. However the storage of forage under aerobic conditions in AFS runs the risk of reheating of silages. Therefore investigations concerning the changes of forage quality in AFS were conducted at the Bavarian State Research Center for Agriculture. The storage of forage as total mixed rations (TMR), high ambient temperatures as well as high initial germ contents influenced the aerobic stability of the forage negatively. Consequently in the summertime during high ambient temperatures a feed storage under aerobic conditions longer than 24 h should be avoided, however it seems to be harmless in the wintertime during low ambient temperatures.

Keywords

Automatic feeding system, forage quality, aerobic stability, germ count, reheating

Abstract

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Due to structural developments, which cause a growing livestock per farm while labour capacity is consistent or even decreasing, dairy farms tend to mechanize and automate different working steps. With a proportion of 16 % feeding represents the third largest part of Bavarian dairy farms labour requirement after milking and taking care of the breed [1]. Consequently the automation of feeding provides another great potential of saving working hours [2]. Therefore Automatic Feeding Systems (AFS) gain under the aspect of simplifying and reducing workload and introducing flexible working hours more and more importance. Beneath the aspects concerning labour, AFS should be able to reduce fodder losses and improve feeding hygiene. However, using AFS is related to a temporary (one or two days) storage of forage (mostly silages) under aerobic conditions. This is described in different studies as a problem concerning the reheating of silages [3; 4; 5; 6].

Under aerobic conditions, yeasts start to multiply while they degrade lactic acid and produce heat. By the reduction of lactic acid, the pH-value increases. Consequently other microorganisms, like moulds and aerobic bacteria, get activated and cause the further spoilage of the silages [4].

Beneath the influence of oxygen, high ambient temperatures [6] as well as high initial germ contents [3; 4; 5] induce the reheating of silage.

In contrast a sufficient percentage of acetic or propionic acid in the silages or their specific addition can retard the reheating and increase the aerobic stability of the forage [3; 7; 8].

Thus exploring the required conditions under which an aerobic storage of forage is possible is highly relevant for the success of AFS. Therefore experiments concerning the changes of forage quality in AFS were conducted at the Bavarian State Research Center for Agriculture.

Material und Methods

Experimental Design

Altogether four experiments in different seasons (summer/winter) were conducted.

All experiments were divided into two sequenced phases, in which on the one hand good silage and on the other hand aerobically deteriorated silage were inserted (**Table 1**). In every experimental phase two groups of dairy cows were fed once a day or several times a day (five to six feeding frequencies).

In the experiments 1, 3 and 4 an AFS with stationary mixer without storage container was simulated. The total mixed ration (TMR) was prepared once a day in the morning in a 9 m³ Feed Mixer Wagon (FMW) with a horizontal mixing auger and was stored there for a maximum of 24 h.

In Experiment 2, the AFS of the company Wasserbauer was employed. This system consists of several storage containers for the forage and a rail mounted feeding wagon.

Table 1

Overview of the conducted experiments

	Lagerung der Futtermittel *Storage of feed*	Futtervorlage *Provision of feed*	Jahreszeit *Season*
Versuch 1 *Experiment 1*	Als Mischung im FMW[1] *as mixed ration in a FMW*	Simulation eines AFS[2] *Simulation of an AFS*	Sommer 2012 *Summer 2012*
Versuch 2 *Experiment 2*	Einzeln in Vorratsbehältern *single within a storage container*	AFS der Firma Wasserbauer *AFS type of the company Wasserbauer*	Winter 2012 *Winter 2012*
Versuch 3 *Experiment 3*	Als Mischung im FMW *as mixed ration in a FMW*	Simulation eines AFS *Simulation of an AFS*	Winter 2013 *Winter 2013*
Versuch 4 *Experiment 4*	Als Mischung im FMW *as mixed ration in a FMW*	Simulation eines AFS *Simulation of an AFS*	Sommer 2013 *Summer 2013*

[1] Futtermischwagen/*Fodder mixer wagon.*
[2] Automatisches Fütterungssystem/*Automatic feeding system.*

In contrast to experiments 1, 3 and 4 all rations in experiment 2 (the ones provided once a day, as well as the ones provided several times a day) were mixed right before their distribution.

