Chapter

Nutrition of the High-Yielding Dairy Cow

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Abstract

In addition to genetics, health status and housing management, the milk yield of the dairy cow is also significantly determined by the feeding regime. In addition to the energy and nutrient supply, the dry matter (DM) intake plays a decisive role. This is influenced by many factors, such as the palatability of the feed, the energy density, the quality of the roughage (silage quality, microbiological status, contamination with mycotoxins) or the ration design in total. Water supply of cows is often forgotten, although it has a significant influence on the feed intake and thus the performance of the cows. This article deals with those factors, gives the latest recommendations and points out possible sources of error against the background of feeding not only according to the species-specific requirements but also according to their energy and nutrient needs, as required by the Animal Welfare Act.

Keywords: dairy cow, cattle nutrition, feed intake, feedstuff, nutritive related disorders

1. Introduction

In everyday life, the feeding of cattle is usually judged from an economic point of view: A feed fulfils its purpose if it supplies the animal in such a way that it achieves its performance and is also as cost-effective as possible. In the process, animal welfare is sometimes overlooked, although this in turn has an influence on performance, useful life and thus also on the economic viability of cattle farming.

Since the 1970s, the performance of dairy cows has increased by more than 35%. At the same time, however, the age of life decreased significantly [1]. Thus, about 30% of dairy cows already drop out in the first lactation. This is mainly caused by udder diseases (around 30% of mergers), but hoof and joint diseases as well as metabolic disorders (around 10% each) are also cited as causes [2]. There is no doubt that several factors are responsible for these developments and must be taken into account and optimised accordingly. However, the question arises as to the importance of feeding in this context. According to the Animal Welfare Act (§ 2), anyone who keeps, looks after or has to look after an animal must feed, care for and house the animal in a manner appropriate to its species and needs.

Here, the interlink between feeding and husbandry becomes clear. In order to ensure sufficient feed intake, the housing conditions must first be designed in such a way that the animal is able to carry out its physiological behaviour with regard to food and water intake as well as chewing behaviour. The design of housing follows the concept of the “five freedoms”, which requires freedom from (1) hunger and thirst, (2) discomfort, (3) pain, injury and disease, (4) fear and stress, and (5) the exercise of normal behaviour. The importance of this behavioural concept for the general performance of animals is underpinned by studies carried out within the AgroClustEr PHÄNOMICS at the University of Rostock and the Leibniz Institute for Farm Animal Biology. It was shown that different temperament types differ not only in their behaviour, but also in their metabolism [3]. Taking into account the species-specific (preferably temperament-specific) requirements helps to make optimal use of existing metabolic pathways.

In order to enable the animal to ingest sufficient quantities of feedstuff, there should be (except in the case of stations in which concentrated feed is offered) an animal to feeding place ratio of 1: 1 (control report 2015 for Lower Saxony and Bremen in accordance with Article 41 of EU Regulation No. 809/2014 for the on-the-spot controls on cross compliance [4, 5]). The feed offered must meet clear legal requirements. According to § 3 of the Animal Welfare Act, it is forbidden to offer feed that causes the animal considerable pain, suffering or damage. This certainly refers to contamination such as foreign bodies (stones, wire, etc.) or poisonous plants, but also to the hygiene status of a feed (e.g. yeast content, contamination with mycotoxins), which can have considerable consequences for the animal's well-being (e.g. tympania in younger cattle after ingestion of heavily contaminated silage). In addition, the ration design itself is also important, which will be discussed in the following chapters. Imbalances in the crude fibre and starch content of the feed, lack of synchronicity in the rumen, energy or mineral deficiencies as well as the use of less palatable feeds are examples to be mentioned here. Finally, the feeding technique is also important, which varies considerably in some cases and affects the quality of the cow's supply and thus their well-being.

2. Ration design: critical points and opportunities for failures

In the following, the general aspects of ration design for high-yielding cows and the problems that arise in practice will be discussed. Data from the service area, in which cases of damage caused by nutritive factors will be presented. In addition, results from ongoing scientific studies will be included accordingly.

2.1 Selection of suitable feed

Feed rations for dairy cows consist of roughage (basic feed) as well as concentrates and mineral feeds. The quality of the roughage already has a significant influence on the amount of feed consumed [6, 7]. When checking the hygiene status of grass silage (n = 109), 41% of the samples showed an increased yeast contamination, which is associated with poorer acceptance of the feed [8] and thus lower feed intake quantities (see **Table 1**).

