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Influence of wet vs. dry by-product ingredients and addition of branched-chain volatile fatty acids and valerate to dairy diets. 1. Feed intake, milk production and milk composition

H. de Visser and S. Tamminga

Institute for Livestock Feeding and Nutrition Research (IVVO), P.O. Box 160, 8200 AD Lelystad, Netherlands.

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Abstract

A feeding trial was carried out with 56 dairy cows in the first 18 weeks of lactation. Rations consisted of grass silage and maize silage as roughage components, and concentrates based entirely on by-product ingredients. Two groups were formed in which the by-products were fed in a dehydrated (DRY) or in an ensiled (WET) form.

Half of each group received no additive (MINUS) or an additive (PLUS) containing calcium salts of isoacids (iso-butyrate, 2-methyl butyrate, 3-methyl butyrate) and valerate.

No significant effect of the use of the additive was found on feed intake, milk production and milk composition.

Dutch rations based on grass silage and several by-product ingredients with comparatively high protein levels may have sufficient sources of branched-chain carbon skeletons for rumen bacterial growth.

Feed, energy and protein intake, milk protein content and milk protein production were significantly lower after feeding the WET diet as compared to the DRY diet.

Introduction

Use of by-products in dairy cattle feeding is common in the Netherlands. In the past 10 years more than 90 % of concentrate ingredients for dairy cattle were by-products.

In the last few years a tendency has developed to use more ensiled by-products because of high costs of dehydration due to increasing prices of fossil energy. Concentrates are partially substituted with wet by-products. Increasing the moisture content of the diet could decrease voluntary dry matter intake (Lahr et al., 1983). The nature of the energy available in the feed after ensiling or dehydration differs. During ensiling easily fermentable carbohydrates are rapidly used by micro-organisms for maintenance and growth. As a result, less energy is left for rumen micro-organisms, which could decrease total microbial protein synthesized. This may lead to a reduced flow of amino acids to the lower gastrointestinal tract (Miller, 1982; Van Soest, 1982), which may result in lower availability of amino acids for synthesis of milk protein.

Experimental results from the USA (Papas et al., 1984; Pierce-Sandner et al., 1985) indicate a positive influence of dietary addition of branched-chain volatile fatty acids (iso-butyrate, 2-methyl butyrate, 3-methyl butyrate) as well as the straight-chain volatile fatty acid valerate (isoacids) on the production of milk and efficiency by which it is produced. In these studies typical American rations were used, which were largely based on maize products and contained substantial amounts of non-protein nitrogen.

To investigate the usefulness of isoacids under Dutch feeding conditions a trial was carried out in which isoacids and valerate were added to a ration containing wilted grass silage and maize silage as the roughage components. In addition concentrates based on by-product ingredients were fed either in a dehydrated form or wet ensiled.

This study was completed with a metabolism study with four dairy cows fed the same diets (Robinson et al., 1987a, 1987b).

Materials and methods

A feeding trial was completed with 56 dairy cows which were either purebred Dutch Friesian or crossbred Dutch Friesian × Holstein Friesian black and whites. All animals were in second or higher lactation. The trial started on the day of parturition and was continued for 18 weeks.

Prior to the start of the trial animals were allocated over four equal groups based on age and production in previous lactations (Table 1). Animals were fed complete mixed diets twice daily by using a feeding mixing wagon. Of the total daily ration 40 % was offered at 05h00 and 60 % at 15h00. Feeding after parturition started with 15 kg dry matter. Ad libitum intake was achieved and maintained by adjusting every second or third day the daily amount of feed offered. Adjustments were governed by the aim to have refusals of less than 1 kg of material as fed, but were applied in portions of 1 kg of dry matter of the totally mixed diet. On a dry matter basis the diets consisted of 40 % roughage (wilted grass silage and maize silage in a 50:50 ratio) and 60 % concentrates. Part (60 % on a dry matter basis) of the concentrate ingredients (beet pulp, maize gluten feed and brewers' grains) were fed either ensiled (WET) or dehydrated (DRY). Wet and dry by-product ingredients were from different batches. The energy/protein ratio of the diet was calculated with the Dutch Net Energy Lactation system (van Es, 1978) and digestible crude protein (DCP) as advised in 1983 by the Central Bureau of Livestock Feeding in the Ne-

Table 1. Average milk production, milk composition, and age of the cows in previous lactations.