Within the single experiments only the silage quality (good silage/aerobically deteriorated silage) varied, while the remaining ingredients of the feeding ration did not differ. Good silage was removed from the middle part of the silo, where the silage has the highest compression and consequently the lowest influence of oxygen. Aerobically deteriorated silage was either removed from the edge parts of the silo, or leftovers from the removal of the last days were taken. In experiment 1 and 4, which took place in the summer, reheating could already be detected, while removing the aerobically deteriorated silage from the silo. Although this could not be recognized in the winter experiments, it could be assumed, that due to the oxygen input at the edge parts these silages where more contaminated with yeasts and other germs, than the silage in the middle part of the silo.

Data

In all experiments the temperature of the TMR in the feed mixer wagon and at the feed bunk, as well as the ambient temperature were measured.

Furthermore nutrient content, fermentation parameters and germ content of the rations were examined.

In the experiments 1–4 the samples for the chemical analysis were drawn of the recently mixed ration, and in experiment 4 additionally of the orts. The chemical analysis of the forage was realized by the department Quality Assurance and Investigation System of the Bavarian State Research Center of Agriculture in Grub (accredited to DIN EN / IEC 17025). The ingredients were derived from the so called "Weender Analysis", the fermentation parameters were qualified by the Ion Chromatography and the pH-value was measured with a laboratory pH-Meter.

In all experiments the samples for the microbiological analysis were drawn of the recently mixed ration and of the orts of the ration fed once or several times per day.

In the microbiological analysis the laboratory of the Bavarian Animal Health Service (accredited to DIN EN / IEC 17025) analysed lactic acid bacteria, the total bacterial count, yeasts and moulds.

Statistical Evaluation

Except for the forage samples for the microbiological analysis in experiment 4, the data were evaluated descriptively. In experiment 4 the number of the samples for the microbiological analysis were raised (n = 9 per variant), so that the yeast counts of the different variants could be statistically analysed.

By using the t-test the influence of the feed provision several times per day on the yeast count of the TMR should be tested. Explanatory variables were the recently mixed ration, the orts of the ration fed once a day and the orts of the ration fed several times per day.

Results

Fermentation Parameters

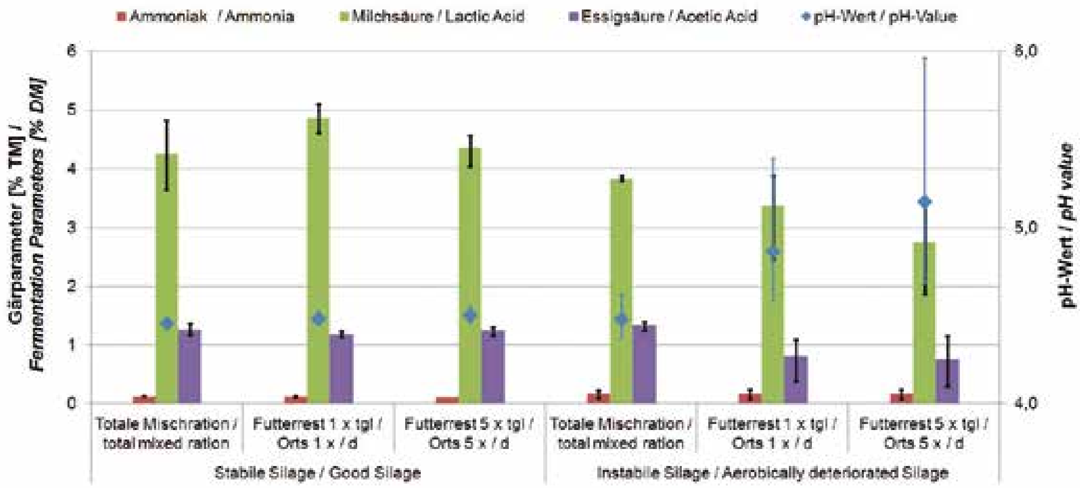
Figure 1 shows the changes in the fermentation parameters in experiment 4 – based on the recently mixed ration to the orts after 24 h.

In both investigation phases, only the fermentation parameters ammonia, lactic acid and acetic acid were detectable in the TMR. The amount of propionic acid and butyric acid were below the detection limit. With good silage, the amount of lactic and acetic acid and consequently the pH-value remained quite steady. In contrast with aerobically deteriorated silage, a descent of the amount of lactic and acetic acid from the moment of mixing the ration to the moment of drawing the samples of the orts (after 24h) could be observed. As a result the pH-value increased considerably. The fermentation acids decreased in a more explicit way when the TMR was provided several times per day, than when it was provided only once a day.