Therefore, it is evident that yeasts are not only found in corn silage, but that in the case of corresponding clinical disorders, the grass silages in the ration should also be considered. In this study, slightly more than 40% of the samples examined had yeast contents that were higher than the usual recommended limit values.

In general, in the case of reduced performance or illnesses in the dairy herd, special attention should be paid to the basic feedstuffs (in addition to corn silage, especially grass silage) and these should be analysed accordingly.

In most cases of clinical disorders in cattle a causal relationship could be established between microbiological findings and pre-reported disorders (see **Table 2**).

Thus, deviations in the hygiene status could be found in every 5th sample examined (22–25%). On average, 25% of the samples already showed deviations in the sensory test. Therefore, it makes sense to take a critical look at the basic feed from time to time.

	Number of samples (n)	Relative proportion (%)
Aerobic bacteria		
Tolerable levels (< 2 x 10^5 cfu/g*)	82	75
Non-tolerable levels (> 2 x 10^5 cfu/g)	27	25
Moulds		
Tolerable levels (< 5 x 10^3 cfu/g)	96	88
Non-tolerable levels (> 5 x 10^3 cfu/g)	13	12
Yeasts		
Tolerable levels (< 2 x 10^5 cfu/g)	64	59
Non-tolerable levels (> 2 x 10^5 cfu/g)	45	41

**Fresh matter.*

Table 1
Microbiological quality of grass silages (n = 109) from practical farms in Germany.

	2017		2018		2019		2020	
	n	%	n	%	n	%	n	%
Total grass silage sent in*.	64		63		80		63	
Deviations in hygiene status	15	23.4	16	25.4	19	23.4	14	22.2
Preliminary report								
Post-heating after silo opening	2	13.3	6	37.5	3	15.8	1	7.1
Deviations in the sensory test	4	26.7	4	25.0	3	15.8	4	28.6
Reduced feed intake/milk yield	2	13.3	2	12.5	6	31.5	5	35.7
Enteritis, diarrhoea	4	26.7	1	6.25	5	26.3	—	—
Mastitis, abortions	1	6.7	2	12.5	1	5.3	4	28.6
Metabolic disorders, liver diseases	2	13.3	1	6.25	1	5.3	—	—

**Analyses due to clinical disorders, no control analyses.*

Table 2.
Quality of grass silages sent in to the institute (2017–2020).

In addition to the hygiene status, attention should also be paid to the botanical composition of the green fodder. The presence of velvet grass leads to a poorer acceptance of the forage and to a reduced regurgitation. While the number of chews per bolus averaged 250 ± 57 when hay is offered, the chewing frequency is significantly lower (146 ± 91 chews per bolus) due to the proportion of velvet grass (*H. lanatus*). On the one hand, this means that a smaller quantity of basic feed is consumed, which can lead to a loss of performance. At the same time, chewing and ruminating is reduced and less saliva is produced, so that the buffering effect is reduced.

Due to the more intensive nitrogen (N) fertilisation and the partly developing resistance to common herbicides, there has been an increasing trend in recent years towards the infestation of monocultures with poisonous plants [9]. Examples are the occurrence of black nightshade (*S. nigrum*) in maize crops [7, 9] or the dispersal of dog's mercury (*M. annua*) in intensively cultivated beet fields [10]. Whereas in past years illnesses of dairy cows as a result of ingestion of poisonous plants or plants with poisonous ingredients were rather the exception, recently more questions have been asked about this problem and there have been an increasing number of cases of poisoning.

This development can be explained, among other things, by altered management of agricultural land, such as the trend towards extensification (migration of poisonous plants from fallow land into cropland, restrictions of fertilisers, ban on herbicides). Renaturation measures (e.g. raising the groundwater level) can also promote the spread of certain poisonous plants (e.g. marsh horsetail). In addition, there are neophytes, i.e. plants that are not endemic to the respective area but are spreading more and more over time and as a result of climate change. For example, golden oat grass (Vit. D efficacy!), whose distribution was previously limited to the Alpine regions and southern Germany [11], is now also increasingly found in northern Germany. On the outskirts of cities, ruminants also come into contact with ornamental plants containing toxic substances that are not usually part of their food spectrum (e.g. planting hedges for privacy protection). In this context, the improper "recreational horticultural disposal" of ornamental plants with toxic ingredients on adjacent pastures should be mentioned [12].

Sometimes, under the assumption that detoxification processes generally take place in the rumen, feeds with a reduced hygiene status are used in ruminants, which is obsolete in other species (e.g. horses). The same applies to contamination of the feed with poisonous plants, although some can be quite lethal, these are used in ruminants under the assumption that they are detoxified in the rumen.

