

MAGNESIUM IN THE CASEIN-CONTAINING COLLOID OF MILK¹

T. G. ALEXANDER AND T. F. FORD

*Dairy Products Section, Eastern Utilization Research and Development
Division, Agricultural Research Service, USDA, Washington, D. C.*

The magnesium content of milk reported in the literature varies from a minimum of 0.0092% to a maximum of 0.0236% (3, 11). There is also considerable variation in figures reported for the amount of magnesium in milk that is insoluble in the colloidal system. Reported nondialyzable magnesium ranges from 13 to 38% of the total (1, 7), and of magnesium retained by the Pasteur-Chamberlain filter tube, from 8 to 34% of the total (11). De Kadt and Van Minnen (3) found by centrifugation appreciably less variation in the magnesium content of milk and in the proportion of the total magnesium that is removed as part of the colloid system. Although they suggested that magnesium was thrown out as magnesium citrate, Ford *et al.* (5) considered the centrifugable magnesium as part of the calcium-caseinate-calcium phosphate complex, present in a molar concentration $\frac{1}{15}$ th that of calcium.

This work was undertaken to determine more precisely the amount of magnesium removed by centrifugation, to check the calcium : magnesium ratio used by Ford *et al.* (5), and to establish, if possible, whether the magnesium is present as part of the casein complex or as magnesium citrate.

EXPERIMENTAL PROCEDURE

Sample preparation: Two methods were employed for preparing samples. In the first, the colloids were separated in a centrifuge having a large (50-ml.) air-driven bowl rotor, twice redispersed in water, and redeposited; these washed colloids were then analyzed for magnesium, calcium, and citrate content. This separation and washing technique has been described elsewhere (5, 8). Such washed colloids were first prepared by Ramsdell and Whittier (9), who used a Sharples supercentrifuge for the separation, however.

The second method of preparation was the depletion technique described by Ford *et al.* (5), using the 50-ml. bowl rotor and analyzing progressively depleted liquid samples for calcium, magnesium, and nitrogen.

Methods of analysis: Magnesium was determined by the method of Hunter (6), citrate by the method of Deysner and Holm (4), soaking the washed colloid in N/30 NaOH, and nitrogen and calcium as described by Ford *et al.* (5).

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TABLE 1
*Results of analysis of various double-washed
centrifugally deposited colloids*

Type of milk	Calcium (%)	Magnesium (%)	Mol ratio, calcium : magnesium
Jersey No. 1	2.55	0.131	11.7
Jersey No. 2	2.67	0.120	13.7
Jersey No. 3	2.90	0.120	14.5
Herd No. 1	2.81	0.110	15.3
Herd No. 2	2.69	0.101	16.0
Holstein No. 1	2.86	0.120	14.3
Holstein No. 2	2.72	0.096	17.0
Averages	2.74	0.114	14.6 ^a

^a This corresponds to a weight ratio of 24.0:1.

RESULTS

A summary of the analyses of double-washed complex is given (Table 1). No citrate was detected in any of these double-washed colloids.

Figure 1 shows the relationship between calcium and magnesium content and nitrogen content on liquid samples, as the colloids are progressively removed by centrifugation. It can be seen that both calcium and magnesium are being thrown out along with nitrogen, in approximately constant ratios. The average mol ratio of calcium removed to magnesium removed, given by the slopes of these lines, is 12.4:1. The values plotted are the differences between analyses on the original skimmilk and on the centrifuged serums.

DISCUSSION

The mol ratios obtained for both deposits and serums are of the same order of magnitude as those calculated from the data of De Kadt and Van Minnen (3).

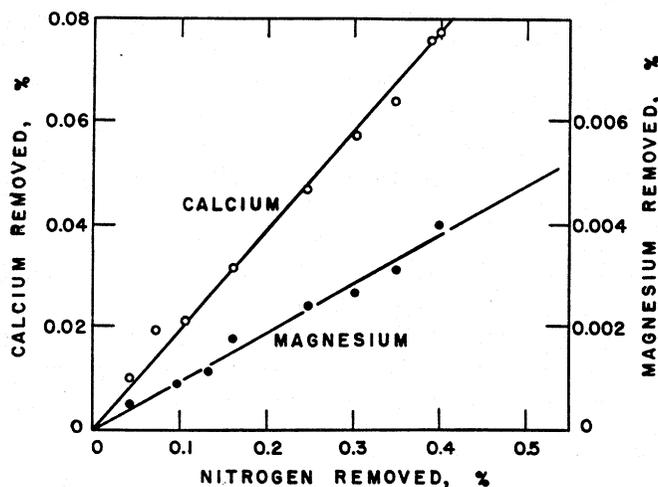


Fig. 1. Calcium and magnesium analysis of ultracentrifuged milk serums. Open circles indicate averages of two or three calcium determinations. Closed circles indicate averages of four or five magnesium determinations.