Temperature and Yeast content

The temperature and yeast count of the TMR is shown in **Table 2**. In experiment 2 and 3, when ambient temperatures were

Fig. 1



Means and range of the fermentation parameters in experiment 4 (n = 3)

low, an increase of the temperature could not be measured. The temperature of the TMR stayed at the base level or even decreased independently of the feeding frequency. Only in experiment 2 when feed was provided only once a day, the yeast count increased. With a feed provision several times a day the yeast count stayed at the base level. In experiment 3 the yeast content did not increase at all.

In experiment 1 and 4 at high ambient temperatures and by using aerobically deteriorated silage in the TMR, temperature increased especially in the feed mixing wagon, where the TMR was stored until its distribution. Maximum temperatures up to 40 °C (single values) could be observed here. Also the yeast counts increased distinctly in the experiments 1 and 4 by using aerobically deteriorated silages. In experiment 4 the statistical evaluation showed a significant difference between the base yeast counts (Y_0) and the yeast counts after 24 h (Y_{24}). Differences between the different feeding frequencies (once or several times per day) did not occur.

Using good silage, the TMR in experiment 1 and 4 did not heat up. Thus the yeast counts also increased and the differences between Y_0 and Y_{24} were also significant in experiment 4. Differences between the feeding frequencies did not exist here, too.

Discussion

Fermentation Parameters

The development of the pH-value and the fermentation parameters in experiment 4 with aerobically deteriorated silages (**Figure 1**) confirms the degradation of lactic acid through yeasts under aerobic conditions and the related increase of the pH-value, as described in the introduction. Using aerobically deteriorated silage the base yeast counts were already quite high and laid over the benchmark for corn silage with 6 log CfU/g FM. Consequently the yeasts could multiply in 24 h to that point, that a visible degradation of lactic acid could be observed. The difference between the feeding frequency once a day or several times per day can probably be traced back to the higher bulk density and the consequently stronger heating of the TMR at the storage in the FMW at the feeding frequency several times per day. It can be assumed, that the yeasts found better growing conditions here, than at the feed bunk at the feeding frequency once a day. Contrarily by using good silage, the yeast counts laid below the mentioned benchmark and their multiplication could not proceed so far, that a degradation of lactic acid became visible.

Temperature and Yeast content

Generally the base yeast counts (Y_0) of the TMR by using good silage laid under the benchmark of 6 log CfU/g FM for corn silage while they exceeded the benchmark when using aerobically deteriorated silage. This shows that the usage of silage from the edge parts of the silo and the silage leftovers were suitable to prepare an aerobically deteriorated experimental ration. Within the aerobically deteriorated TMR the yeasts tended to multiply in a faster way than in the good silage. However the multiplication of yeasts seems not always to be accompanied by an increase of temperature. Thus in the experiments 1 and 4 (summer) with aerobically deteriorated silage and a feeding frequency only once a day the TMR-temperature stayed stable, although the yeast counts increased. Here the TMR was stored for 24 h in a swath at the feed bunk. Due to the large surface the heat, produced by microbiological growth, could be given off to the environment and the forage did not heat, despite there was an increase of the yeast counts.

With a higher feeding frequency of five to six times a day, there was hardly an air exchange with thermal convection in the FMW. The heat produced by microbial growth, could not be given off to the environment and the temperature of the TMR