	DRY MINUS	DRY PLUS	WET MINUS	WET PLUS
Milk (kg/year)	5269	5243	5308	5229
Fat (%/year)	4.29	4.29	4.28	4.30
Protein (%/year)	3.34	3.35	3.34	3.34
Age (months)	53	53	54	52

Table 2. Chemical composition, energy and protein values of roughages and ensiled by-products used in the experiment.

	Grass silage (wilted)	Maize silage	Beet pulp (pressed)	Maize gluten	Brewers' grains
Chemical composition					
Dry matter (g/kg)	537	291	191	438	257
Ash (g/kg DM)	119	71	132	50	55
Crude protein (g/kg DM)	213	94	105	209	250
Crude fibre (g/kg DM)	257	223	206	86	172
Crude fat (g/kg DM)	n.a.	n.a.	7	28	99
Neutral detergent fibre (g/kg DM)	493	451	498	377	628
Starch (g/kg DM)	–	n.a.	–	219	16
Energy and protein values					
Net energy lactation (MJ/kg DM)	5.93	5.91	6.62	7.22	5.03
Digestible crude protein (g/kg DM)	159	54	65	154	186
Acetic acid (g/kg DM)	2.0	2.0	2.0	1.22	5.0
Butyric acid (g/kg DM)	–	–	–	–	1.0
Lactic acid (g/kg DM)	8.6	15.3	7.0	27.8	1.0
Alcohol (g/kg DM)	1.0	1.1	1.8	0.6	0.5

n.a. = not analysed.

therlands. On a dry matter basis an equal amount of each by-product ingredient was fed in each treatment (WET or DRY). The chemical composition of the roughages and ensiled by-products is shown in Table 2. The ingredient profile and chemical composition of the concentrates is shown in Table 3. Organic matter digestibility of the used by-products (beet pulp, maize gluten feed and brewers' grains) was estimated by the in vitro technique of Tilley & Terry (1963) as adapted at IVVO by van der Meer (unpublished). The results were corrected to in vivo values by using standard samples of known in vivo digestibility. Both the ensiled and the dehydrated form of maize gluten feed and brewer's grains were tested for in vivo digestibility with wethers. The wethers were fed at or close to maintenance with a basal diet of ca. 250 g DM as long meadow hay and ca. 750 g DM from the by-product to be in-

Table 3. Ingredients and chemical composition of the concentrates used in the experiment.

	DRY MINUS	DRY PLUS	WET MINUS	WET PLUS
Ingredient composition (%)				
Beet pulp (dehydrated)	30.0	30.0	–	–
Maize gluten feed (dehydrated)	20.0	20.0	–	–
Brewers' grains (dehydrated)	10.0	10.0	–	–
Soya bean meal	10.0	10.0	25.0	25.0
Coconut expeller	7.5	7.5	18.8	18.8
Palm kernel expeller	7.5	7.5	18.8	18.8
Cane molasses	3.0	3.0	7.5	7.5
Animal fat (tallow)	1.0	1.0	2.5	2.5
Soya bean hulls	8.2	8.2	20.5	20.5
Minerals and vitamins	2.8	2.8	6.9	6.9
Isoacids (ISOPLUS^{TM})	–	0.7	–	2.1
Chemical composition				
Dry matter (g/kg)	894	894	894	891
Ash (g/kg DM)	100	102	124	128
Crude protein (g/kg DM)	194	194	216	210
Crude fibre (g/kg DM)	143	143	169	163
Crude fat (g/kg DM)	45	44	74	69
Neutral detergent fibre (g/kg DM)	389	393	427	406
Sugars (g/kg DM)	107	111	94	96
Starch (g/kg DM)	54	53	12	18
Net energy lactation (MJ/kg DM)	7.34	7.34	7.53	7.53
Digestible crude protein (g/kg DM)	151	151	179	179
Digestibility in vitro (organic matter)	83.4	83.6	81.0	81.0

vestigated. Apparent digestibility was calculated by difference assuming that digestibility of hay and by-product ingredients were additional.