While in the years 2000 to 2005 only about 5 to 10 cases per year were sent in, in which feed was to be checked for the presence of poisonous plants or plants with poisonous ingredients, in the past two years there were already 87 (2019) and 117 cases (2020) in which the suspicion of possible contamination with poisonous plants was expressed in the preliminary report.

Offering a feed contaminated with dog's mercury resulted in severe clinical signs. This toxic plant contains mercurialin (= methylamine), trimethylamine, hermidine, saponin (1% in the herb, highest content at fruit ripeness) and essential oils. The main ingredient mercurialin, which belongs to the saponins, leads to liver damage and haemolysis in cattle (typical clinical sign: icterus). The animals typically show apathy, salivation, reduced rumen motility and are often laying in autoscultatory posture. Corresponding laboratory analyses show a high degree of haemolytic anaemia as well as haemoglobinuria [10].

The effect of mercurialin is also present in dried plant material, whereas no information is available on a possible influence of ensiling on the toxic ingredients. In order to clarify the extent to which the ensiling process leads to a degradation of the toxic ingredients, heifers (n = 6) were offered beet leaf silage contaminated with 20% dog's mercury in a feeding trial. Compared to the control group (n = 6), there was a significantly reduced basal feed intake (see **Figure 1**).

The presence of marsh horsetail in a total mixed ration TMR for dairy cows also leads to a significantly reduced feed intake (see **Figure 2**) and thus poorer milk production even at levels of only 1.25%.

In addition to the roughage, the composition of the milk performance feed is also significantly responsible for the performance of the dairy cow. Macroscopically noticeable deviations (also in comparison to the previous batch) upon delivery of the feed should be a reason to have not only the chemical but also the botanical composition of the feed checked. A check revealed considerable discrepancies between declared and actually found feed materials in almost 35%. In one clinical case report (reduced milk yield), a high proportion of rapeseed cake instead of rapeseed extraction meal led to a fat content in the milk performance feed of 7.5% (instead of the declared 3.5%). The use of this feed led to a fat content of over 1500 g/animal/d (tolerated limit: 800 g crude fat/cow/d) and thus to fermentation disorders in the rumen.

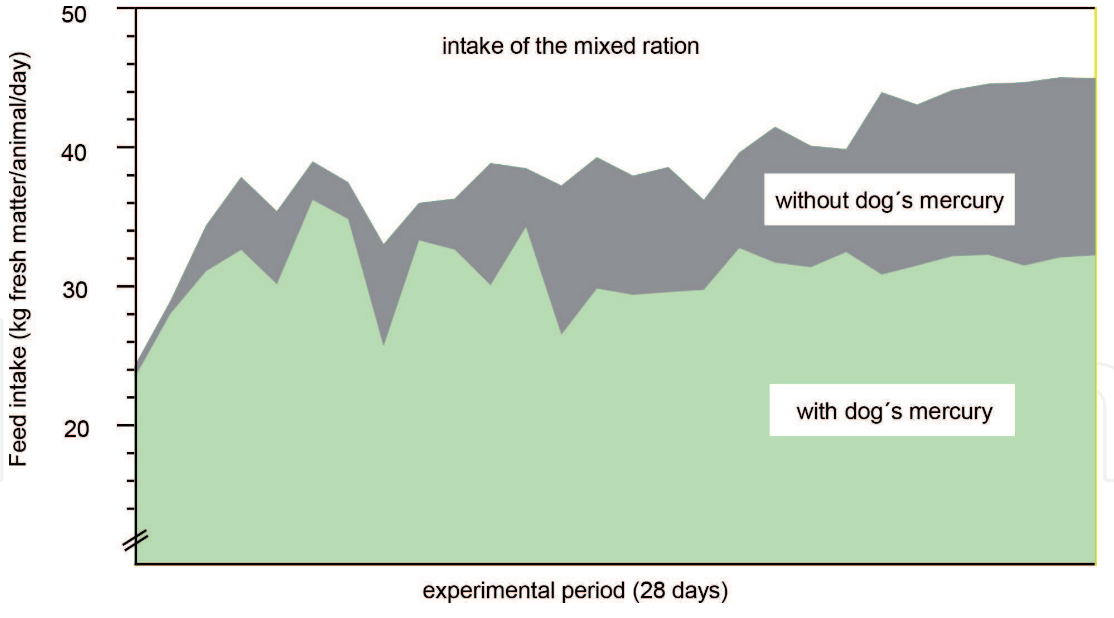

Figure 1.
Roughage intake of heifers feeding beet leaf silage with and without dog's mercury.

