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PREVENTION OF MILK FEVER (HYPOCALCEMIC PARESIS PUERPERALIS) BY DIETARY SALT SUPPLEMENTS

By

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DISHINGTON, INGER W.: *Prevention of milk fever (hypocalcemic paresis puerperalis) by dietary salt supplements.* Acta vet. scand. 1975, *16*, 503—512. — Twelve cows of 14 given a basic diet supplemented with Na_2CO_3 and $NaHCO_3$ during four weeks pre partum and one week post partum were attacked by milk fever (hypocalcemic paresis puerperalis), while 12 cows of 13 receiving the same basic diet supplemented with sulfates and chlorides remained healthy. A mixture of $CaCl_2$, $Al_2(SO_4)_3$ and $MgSO_4$ was found to be a convenient prophylactic supplement.

It was found possible to induce and prevent milk fever at successive parturitions in the same cow by altering the dietary conditions.

The data give further support to the hypothesis that the alkali alkalinity of the diet is the major factor in induction or prevention of milk fever.

milk fever; dairy cow; prophylactic diet.

Milk fever has for a long time been regarded as primarily an endocrinological disturbance, reflected in a more or less pronounced hypocalcemia and hypophosphatemia. The idea that nutritional factors might be of decisive influence in the etiology as well as the prevention of milk fever has, however, also been entertained by some workers (*Boda & Cole* 1954, *Osinga* 1963, *Brochart* 1964, *Stott* 1965, *Kendall et al.* 1966, *Ringarp et al.* 1967, *Payne* 1970, *Westerhuis* 1974, and others). The concepts as to which dietary errors produce the disease have, however, been divergent. The first results on dietary induction and prevention of hypocalcemic milk fever from this laboratory (*Ender et al.* 1956, 1962, *Ender & Dishington* 1967) appeared to support the notion that the dietary Ca/P-ratio is the decisive factor. But our latest studies with fodder rich in AIV silage, on the one hand, and fodder rich in beets, on the other, respectively preventing and inducing milk fever, even if the contents of Ca and P were brought back to normal levels (*Ender & Dishington* 1970, *Ender et al.* 1971), made us propose the hypothesis that the alkali alkalinity* of the diet was of overriding importance in determining calcium availability, and that the milk fever preventing effect of AIV silage could be ascribed to the negative AA of the diet.

AIV-silaging has gone out of use in recent years. The present paper decribes experiments aimed at finding alternative practical ways of establishing a low AA in the diet. Such experiments would also be a further test of our theory of milk fever prevention.

MATERIAL AND METHODS

Animals

Thirty-one pregnancies in 14 cows of the Norwegian Red and White breed were studied, their age varying between five and ten years. The cows were stalled at the research farm at Heggedal, and the experiments carried out under the clinical supervision of the manager, Docent Arne Helgebostad.

Blood samples for analyses were drawn regularly. During the critical period before, during and after parturition up to seven blood samples a day were taken in order to register the lowest obtainable serum Ca values. In cases of milk fever the cows were treated with intravenous injections of Ca (25 g $CaCl_2$ or 125 g Ca-borogluconate in sterilized water).

Mineral analyses

The contents of Ca, Mg, Na and K were determined using atomic absorption (Perkin-Elmer 303), and inorganic phosphorus was determined according to *Fiske & Subbarow* (1925). For serum these determinations were done directly, while for dietary compounds, feces, milk and refused fodder, wet ashing with $HNO_3 + H_2SO_4$ was carried out. The contents of sulfur and chlorine were calculated from available tables.

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* meq. [(K + Na)—(S + Cl)] daily = AA.

Table 1. Composition of the diets.

	Hay kg	Beets kg	Formic acid silage kg	Molasses kg	Herring meal kg	Wheat and barley kg	Peanut meal kg	$CaCO_3$ g
Starting diet (12—5 weeks pre partum)	5	12	3	0.4	0.12	1.5		50
Basic diet (4—1 weeks pre partum)	8	3	3	0.4	0.6	1.8		50
Basic diet (post partum)	9	3	3	0.4	0.20	5.0	1.0	50

Supplement: 20 g NaCl + 10 g MgO + tablets containing Cu, Co, Mn, Zn, Ni, Fe and Al.