Half the number of animals receiving the WET or DRY diet received a supplement with approximately 80 g calcium salts of the isoacids iso-butyrate, 2-methyl butyrate, 3-methyl butyrate and the straight-chain volatile fatty acid valerate (ISOPLUS^{TM}) (PLUS), the other half received no supplement (MINUS).

Milk production was recorded and sampled during two consecutive days a week. Samples were taken for individual milkings and analysed for fat and protein content. Live weight of the animals was measured once a week. The results of the trial were statistically analysed as a 2 × 2 factorial design. The results were also tested for possible interactions between the two factors involved (type of diet versus additive). For analysis the statistical programme Genstat was used (Alvey et al., 1982).

Results and discussion

During the trial one animal (1170) of group DRY MINUS had to be removed from the trial because of sepsis. From week fourteen onwards the results of this animal were lost.

Results of in vitro digestibility of beet pulp, maize gluten feed and brewers' grains (ensiled or dehydrated) (Table 4) and results of in vivo digestibility of maize gluten feed and brewers' grains (ensiled or dehydrated) are given in Table 5. In vitro digestibility of beet pulp is high, which is in agreement with previous observations at IVVO (Steg & Haaksma, unpublished). No difference is found between ensiled or dehydrated beet pulp. Digestibility in vitro of organic matter of the maize gluten feed (ensiled or dehydrated) agrees with results of previous trials. However, in vivo digestibility of the ensiled maize gluten feed is lower than expected. Especially the dehydrated maize gluten feed is extremely low in digestibility in vivo. Chemical composition cannot explain these differences. In previous trials Steg (unpublished) found good relationships between in vivo and in vitro digestibility of the organic matter for dehydrated maize gluten feed. Calculation of energy value of the maize gluten feed of the feeding trial is based on in vitro digestibility.

The digestibility of the ensiled brewers' grains is lower than expected. The ranking of the results in vivo and in vitro are in agreement with each other. The ensiled brewers' grains must have been of poor quality, not only when compared with the dehydrated form fed in this experiment, but also in comparison with other batches of which organic matter digestibility has been studied in vitro and in vivo.

Table 4. Digestibility (%) in vitro of organic matter in beet pulp, maize gluten feed, and brewers' grains.

	Digestibility in vitro	
	dehydrated	ensiled
Beet pulp	86.8	86.2
Maize gluten feed	85.7	87.2
Brewers' grains	67.8	58.2

Table 5. Digestibility (%) in vivo of maize gluten feed and brewers' grains.

Digestibility	Maize gluten feed		Brewers' grains	
	dehydrated	ensiled	dehydrated	ensiled
Dry matter	71.4	78.7	57.3	44.7
Organic matter	75.0	81.9	60.9	48.9
Crude protein	65.5	71.5	68.1	74.3
Crude fat	76.4	72.1	86.7	89.9
Crude fibre	57.2	76.5	28.4	15.5
Nitrogen free extract	81.3	87.0	62.7	37.2

Interaction between type of diet (WET versus DRY) and addition of isoacids (MINUS or PLUS) was first tested for significance. No significant interactions were found. Thus results were analysed for main effects according to the 2 × 2 factorial design.

Effect of MINUS versus PLUS treatment

The results of the addition of isoacids are given in Table 6. Lack of significant differences in milk production parameters between MINUS and PLUS groups are not in agreement with those of Papas et al. (1984) and Pierce-Sandner et al. (1985) who observed a significant difference in milk production for groups fed isoacids. However in their study feed intake was significantly higher for isoacids groups in the first weeks post partum, which might explain higher milk production due to the higher energy intakes. In the later part of lactation some of their groups were fed according to milk yield, which might explain continuation of the difference in milk yields.