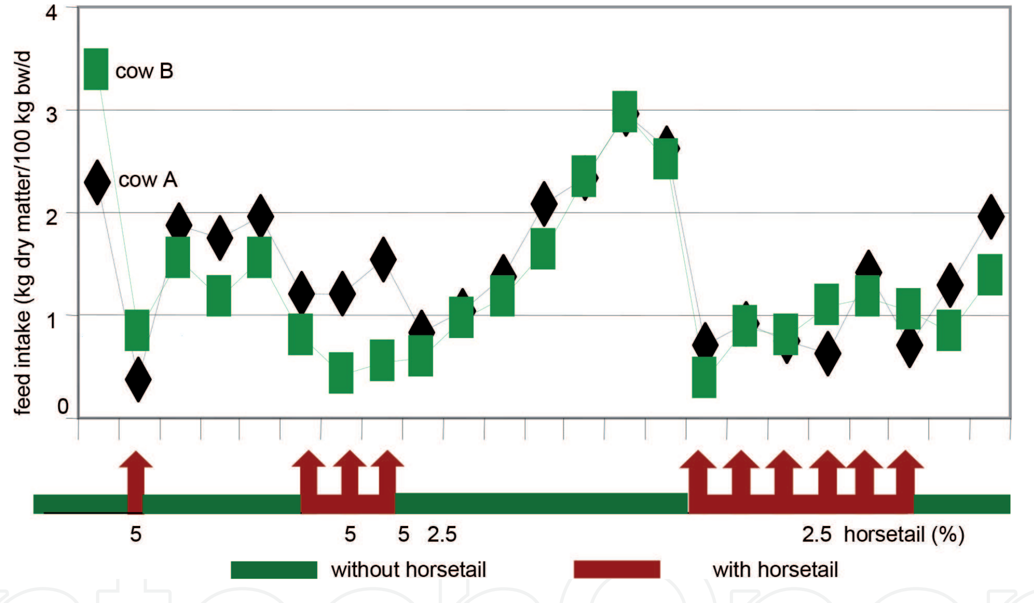

Figure 2.
DM intake of dairy cows when offered a TMR with different contents of marsh horsetail.

2.2 Meeting energy and nutrient requirement

The calculation of the ration by means of a computer program and table values must be preceded by an assessment (sensory testing, laboratory analyses), especially in the case of farm-produced feedstuff, as the nutrient content of feed can vary in a high range. This often results in discrepancies between calculated and actually fed rations, which give rise to complaints (see **Table 3**).

Often the rations had insufficient fibre content (< 16%) and at the same time very high starch and sugar content (in total > 300 g/kg dm). This feeding situation involves the risk of rumen acidosis. During the dry period, the animals were often oversupplied with energy. A possible fatty degeneration associated with this is undesirable, especially around the time of birth. In almost 20% of the samples, elevated mineral content was detected, which is contrary to the DCAB concept and involves the risk of milk fever.

	Checked rations (n)	Objections (%)
Lactation	87	
Crude fibre↓, Σ starch + sugar ↑	42	48.3
Crude fibre ↓, Σ starch + sugar ✓	11	12.6
Calcium ↑	13	14.9
Cu, Zn, Se ↓	10	11.5
Dry period	52	
Energy density↑ crude fibre↓	19	36.5
Minerals ↑ (DCAB)	10	19.2
Cu, Zn, Se ↓	5	9.6

Table 3.
Criticism of rations for cows during lactation and dry period.

Microbial fermentations during silage preparation not only influence the energy and nutrient intake of cows, but - depending on the amount and proportional composition - also milk yield and composition [13].

For the assessment of ensiling success and protein intake via fresh and preserved green fodder, the pure protein content provides important information (see **Table 4**).

If ensiling is only insufficiently successful, proteolytic processes can lead to protein degradation [14]. The result is reduced pure protein content, which - if only the crude protein content of the fresh and preserved green fodder is assessed - can lead to an incorrect assessment of the protein supply of the dairy cow (see **Table 5**).

Grass silages with a low true protein percentage in the total crude protein are supposed to contribute to the aetiology of a disease that is described as "factorial disease of dairy herds" or a higher incidence of fertility disorders, respectively [15].

During such proteolyses, biogenic amines are produced, among other things, which significantly influence the acceptance of a feed. Gamma-aminobutyric acid (GABA) is the so-called lead substance, the analytical detection of which can be carried out quickly and without great effort in the laboratory. GABA correlates closely with the pure protein level of a silage (see **Figure 3**) and thus gives a first impression of the silage quality. It is also known from feeding trials that GABA contents >7 g/kg dry matter lead to a massive reduction in feed intake [15, 16].