Feeding regimens and diets

The experimental feeding started three months before expected parturition. During the first two months all cows received the milk-fever inducing starting diet used in previous experiments (*Dishington* 1974). Four weeks pre partum the amounts of beets were greatly reduced and replaced by nutritionally equivalent amounts of hay. These diets had the composition given in Tables 1 and 2. Experimental diets given from about four weeks pre to one week post partum consisted of the basic diet with the supplements specified below. When using supplements 2—4, an additional 100 g of $CaCO_3$ was also given, directly in the fodder, or as neutralizing agent in solutions.

Table 2. Feed values and alkali alkalinity of the pre-partal diets.

	Scand. feed units	Crude protein g	K g	Na g	S g	Cl g	Alkali alkalinity meq.
Starting diet	5.75	577	150	30	14	48	+ 2910
Basic diet	7.05	683	162—172	16—20	13—15	61—65	+ 2055—+ 2770
Basic diet + Suppl. 1	7.05	683	172	46	13	61	+ 3875
Basic diet + Suppl. 2	7.05	683	162	16	15	67	+ 2025
Basic diet + Suppl. 3	7.05	683	172	20	61	101	— 1340*
Basic diet + Suppl. 4a	7.05	683	162	16	47	81	— 385*
Basic diet + Suppl. 4b	7.05	683	162	16	45	81	— 255

* These figures represent lower limits, since considerable losses of acid occurred during the preparation of the Supplement 3 "silage". With Supplement 4a the losses were smaller.

Supplement 1: 40 g Na_2CO_3 and 40 g $NaHCO_3$ were mixed well into morning rations of concentrates.

Supplement 2: 19 l of water was acidified with AIV-acid and pressed into 6 kg of hay over night; 25.5 meq. of acid was necessary in order to bring pH to the level found in acid silage (3.6—3.8).

Supplement 3: 117 ml conc. HCl, 90 ml conc. H_2SO_4 and 100 g of $CaCO_3$ were dissolved in 19 l of water (pH 3.6—3.8) and pressed into 6 kg of hay over night. When calculating the amounts of acid to be used, account was taken of the great losses experienced during the preparation of the "silage".

Supplement 4a: 33 g $CaCl_2 \cdot 2H_2O$ and 115 g NH_4HSO_4 were dissolved in 10 l of water, neutralized to pH 3.6—3.8 with $CaCO_3$ and pressed into 6 kg of hay over night.

Supplement 4b: 33 g $CaCl_2 \cdot 2H_2O$ in 1 l of water was evenly dispersed on 6—8 kg of hay, followed by 1.5 l of water containing 130 g $Al_2(SO_4)_3 \cdot 16H_2O$ and 80 g $MgSO_4$. The separate addition delays the precipitation of $CaSO_4$ until the solution has been dispersed on the hay. These solutions were not acid enough to require any neutralization and could quite safely be sprayed directly on the first hay ration in the morning. One-hundred g of $CaCO_3$ was given mixed into the concentrates.

RESULTS

Sodium-supplemented diet

A group of cows received supplements of Na_2CO_3 and $NaHCO_3$ to the basic diet in amounts sufficient to establish an AA equal to that of the milk-fever inducing feed of the previous study. The clinical and analytical results, as well as the clinical observations during parturition the previous year, are presented in Table 3. Only two of 14 cows tested showed no signs of milk fever on this regimen. Serum Ca-, Mg- and P-values as well as Ca-balance values were in close agreement with the results obtained with the milk-fever inducing beet-containing fodder in earlier experiments (*Ender et al.* 1971). Thus, serum Ca- and P-values are reduced, while Mg-values are normal or slightly increased. No increase in serum Na-values are observed, the Na- and K-values are within the normal range. Ca-balance values are clearly negative.