Probably the differences between our study and those of Papas et al. (1984) and Pierce-Sandner et al. (1985) are a consequence of the difference in composition of diets. In our trial a higher content of crude protein was fed (18 % versus 14 % in the

Table 6. Dry matter intake, milk production, milk composition and energy and protein intake and requirements.

	MINUS	PLUS	DRY	WET	SEM	Sign.
Roughage intake (kg DM)	8.5	8.2	8.4	8.2	0.14	NS
Concentrate and by-product intake (kg DM)	12.1	11.9	12.6[a]	11.4[b]	0.17	$P<0.01$
Total dry matter intake (kg DM)	20.6	20.1	21.1[a]	19.6[b]	0.26	$P<0.01$
Net energy lactation intake (MJ)	136	133	143[a]	128[b]	1.68	$P<0.01$
Net energy lactation requirement (MJ)	141	138	142	138	2.33	NS
Net energy supply (%)	98	97	102[a]	93[b]	1.24	$P<0.01$
Digestible crude protein intake (g)	2716	2650	2827[a]	2539[b]	33.4	$P<0.01$
Digestible crude protein requirement (g)	2483	2423	2484	2422	42.5	NS
Digestible crude protein supply (%)	109	109	114[a]	105[b]	1.14	$P<0.01$
Milk (kg)	31.8	30.8	31.7	30.9	0.64	NS
Milk fat (%)	4.29	4.29	4.31	4.29	0.05	NS
Milk protein (%)	3.17	3.17	3.21[a]	3.13[b]	0.03	$P<0.05$
Milk fat (g)	1362	1323	1362	1323	29.1	NS
Milk protein (g)	1006	976	1015[a]	967[b]	16.6	$P<0.05$
Fat-corrected milk (kg)	33.2	32.2	33.1	32.2	0.66	NS
Live weight (kg)	611	611	618	604	11.7	NS

SEM = standard error of mean.

NS = not significant.

Figures with a different superscript are significant ($P<0.05$).

DM), because protein feeding standards in the Netherlands are higher than in the USA. In most of the diets applied by Papas et al. (1984) and Pierce-Sandner et al. (1985) a large proportion of dietary crude protein was maize protein and often a substantial part of the dietary crude protein was fed as non-protein nitrogen (urea). In our trial five products relatively rich in protein were used (soya bean meal, maize gluten feed, palm kernel expeller, coconut expeller, brewers' grains).

Degradation of these protein sources may have led to an adequate supply of isoacids in the rumen. Using one major protein source as was the case in the trials of Papas et al. (1984) and Pierce-Sandner et al. (1985) may supply suboptimal amounts of isoacids for rumen fermentation due to an inadequate amino acid profile. Degradation of non-protein nitrogen (urea) does not contribute to the pool of isoacids in the rumen. Robinson et al. (1987a) fed the same diets to rumen-cannulated dairy cows and their results indeed suggested an adequate supply of isoacids in the rumen after feeding diets without supplement of isoacids. Nevertheless, these authors observed increased rumen concentrations of isoacids when ISOPLUS™ was added to the ration. It is therefore likely that the amount of isoacids produced on the MINUS diets was sufficient to optimize rumen bacterial growth. Thus supplemental isoacids from the ISOPLUS™ would not increase bacterial growth and efficiency of bacterial growth.

Use of one major protein source in a concentrate for dairy cows is not common in the Netherlands, nor is it likely to be in the near future. Non-protein nitrogen is very seldom used in dairy rations. At present supplemental isoacids do not seem promising for Dutch dairy rations based on grass and by-product ingredients with crude protein levels between 17 and 20 % of the dry matter. There is however an increasing interest in maize silage as a major component of dairy rations and research on the effect of a supplement of isoacids with diets largely based on maize silage seems of interest.