Table 2

Temperature and yeast count in the TMR

	$TMR\text{-}H_0$ *$TMR\text{-}Y_0$*	$TMR\text{-}H_{24}$ *$TMR\text{-}Y_{24}$*	Außentemperatur *Ambient temperature*	$TMR\text{-}T_0$ *$TMR\text{-}T_0$*	$TMR\text{-}T_{20}$ *$TMR\text{-}T_{20}$*
	log KbE/g FM / *log CfU/g FM*		°C		
Winter/*Winter*					
Instabile Silage (V2)/*Aerobically deteriorated silage (E2)*			Ø 4,6		
Futtertisch 1x tgl. Füttern/*Feed bunk, feeding 1x / d*	6,54	6,86	min. 1,0	8,8	7,9
Futtertisch 6x tgl. Füttern/*Feed bunk, feeding 6x / d*	6,21	6,19	max. 9,8	9,5	10,0
Stabile Silage (V2)/*Good silage (E2)*			Ø 7,0		
Futtertisch 1x tgl. Füttern/*Feed bunk, feeding 1x / d*	5,51	6,25	min. 1,7	12,3	9,9
Futtertisch 6x tgl. Füttern/*Feed bunk, feeding 6x / d*	5,34	5,45	max. 9,9	14,3	11,6
Instabile Silage (V3)/*Aerobically deteriorated silage (E3)*					
FMW[1)]/*FMW[1)]*			Ø -1,7	3,6	1,9
Futtertisch 1x tgl. Füttern/*Feed bunk, feeding 1x / d*	5,49	5,36	min. -5,9	2,4	-1,9
Futtertisch 6x tgl. Füttern/*Feed bunk, feeding 6x / d*		5,06	max. 2,0	3,6	-1,5
Stabile Silage (V3)/*Good silage (E3)*					
FMW / *FMW*			Ø 1,1	3,8	3,0
Futtertisch 1x tgl. Füttern/*Feed bunk, feeding 1x / d*	5,30	5,26	min. -3,3	2,1	1,3
Futtertisch 6x tgl. Füttern/*Feed bunk, feeding 6x / d*		5,17	max. 2,7	1,2	1,9
Sommer/*Summer*					
Instabile Silage (V1)/*Aerobically deteriorated silage (E1)*					
FMW/*FMW*			Ø 19,9	22,7	34,0
Futtertisch 1x tgl. Füttern/*Feed bunk, feeding 1x / d*	6,52	7,74	min. 9,7	23,3	22,9
Futtertisch 6x tgl. Füttern/*Feed bunk, feeding 6x / d*		7,75	max. 32,7	23,0	32,9
Stabile Silage (V1)/*Good silage (E1)*					
FMW/*FMW*			Ø 16,5	19,6	20,1
Futtertisch 1x tgl. Füttern/*Feed bunk, feeding 1x / d*	5,62	5,56	min. 9,5	21,1	18,6
Futtertisch 6x tgl. Füttern/*Feed bunk, feeding 6x / d*		6,48	max. 25,5	21,0	19,9
Instabile Silage (V4)/*Aerobically deteriorated silage (E4)*					
FMW/*FMW*			Ø 22,4	21,3	33,9
Futtertisch 1x tgl. Füttern/*Feed bunk, feeding 1x / d*	6,51[a)]	7,98[b)]	min. 15,1	19,5	19,7
Futtertisch 5x tgl. Füttern/*Feed bunk, feeding 5x / d*		8,07[b)]	max. 28,9	19,5	21,4
Stabile Silage (V4)/*Good silage (E4)*					
FMW/*FMW*			Ø 21,2	18,4	20,3
Futtertisch 1x tgl. Füttern/*Feed bunk, feeding 1x / d*	5,35[a)]	6,35[b)]	min. 11,6	16,9	16,7
Futtertisch 5x tgl. Füttern/*Feed bunk, feeding 5x / d*		6,31[b)]	max. 29,6	16,3	17,1

$TMR\text{-}H_0$ = Hefegehalt der Totalen Mischration nach dem Mischen/*$TMR\text{-}Y_0$ = Yeast count of the total mixed ration after mixing*
$TMR\text{-}H_{24}$ = Hefegahalt der Totalen Mischration nach 24 h/*$TMR\text{-}Y_{24}$ = Yeast count of the total mixed ration after 24 h*
$TMR\text{-}T_0$ = Temperatur der Totalen Mischration nach dem Mischen/*$TMR\text{-}T_0$ = Temperature of the total mixed ration after mixing*
TMR-T20 = Temperatur der Totalen Mischration nach 20 h/*TMR-T20 = Temperature of the total mixed ration after 20 h*

[1)] Futtermischwagen/*Fodder mixing wagon*.
[a,b)] Innerhalb der ersten beiden Spalten und der Versuchsphasen unterscheiden sich die Mittelwerte mit unterschiedlichen Buchstaben signifikant/*Within the first two columns and experimental phases means with different letters differ significantly.*

increased. Although after the distribution of the forage the TMR cooled down partially, it was warmer than the once daily distributed ration throughout the day.

In experiment 2 it could be observed, that the yeast counts in the orts were contrarily to all other experiments higher at a feeding frequency once a day, than at a feeding frequency several times per day. The reason might be that in this experiment the several times per day fed ration was mixed every time right before its distribution, whereas the once fed ration was stored as TMR at the feed bunk.

Conclusions

With using AFS it is very important to pay attention at a good silage quality or, if necessary, maybe even to guarantee a good silage quality by applying silage additives, especially during the summer time with average ambient temperatures higher than 20 °C. During the summertime even a maximum aerobic storage time of 24 hours can lead to reheating in the silages.

This is different in the wintertime. With average ambient temperatures lower than 7 °C, according to the presented results, even the aerobic storage of aerobically deteriorated silage for more than 24 hours is possible.

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