Chloride- and sulfate-supplemented diets

In these experiments the aim was to supplement the basic diet so that the diet would have properties corresponding to those of the milk-fever preventing, AIV-silage diet (*Ender et al.* 1971).

T a b l e 3. Clinical and analytical results for cows fed a sodium supplemented diet (Supplement 1).

Clinical observation preceding year	Cow	Age yrs	Exp. year	Serum values at lowest Ca level observed post partum: mg/100 ml					vol. %	Balance levels average g/day four days post partum			Clin. obs.*
				Ca	Mg	P	Na	K	CO_2	Ca	Mg	P	
H	Sissel	5	1970	6.4	2.8	2.5	270	17.6	68.7	—18.8	—2.2	— 8.1	M
M	Rödlin	8	1970	5.6	2.6	2.3	350	23.8	54.5	—27.4	—6.6	—26.1	M
M	Guri	10	1970	3.3	3.3	0.7	321	27.0	53.5	—21.3	—1.2	—32.4	M
M	Fagerlin	9	1970	5.9	2.6	2.6	348	21.1	54.7	—15.2	—3.9	—26.3	B
H	Frida	7	1971	4.2	2.7	1.4	335	19.7	57.9	—29.0	—2.4	—22.0	M
H	Lise	6	1971	6.9	2.1	2.6	318	33.2	74.7				M
B	Fagerlin	10	1971	5.8	2.7	2.3	330	19.0	49.0				B
H	Mari	6	1972	6.8	3.1	2.9	345	22.1	54.6				B
H	Lykke	6	1973	4.0	2.9	0.7	325	17.0	56.5				M
H	Mona	7	1973	8.2	2.7	3.6	—	—	—				H
H	Frida	10	1974	3.3	2.2	0.5	335	12.1	—				M
H	Dagros	6	1974	7.2	3.4	2.9	330	—	—				B
H	Mona	8	1974	8.3	2.7	2.1	340	18.5	—				H
H	Mari	8	1974	4.1	2.9	0.6	315	17.0	—				M

* M = milk fever, B = borderline symptoms (partial paresis), S = slight symptoms, H = healthy.

The data of Table 4 show that simple reduction of pH to that of the silage diet was not sufficient. Three of the five cows came down with milk fever. This addition of acid lowered AA to a minor extent only. Serum Ca-, Mg- and P-values and Ca-balance values correlated well with the clinical observations. Mg- and P-balance values appear to be of uncertain diagnostic value.

T a b l e 4. Clinical and analytical results for cows fed an acidified diet (Supplement 2).

Clinical observation preceding year	Cow	Age yrs	Exp. year	Serum values at lowest Ca level observed post partum: mg/100 ml					vol. %	Balance levels average g/day four days post partum			Clin. obs.*
				Ca	Mg	P	Na	K	CO_2	Ca	Mg	P	
H	Frida	6	1970	7.3	2.6	3.8	300	26.2	67.0	— 5.2	—3.3	—25.4	H
H	Lise	5	1970	8.0	2.2	4.1	385	38.4	69.2	+20.8	—4.1	—26.0	H
M	Sissel	6	1971	3.3	4.2	0.8	335	15.8	64.5	—20.9	—6.2	— 8.4	M
M	Rödlin	9	1971	4.6	3.3	1.3	295	22.1	48.9				M
M	Lise	7	1972	5.6	3.1	2.0	290	21.6					M

* H = healthy, M = milk fever.

Table 5. Clinical and analytical results for cows fed chloride- and sulfate-supplemented diets.