Effect of DRY and WET treatment

The results of the type of diet (WET or DRY) are shown in Table 6. Dry matter content in different batches of the ensiled by-products, especially the pressed beet pulp, within one silo varied more than expected. This has led to overestimation of the dry matter content, resulting in a lower amount of dry matter from pressed beet pulp in total dry matter of the WET diet compared with the DRY diet.

The amount of roughage eaten by the cows did not differ significantly between DRY and WET groups. The concentrate and by-product intake was however significantly lower for the WET group.

Differences were not similar during the entire experiment. Especially in the early weeks of lactation the difference was more pronounced.

Dry matter intake of the DRY ration declined in the second part of the experiment to a greater extent than cows fed WET diets. This might be due to the increased temperature in the stall. Storage of the WET diet in a refrigerator to prevent heating may have slowed the drop in feed intake for WET diets. However, total dry matter intake over the entire experimental period was significantly lower for the WET diet. Lower total dry matter intake of the WET diet may partly be a consequence of the lower digestibility of the ensiled brewers' grains (Table 4). Higher moisture content of total ration may have influenced total dry matter intake as well. Lahr et al. (1983) found highest dry matter intakes when dry matter content of the diet was approximately 60 %, which is more or less equal to the dry matter content of the DRY diet. In trials in which wet by-products were fed separately and the total amount of ensiled products (roughage and by-products) was not above 50 % of total ration dry matter, no negative influence on feed intake was observed (de Brabander et al., 1980; Schingoethe et al., 1983; Porter et al., 1977; Dulphy et al., 1978; Castle & Watson, 1982). The high proportion of ensiled products in the diets fed in our trial (80-85 %) may have been important in this respect.

Energy and protein intake of the DRY diet was significantly higher. The combination of the higher total dry matter intake and the higher energy and protein content of the dehydrated by-products caused this difference.

The ratios between energy requirement and intake and protein requirement and intake were significantly different between the groups, both in favour of the dry diet. The higher intake in the first weeks of lactation was mainly responsible for this difference (Figs. 1 and 2). The supply of energy of the total experimental period was approximately 100 % for the DRY diet, whereas the WET group was fed ca. 8 % below requirements. The supply of protein was 114 % for the DRY diet and 105 % for the WET diet. The amount of milk produced was not significantly different between the groups. There was a tendency for a higher milk production with the DRY group, which may simply reflect higher intake. Differences in milk produc-

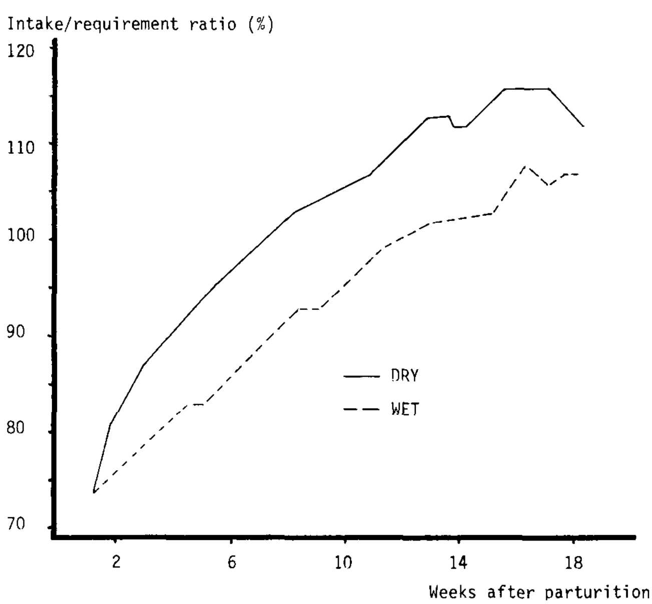

Fig. 1. The Net Energy Lactation intake/requirement ratio of the DRY and WET diet.