They reported six analyses of skimmilks and corresponding centrifuged serums, from which mol ratios of 15.0 to 21.5 (average 18.3) can be calculated, and two analyses of unwashed deposits, giving mol ratios of 18.2 and 15.6. Ford, Ramsdell, and Landsman (unpublished data) obtained the ratios 13.8 and 16.9 by analysis of unwashed and washed deposits.

De Kadt and Van Minnen's suggestion, that magnesium is thrown out as magnesium citrate, is neither supported nor completely ruled out by the present results. Their analyses were on unwashed deposits, and since our washed deposits give no test for citrate, but do contain magnesium, it must be concluded that such magnesium is not present as magnesium citrate. However, De Kadt and Van Minnen's unwashed deposits contain more citrate than can be accounted for as citrate proportional to the entrained serum water. More elaborate experiments will be required to determine the condition of this excess citrate.

If milk averages 3% casein-containing colloid and the colloid is 0.114% magnesium, then milk contains 0.0033% magnesium associated with the colloid. Taking the total magnesium content to be 0.012% [based on data given in References (3) and (11), and on an average value of 0.011% given by analyses run in this laboratory], then about one-third of the magnesium in milk is in combination with the colloid. This compares with De Kadt and Van Minnen's 25% for the amount of the magnesium that is thrown out by centrifugation.

Reference has been made to data, reported by Van Slyke and Bosworth (11), on the amounts of calcium and magnesium retained by Pasteur-Chamberlain filter tubes. These authors also give results of analysis of the original skimmilks. Therefore, calcium to magnesium ratios for the retained colloids can be calculated from their data. (Columns 2 and 3 of Table 2 are calculated from Table 3 of the article by Van Slyke and Bosworth. Column 4 is Column 2 divided by Column 3, and multiplied by the atomic weight factor, 24.3:40.1.)

Noting that De Kadt and Van Minnen's figures indicate 25% of the magnesium to be colloid-bound, that dialysis experiments (1, 7) indicate 13 to 38%, and that our data indicate about 33%, it is suggested that, since Van Slyke and Bosworth's high calcium-to-magnesium ratios always coincide with low retention of magnesium and of calcium by their filters, it is probable that in these cases the pores were too coarse to properly retain the casein-containing colloid. It is suggested, therefore, that these particular ratios can be ignored. The remaining results are much more consistent among themselves; and the indicated calcium:magnesium ratios at high retention values are in good agreement with the results presented here.

In a recent article, Van Kreveld and Van Minnen (10) state that one-sixth of the magnesium in milk is present in ionic form. Christianson, Jenness, and Coulter (2) report 0.82 to 0.85 millimoles of magnesium ion in a liter of milk. Since there is, on the average, a total of about 5 millimoles of magnesium in a liter of milk, their figures also indicate that about one-sixth of the magnesium is present in the ionic form. Thus, subtracting one-sixth (present as ions) plus one-third (associated with the colloid) from the total, there remains about one-half of the magnesium in milk to be accounted for in some other form.

TABLE 2
Calcium : magnesium ratios for the retained colloids^a

1 Cow No.	2 of total calcium retained	3 of total magnesium retained	4 mol ratio calcium : magnesium in retained colloid
	(%)	(%)	
1	54	8	40.7
2	63	14	27.8
3	60	21	13.0
3	66	8	44.5
4	77	30	12.4
5	62	20	16.4
5	64	9	37.5
6	74	21	19.2
7	64	16	24.7
7	70	28	13.1
8	71	23	18.5
9	71	26	14.4
10	61	16	19.5
11	74	29	12.7
12	75	36	11.1
13	69	31	12.5

^a Calculated from the data of Van Slyke and Bosworth.

SUMMARY

It has been shown that about one-third of the magnesium in milk is present in the casein-containing colloid, and that the calcium-to-magnesium mol ratio in the colloid is about 15:1.

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