Clinical observation preceding year	Cow	Age yrs	Exp. year	Suppl. no.	Serum values at lowest Ca level observed post partum						Clin. obs.**
					mg/100 ml					vol. %	
					Ca	Mg	P	Na	K	CO_2	
M	Guri	11	1971	3	7.1	3.0	3.1	315	17.8	57.3	H
M	Rødlin	10	1972	3	7.4	2.5	3.2	390	31.7	51.4	H
B	Fagerlin	11	1972	3	5.0	3.0	1.8	315	29.6	46.9	B
M	Frida	8	1972	3	6.6	3.1	3.3	—	—	61.9	H
H	Frida	9	1973	3	7.3	3.2	3.4	380	20.8	51.7	H
M	Lise	8	1973	3	7.9	1.7	2.9	—	31.9	42.7	H
B	Mari	7	1973	4a	7.4	2.4	4.4	305	28.0	57.7	H
M	Turid	7	1974	4b	8.3	2.3	3.6	327	31.6	—	H
M	Lykke	7	1974	4b	5.0	3.3	1.6	317	—	—	H
H	Lydig	6	1974	4b	6.3	3.7	5.1	335	—	—	H
H	Lise	9	1974	4b	8.2	2.0	2.3	—	—	—	H
M	Bessi*	7	1974	4b	6.5	1.3	2.5	335	19.0	—	H
M	Heika*	7	1975	4b	9.4	1.9	4.4	325	18.5	—	H

* These two cows are "milk-fever-cows", i.e. cows who had had milk fever several times at their respective farms before they were transferred to Heggedal. They arrived at Heggedal about two months pre partum and were fed continuously a normal diet as close to the one used at their farms as possible. During the last four weeks pre partum and 10 days post partum the same diet was given with Supplement 4 b, AA being —250 meq./day.

** H = healthy, B = borderline symptoms (partial paresis).

In the next experiment sufficient chloride and sulfate were added in the form of sulfuric and hydrochloric acid neutralized with $CaCO_3$ to pH 3.6—3.8, to establish an AA as negative as that found in the AIV-silage diet. Of six cows tested, five were without symptoms of milk fever, one was a borderline case (Table 5).

These results were encouraging. We felt it would be desirable, however, to avoid, if possible, the use of concentrated acids. $CaCl_2$ was chosen as the source of chloride, and neutralized NH_4HSO_4 as the sulfate source for one cow. As a more convenient source of sulfate we tried a mixture of $Al_2(SO_4)_3$ and $MgSO_4$ (six cows). The data of Table 5 demonstrate that all cows receiving these salt additions remained healthy despite the milk-fever inducing diet given until four weeks pre partum.

The clinical findings are parallelled by significantly higher post partum serum calcium levels, a mean of 7.28 mg/100 ml in

Table 6. Data for five cows tested over successive years with regimens of both high and low alkali alkalinity from three to four weeks pre partum following the milk-fever inducing diet given from three months pre partum.

Cow	Age yrs	Diet	Alkali alkalinity meq.	Lowest serum Ca value observed mg/100 ml	Clin. obs.*
Lise	5	Basic diet + Supplement 2	+2025	8.0	H
	6	Basic diet + Supplement 1	+3875	6.9	M
	7	Basic diet + Supplement 2	+2025	5.6	M
	8	Basic diet + Supplement 3	—1350	7.9	H
	9	Basic diet + Supplement 4b	— 255	8.2	H
Guri	6	Diet with 25 kg AIV silage	— 255	7.1	H
	7	Diet with 25 kg beets	+3010	6.8	S
	8	Diet with 25 kg AIV silage	— 255	5.6	H
	9	Diet with 25 kg beets	+3010	3.6	M
	10	Basic diet + Supplement 1	+3875	3.3	M
	11	Basic diet + Supplement 3	—1340	7.1	H
Frida	5	Diet with 25 kg AIV silage	— 255	9.0	H
	6	Basic diet + Supplement 2	+2025	7.3	H
	7	Basic diet + Supplement 1	+3875	4.2	M
	8	Basic diet + Supplement 3	—1340	6.6	H
	9	Basic diet + Supplement 3	—1340	7.3	H
	10	Basic diet + Supplement 1	+3875	3.3	M
Rødlin	6	Diet with 25 kg AIV silage	— 255	5.6	S
	7	Diet with 25 kg beets	+3010	4.5	M
	8	Basic diet + Supplement 1	+3875	5.6	M
	9	Basic diet + Supplement 2	+2025	4.6	M
	10	Basic diet + Supplement 3	—1340	7.4	H
Mari	6	Basic diet + Supplement 1	+3875	6.8	B
	7	Basic diet + Supplement 4a	—1340	7.4	H
	8	Basic diet + Supplement 1	+3875	4.1	M