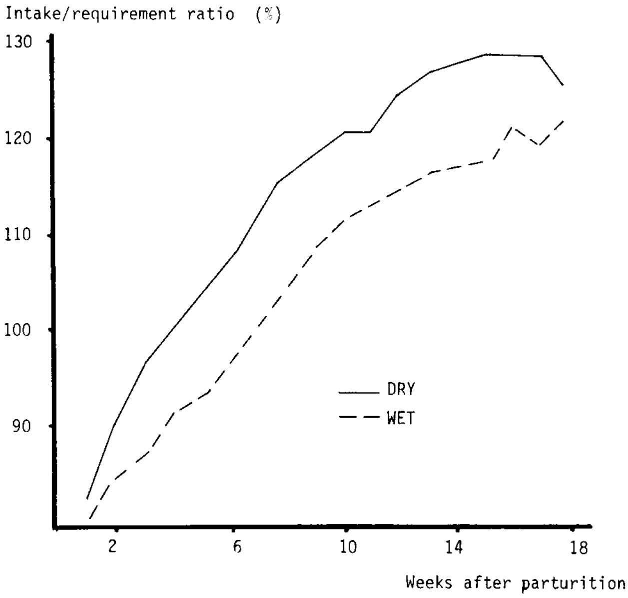

Fig. 2. The digestible crude protein intake/requirement ratio of the DRY and WET diet.

tion were significant in the first eight weeks of lactation. Afterwards the differences decreased. At the same time feed intake of the WET diet was increased, while intake of the DRY group remained constant or decreased slightly.

Milk fat content and total amount of milk fat produced was not significantly different between the groups: for individual by-products the effect on milk fat is different. De Brabander et al. (1980) found lower milk fat percentages when feeding wet beet pulp, in which some 10 % of the moisture had been removed by pressing, leaving a residue with approximately 18 % dry matter. No influence was found, however, when wet brewers' grains and maize gluten feed were fed (Staples et al., 1984; Polan et al., 1985; Murdock et al., 1981).

The protein production and the protein content of the milk were significantly lower for the WET diet (Figs. 3 and 4, Table 6). Staples et al. (1984) found lower protein percentage when feeding wet maize gluten feed, while Schingoethe et al. (1983) found no influence. Murdock et al. (1981) found no influence when feeding wet brewers' grains. De Brabander et al. (1980) found higher milk protein contents when feeding pressed beet pulp. A reduced milk protein content may result from either a negative energy balance or from an inadequate protein supply from the gastrointestinal tract. Due to a negative energy balance either insufficient protein as compared to energy is mobilized from body reserves or protein is being used as a source of energy. An inadequate protein supply may result from excessive degradation of feed protein or from an inadequate microbial protein synthesis in the rumen.

With regard to the influence of a negative energy balance, this situation was

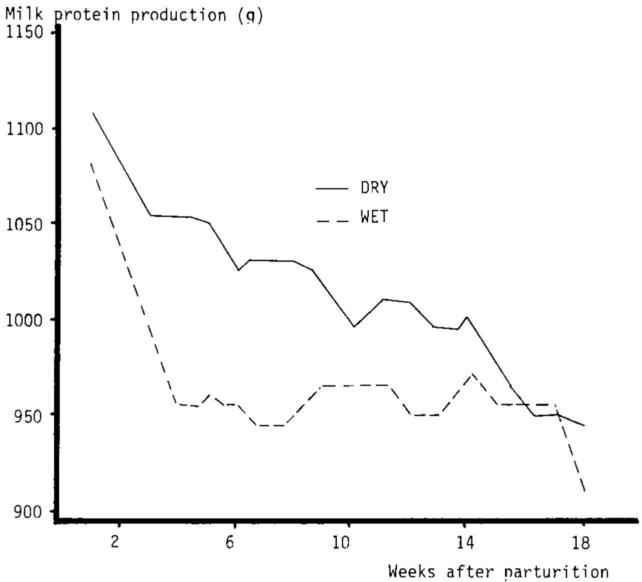

Fig. 3. The milk protein production of the DRY and WET diet.