In the case of inhomogeneous mixtures (insufficient mixing, strongly inhomogeneous particle lengths of the individual ingredients), the cows can select more palatable components (e.g. maize silage), so that - despite a balanced ration calculation on paper - there can then be insufficient fibre and simultaneously higher starch/sugar intakes [17].

Feedstuff	n	Crude protein (% TS)	Pure protein (% of dry matter)	Pure protein portion of the crude protein (%)
Gras, fresh	40	21.3 ± 2.5	18.9 ± 2.4	87.5 ± 2.87^{a}
Hay	36	14.2 ± 5.9	11.5 ± 3.9	82.3 ± 4.57^{a}
Gras silage	186	17.4 ± 2.4	8.9 ± 1.2	51.1 ± 9.54^{b}

Different lowercase letters indicate significant differences ($p < 0.05$) depending on the preservation method.

Table 4.
Crude protein and pure protein levels in fresh and preserved green fodder.

		High quality	Low quality
Dry matter	g/kg fm	375 ± 111	364 ± 108
Crude protein	g/kg fm	171 ± 20.8	180 ± 15.3
Pure protein	g/kg fm	94 ± 12.7	70 ± 7.3
Relation	% of crude protein	55 ± 6.1	39 ± 4.0

Table 5.
Pure protein content in grass silage of high or poor ensiling quality.*

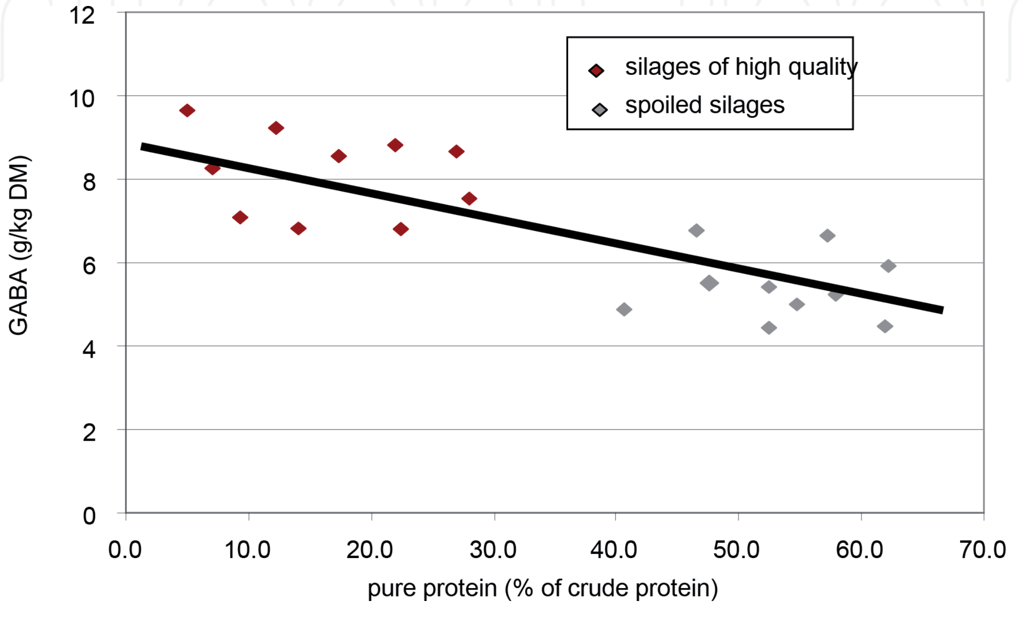

Figure 3.
GABA-levels in dependence of the pure protein level of grass silages.

A Total Mixed Ration (TMR) fulfils this requirement offering a simultaneous amount of richly-structured fibre and energy-rich components at the same time. But even if a homogenous and well-balanced feed mixture is offered the chemical composition (especially starch and fibre content) might differ between the offered and the actually ingested feed due to a selective feed intake behaviour in cows. In order to investigate this aspect 158 cows (Holstein Frisian) were split into two groups (group A, n = 76, TMR: 30.0 kg corn silage, 11.0 kg grass silage, 5.0 kg concentrate, 3.0 kg soybean meal, 2.4 kg alfalfa; Group B, n = 82, TMR: 29.0 kg corn silage, 11.0 kg grass silage, 3.6 kg concentrate, 2.0 kg soybean meal, 2.0 kg alfalfa). Starch and crude fibre were analysed using conventional methods. Measurement of particle size distribution followed recommendations of a commercial forage particle separator (Shaky 4.0, Wasserbauer, Waldneukirchen, Austria), consisting of three sieves with hole diameters of 19, 8 and 4 mm besides a collection tray for particles <4 mm.