* H = healthy, M = milk fever, S = slight symptoms,
B = borderline symptoms (partial paresis).

healthy cows (Table 5), as compared to 5.29 mg/100 ml for milk-fever induced cows (Table 3). Serum P was higher and serum Mg slightly lower in these cows than in the milk-fever induced, but no difference was observed in Na- and K-serum values.

Previous milk fever as causative factor

It has been claimed that once a cow gets milk fever, there is a tendency for it to get it over and over again at the following parturitions. Our data demonstrate that this need not be so. In Table 6 data for five different cows which have been tested over six years with regimens of both high and low AA are assembled to illustrate this point. Feeding regimens of negative AAs resulted in healthy parturitions after single or repeated parturitions accompanied by milk fever.

DISCUSSION

Hypocalcemic paresis puerperalis is a man-made disease in highly productive dairy cows, evoked by a temporary imbalance between calcium supply and requirement at onset of lactation. The widely accepted view that parathyroid insufficiency is the main cause of paresis appears unfounded. The parathyroid in cows suffering from paresis functions more intensively than in healthy cows (*Nurmio* 1968). The theory that an erroneous dietary composition is the main cause of calcium imbalance in connection with parturition has, on the other hand, received further support in this work. The results obtained with the different diet supplements agree with the hypothesis that dietary composition, especially the contents of Na, K, S and Cl in daily rations, are decisive factors as to induction and prevention of hypocalcemic paresis. A high positive dietary alkali alkalinity reduced calcium absorption from the intestine and resulted in hypocalcemia, whereas a negative value apparently brought about the increased absorption needed to maintain a normal calcium balance. Positive Ca-balance values associated with negative AA-values have been demonstrated earlier (*Ender et al.* 1971).

The possibility of eliciting alternating parturitions with and without milk fever in the same cow by dietary means (Table 6) is a particularly striking confirmation of our hypothesis.

Of the three procedures to reduce dietary alkali alkalinity, the one of $CaCl_2$, $Al_2(SO_4)_3$ and $MgSO_4$ was found to be the most rewarding. The results were good also in the experiments with neutralized acids, but the procedure was decidedly more time consuming and the amounts of supplements could not be estimated exactly because of the losses during the preparation of the "silage". The salts were, on the other hand, easy to handle. They were all soluble in small quantities of water and were given directly on the daily ration of hay and silage.

Further experiments as well as field tests in cooperation with practicing veterinarians are under way in order to establish the minimal amounts of salts required and the minimal time before parturition in which the prophylactic diet must be used.

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SAMMENDRAG

Forebyggelse av melkefeber ved tilskudd av salter til fôret.

Tolv av fjorten kuer som fikk grunnfôr (Tabell 1) med tilskudd av Na_2CO_3 og $NaHCO_3$ til alkali alkalitet $> + 3000$ meq./dag fra 3—4 uker før til 7 dager etter partus, ble angrepet av melkefeber (hypokalsemisk paresis puerperalis) (Tabell 3), mens tolv av tretten kuer som fikk samme fôr med tilskudd av sulfater og klorider til alkali alkalitet < -250 meq. hadde friske kalvinger (Tabell 5). Flere tilskudd ble prøvet, men blanding av $CaCl_2$, $Al_2(SO_4)_3$ og $MgSO_4$ løst i vann og tilsatt stråfôret hver for seg er funnet å være det beste profylaktiske tilskudd. Melkefeberinduserende fôr (*Dishington* 1974) ble gitt i 2 måneder før fôromlegning og salttilskudd.

Det er vist at samme ku vekselvis kan påføres og beskyttes mot melkefeber ved flere på hverandre følgende kalvinger ved at fôrets alkali alkalitet forandres (Tabell 6).

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