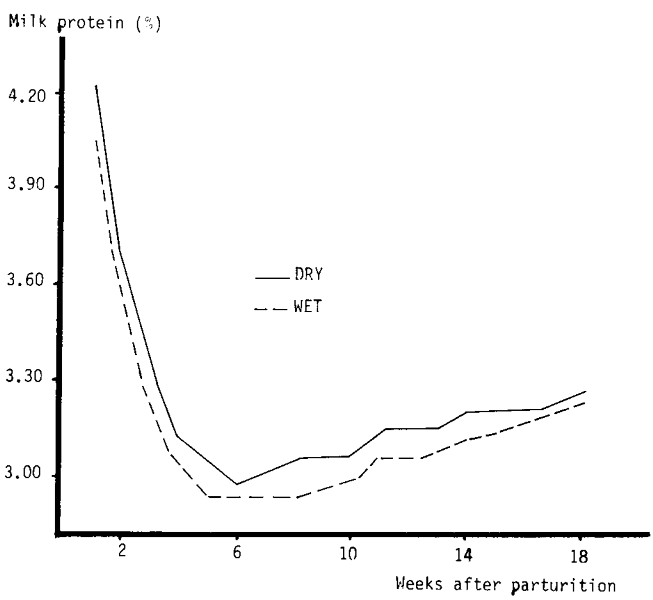

Fig. 4. The milk protein percentage of the DRY and WET diet.

maintained longer on the WET than on the DRY diets (Fig. 1). From Fig. 4 it can be seen that the milk protein content does not start to rise again after the initial sharp fall post partum until the energy supply equals the animal's demand. This latter situation occurred in the weeks 5 and 10 for the DRY and WET diets, respectively, and this moment coincides rather well with the start of the rise in milk protein content.

However after energy supply had started to exceed demand, the difference in milk protein content between DRY and WET diets remained. Additional research (Robinson et al., 1987b) showed that ruminal non-bacterial non-ammonia-N, as proportion of N intake, did not differ between DRY and WET diets, suggesting only negligible differences in rumen degradation of feed N due to the diet. There was however a significant difference in bacterial organic matter (OM) as % of rumen OM in favour of DRY diets. This difference may have led to a higher supply of microbial N after feeding the DRY diets, resulting in an increased milk protein content. Feeding large quantities of a dairy ration as ensiled products may have a negative influence on energy availability for rumen microbes, because of the extraction of part of the energy by microbes during the ensiling process. The efficiency of microbial synthesis from those diets was lower than from non-ensiled diets (Miller, 1982; Van Soest, 1982; Anonymous, 1984). Also the results of the rumen fermentation study of Robinson et al. (1987a, b) showed a lower ammonium concentration for the DRY diets, despite a higher N to net energy ratio in DRY diets. This indicates that more ammonia was captured by bacteria with the DRY diets.

Fat-corrected milk (FCM) production (4 %) tended to be higher for the DRY diet. It could be explained by the higher intake. FCM production showed the same pattern as milk production.

Live weight did not differ between the groups. The higher energy intake for the DRY diet was not reflected in a higher increase in live weight. The DRY group showed two weeks earlier an increase in bodyweight, but this was not significant.

Conclusions

Digestibility of brewers' grains and the maize gluten feed differed between the dehydrated and ensiled form, probably due to the quality of the material.

No interaction was found between ISOPLUS™ as an additive and type of diet (WET or DRY).

No significant differences with regard to feed intake and milk production or milk composition were found between cows fed diets with or without the additive. Type of roughage and number of different ingredients in the diet are most likely responsible for the absence of an effect of ISOPLUS™.

The dry matter, energy and protein intake was negatively influenced by the use of wet by-product ingredients. Also the milk protein content and milk protein production was significantly decreased. Lower digestibility and reduced microbial protein synthesis in the rumen seems the most plausible explanation for this observation.

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