Already in the first 30 minutes after feed offer a selective feed intake behaviour could be observed (see **Table 6**).

The distribution of particle sizes at the particular points of time as well as the chemical analysis of the feed suggest that the dairy cattle preferably ingest certain nutritious components (here probably corn silage). This selective feed intake behaviour implies the risk of SAARA due to the high starch and low fibre content in the actually ingested feed. The presented results show that selective feed intake is a non-negligible factor in dairy cattle nutrition. A synchronised intake of crude fibre and starch is not ensured even if the feed is offered homogenously. To avoid this

Group		n	Sieve analysis ≥ 19 mm	Sieve analysis < 4 mm	Chemical composition Crude fibre (% i. DM)	Chemical composition Starch (% i. DM)
A	Feed offer	5	34.7 ± 21.7	31.2 ± 8.38	21.5 ± 2.45	22.7 ± 1.57
	After 30 min	5	33.1 ± 4.95	29.1 ± 1.45	23.4 ± 0.92	19.9 ± 3.11
	After 7.5 h	5	54.5 ± 16.9	12.8 ± 2.46	26.7 ± 1.97	15.5 ± 1.57
B	Feed offer	5	25.7 ± 10.9	32.7 ± 2.12	24.0 ± 0.55	22.1 ± 3.76
	After 30 min	5	34.2 ± 14.9	27.4 ± 6.79	25.0 ± 1.10	18.7 ± 3.16
	After 7.5 h	5	51.7 ± 9.88	24.7 ± 9.19	25.7 ± 2.04	19.0 ± 3.69

Table 6.
Development of particle size distribution and crude and fibre level in a TMR in the period following feed offer.

selection all components would have to have identical particle sizes (as practiced with the compact-TMR or shredlage). The question is, however, if the cows would still show a physiological rumination behaviour under those conditions.

For decades, the question of the desirable/necessary supply of structured fibre to dairy cows (including cattle) has been the focus of animal nutrition science. Against this background, in 2014 the assessment of rations for dairy cows with regard to "fibre supply" was changed to a new system, namely the "physically effective NDF" (peNDF; [18]). The innovative feature of this concept is the unification of two criteria previously treated separately, namely.

- the physical form (length of fibres, size of particles, i.e. structure, determined in a sieve analysis) and

- the chemical composition of the total ration (sum of cell wall components, i.e. the NDF);

by multiplying the result of the sieve analysis (%, mass fractions) by the NDF content in the total ration (% of DM). According to previous studies and experience, a TMR should contain >18% peNDF>8 or > 32% peNDF>1.18 in the total DM to achieve optimal structural supply in dairy cows [19].

In feeding practice, the "shaker box" (so-called Penn State Particle Separator) offers an important tool for assessing the particle size distribution of a ration and, together with the NDF content, also for assessing the "structural effectiveness" of a ration. In our own investigations, however, it was shown that this approach is subject to various errors (**Figure 4**).

In addition to the mesh size of the sieves and the dry matter content of the silage (moist silage tends to stick together and thus gives the impression of longer particles), the result also depends to a large extent on the person carrying out the analysis. If an identical grass silage is examined by different persons, there is a very high scattering of the results.

2.3 Assessment of the feeding situation on the farm

A frequent animal welfare-relevant problem in the feeding of dairy cows is the insufficient intake of fibre-rich coarse feeds or the lack of synchronicity in the rumen. Consumption of sufficient quantities initially requires the production of

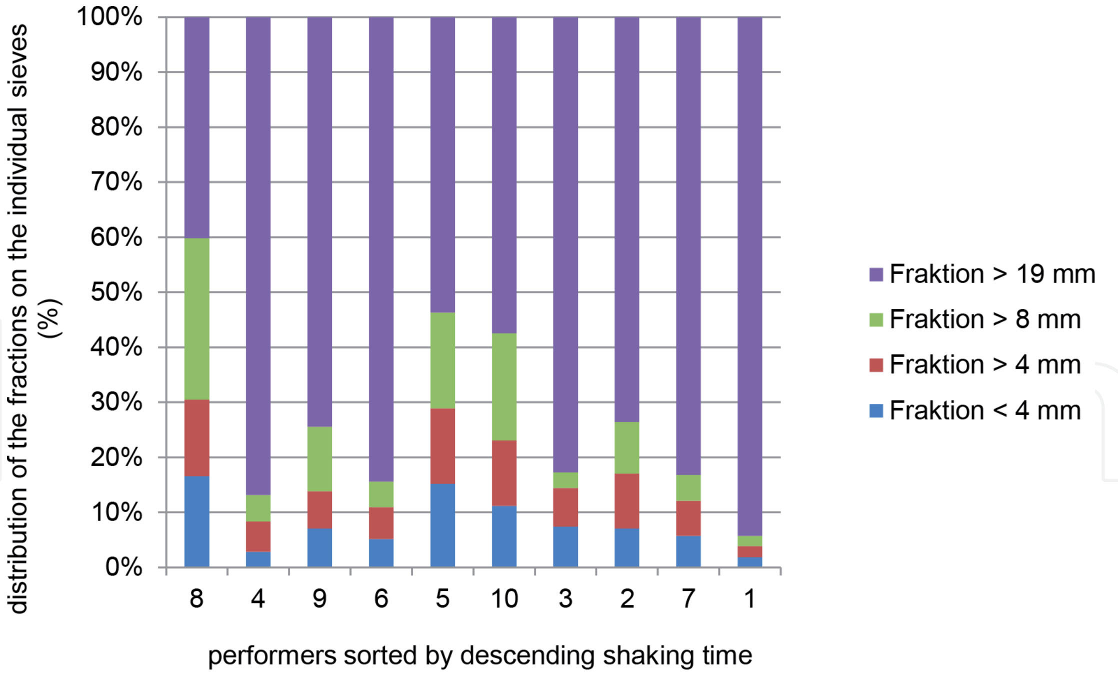

Figure 4.
Particle size distribution in a grass silage depending on the person carrying out the analyses.

high-quality grass silage and hay. However, studies from practice show that these often have higher contents of spoilage-indicating microorganisms (e.g. yeasts), sand, less palatable components (e.g. velvet grass) and ingredients (e.g. gamma-aminobutyric acid) or even just an unfavourable low dry matter (DM) content [7]. If these are mixed into a total mixed ration, the actually realised DM intake falls short of the expected one and the cow is sometimes not sufficiently supplied with energy and nutrients.

The factors influencing the DM intake of the dairy cow and thus ultimately also the performance are manifold and are summarised in the following **Table 7**.

A suitable indicator to check whether feeding is in line with animal welfare is the recording of feed intake quantities. Here the question arises as to whether the quantities of feed presented via the feed mixer and the quantities of concentrated feed correspond to the herd size. However, this approach considers the herd as a whole and not the individual animal. The same applies to the milk yield data, which

Feed	**Feeding**
DM content, structure	Adaptation (dry period)
Digestibility (Rfa)	Proportion of basic/fuel feed
Silage quality (fermentation process)	Quality (silage success)
Palatability	Availability of feed
Contamination	Water supply
Feed intake capacity	**Cow comfort**
Body weight, forestomach volume	Social stress, restlessness
Energy requirement	Climatic influences
Body fat content	Movement possibilities
Lactation status	Metabolic disorders

Table 7.
Factors influencing the dry matter intake of dairy cows.

provide conclusions on the supply of energy and nutrients (protein, fibre). Feedback from the slaughterhouse (e.g. increased incidence of fatty liver or liver abscesses) allows an assessment of the feeding situation on the farm, also under animal welfare aspects. For the assessment of the individual animal, the assessment of the Body Condition Score (BCS), which is also a component of the Animal Welfare Quality® Assessment protocol reviewed at PHÄNOMICS, is a suitable method. This procedure enables an assessment of the quality of the husbandry system from the animal's point of view. This would also satisfy another legal regulation of the Animal Welfare Act (§ 11, para. 8), which reads: "Anyone who keeps farm animals for commercial purposes must ensure through in-house inspections that the requirements of § 2 are met. In particular, he shall collect and evaluate appropriate animal-related characteristics (animal welfare indicators) for the purpose of his assessment that the requirements of § 2 are met." Thus, the livestock farmer cannot escape the responsibility to continuously check the feeding of his animals under animal welfare aspects (cross compliance; Directive 98/58 Annex No. 2; TierSchNutztV § 4 para. 1).

3. Conclusion

Feed and feeding conditions (especially ration design) are not infrequently the cause of health problems and/or performance losses in dairy herds. The possible damage (in terms of financial losses) ranges from reduced performance in the form of lower fertility, reduced milk yield or changes in milk quality to clinical disorders (coupled with treatment costs) and animal losses (e.g. sudden death of one or more animals). In contrast to the conditions in pig and poultry farming, where complete feed concepts are common, in dairy cow feeding the detection of weak points and failures, i.e. the causal clarification of feeding problems, is much more difficult. The variety of feeds and their variation in composition and quality, the differences in ration design depending on farm conditions (housing/feeding technique) and performance stage (dry period/high lactation) and, last but not least, the considerable individual variation in feed intake (concerning the quantity and ratio of various components of the ration) explain the particular challenge when it comes to possibly feed-related problems in dairy farms.

Satisfactory feeding practices require due diligence along the path from feed to food (´from stable to table´). However, ensuring these requirements and striving to avoid feeding-related problems in the dairy herd ultimately requires cooperation between the livestock farmer and the veterinarian.

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References

[1] Ducrocq V (1987): An analysis of length of productive life in dairy cattle. PhD Diss Cornell Univ., Ithaca, NY

[2] Römer A (2011): Studies on the duration of use in German Holstein cows. Züchtungskunde, 83: 8-20.

[3] Brand B, Hadlich F, Brandt B, Schauer N, Graunke KL, Langbein J, Repsilber D, Ponsuksili S, Schwerin M (2015): Temperament type specific metabolite profiles of the prefrontal cortex and serum in cattle. PLOS ONE, DOI: 10: e0125044

[4] BML (1988): European Convention for the Protection of Animals kept for Farming Purposes - Recommendation for the Keeping of Cattle. https://www.bmel.de/DE/Tier/Tierschutz/Tierschutzgutachten/_texte/Europaratsempfehlungen.html.

[5] LAVES (2007): Animal welfare guideline for the keeping of dairy cows. www.laves.niedersachsen.de/download/41962

[6] Grant RJ, Ferraretto LF (2018): Silage review: Silage feeding management: Silage characteristics and dairy cow feeding behaviour. J Dairy Sci 101(5): 4111-4121

[7] Kamphues J, Wolf P, Mösseler A (2009): Feed-related damage in dairy herds. Züchtungskunde 81: 451-460.

[8] Martin NH, Snyder A, Wiedmann M (2020): Yeasts and Molds: Spoilage Mold in Dairy products. Reference Module in Food Science. Doi.org/10.1016/B978-0-08-100596-5.23017-5

[9] WOLF P (1996): Poisonous plants in cattle feed. Übers. Tierernährg. 24, 102-110

[10] Hollberg W, Winkelmann J (1989): Enzootic haemoglobinuria in a dairy herd due to dog's mercury poisoning. Tierärztl. Umschau 44 (3), 162-164

[11] Brühlmann M, Thomet P (1991): Course of the quantitative and qualitative forage supply on alpine pastures. Landwirtschaft. Schweiz 4 (10), 547-554

[12] Wolf P, Blanke HJ, Kamphues J, Stöber m (2003): Tulip onions with leaf (*Tulipa gesneriana*) – a very unusual and risky component in a ration for cattle. Dtsch. Tierärztl. Wochenschr. 110 (2003), 302 – 305

[13] Huhtanen P, Nousiainen JL, Khalili H, Jaakola S, Heikkila T (2003): Relationship between silage fermentation characteristics and milk production parameters: analyses of literature data. Livest Prod Sci 81:57-73

[14] Kung L, Shaver RD, Grant RJ, Schmidt RJ (2018): Silage review: Interpretation of chemical, micobial, and organoleptic components of silages. J Dairy Sci 101(5): 4020-4033

[15] Gressner N (2011): Studies on the effects of grass silages with low true protein contents on protein metabolism in ruminal fluid in-vitro. Diss. med. vet. Hannover

[16] Whang DM, Liu HY, Wang C, Liu JX, Ferguson JD (2013): Effects of rumen-protected gamma-aminobutyric acid on feed intake, performance and antioxidative status in transition cows. Livestock Sci 153:66-72

[17] Maulfair DD, Heinrichs AJ (2013): Effects of varying forage particle size and fermentable carbohydrates on feed sorting, ruminal fermentation, and milk and component yields of dairy cows. J Dairy Sci 96:3085-3097

[18] White RR, Hall MB, Firkins JL, Kononoff PJ (2017): Physically adjusted

neutral detergent fiber system for lactating dairy cow rations. J Dairy Sci 100(12): 9551-9568

[19] Nasrollahi SM, Imani M, Zebeli Q (2015): A meta-analysis and meta-regression of the effect of forage particle size, level, source, and preservation method on feed intake, nutrient digestibility, and performance in dairy cows. J Dairy Sci 98(12):8926-8939