544

9.4   Use of carbonation lime from beet

9.4.1   Carbonation lime: composition and utilization

Carbonation lime is a by-product of beet juice purification. After mechanical conditioning (which determines whether it can be distributed evenly by fertilizer spreaders), it is available for agricultural use in the following forms:

- Pressed to a dry substance content of 68–72% and with an alkaline $CaCO_3$ content equal to more than 26% CaO. In Germany, mechanically dewatered carbonation lime is allowed as a fertilizer under the designation "Carbokalk" (carbolime) (*Kluge* and *Embert* 1989, Dünge-mittel-VO 1991). The legal requirements are a minimum content of 45% $CaCO_3$ and passage of at least 97% through a 4 mm mesh screen. In other countries, lime fertilizers are not officially regulated and there are no uniform standards (*Hanley* 1951). However, in a review article, *Vandergeten* (1993) used the same classification. There are recommendations for the application of lime fertilizer to improve soil acidity (*Rehm* et al. 1992, *Jared* 1992).
  In the USA these products are regulated by the individual Departments of Agriculture in the respective states.
- Directly spread carbonation lime (*Draycott* 1972): Carbonation lime. e.g. from rotary filters, dried in ponds to 45–55% dry substance content.
- Directly spread carbonation lime (*Draycott* 1972): Aqueous suspensions of about 48% dry substance content (*von Kessel* 1988).

On average, 50 kg carbonation lime dry substance content is produced per t of beets processed, i.e. 2500 kg per hectare of sugar beets. The amount produced as well as the nutrient content (e.g. P, Mg) vary, depending on how much lime is introduced during juice purification. For environmental aspects of carbonation lime disposal see *Broughton* et al. (1993).

9.4.1.1 Composition of carbonation lime

Mechanically dewatered carbonation lime averages approximately 50% $CaCO_3$ (basic components calculated in terms of $CaCO_3$), equivalent to 28% CaO, and, in addition, contains nutrients, such as magnesium, phosphate, organic nitrogen, and small amounts of potassium. Its organic matter content (beet cell fragments, precipitated organic acids, protein, pectin and hemicellulose complexes) amounts to about 10% (Table 9/15). Pond-dried lime (45–55% dry substance content) has less nutrients, owing to its higher water content.

The composition depends on the nonsugar content of the beet, the amount of lime introduced for juice purification (CaO/nonsugar ratio), and the type of lime used (e.g. differences in magnesium content).

Carbonation lime contains, without exception, very low amounts of heavy metals (Table 9/16). The observed values are far below the maxima

Table 9/15: Nutrient content of carbonation lime of 60 to 70% dry substance content in kg/1000 kg (*Amberger* and *Gutser* 1982, *Werner* and *Solle* 1984, *Irion* 1988 and others)

Nutrient	Average	Range
Basically active components in terms of $CaCO_3$	500	460–540
Organic matter	100	80–150, max. 180
Total N	4	3–6
P_2O_5	9	6–18
K_2O	1	0.2–2
MgO	10	5–13, max. 22

plus ca. 2.5 kg S (of which 90% SO_4-S), 1 kg Na and 0.9 kg B (*Vandergeten* 1988, modified with new results)

Table 9/16: Heavy metal contents of carbonation lime, 60–70% dry substance content, averages of 5 samples in mg/kg (*Budig* 1984)

|				
Cu	17	Pb	< 2	(200)*
Zn	33	Cd	< 0.2	(6)*
Cr	6	Hg	< 0.01	(4)*
Ni	17 (100)*			

* Maximum in lime sediment (*Kluge* and *Embert* 1989)

fixed for waste lime in the German fertilizer regulations, so that application in Germany is not restricted because of heavy metal content. Carbonation lime is hygienically harmless to plants. To begin with, it is practically sterile, owing to the high temperatures (70–90 °C) during juice purification. After long storage, residual sugar in the lime often promotes a weak surface growth of fungi which, however, is not injurious to plants.

9.4.1.2 Nutrient effects of carbonation lime

Lime effect. Carbonation lime consists essentially of precipitated calcium carbonate. This has a markedly greater surface area than the usual pulverized calcium carbonate from limestone. According to *Weichert* (1982), carbonation lime has seven times the specific surface of finely ground calcium carbonate (5.8 m^2/g against 0.8 m^2/g). It dissolves correspondingly faster in HCl (pH = 4.0) than calcium carbonate, particularly that of dolomite origin (Figure 9/66). Earlier experiments by *Morley Davies* in 1931 and *Mackenzie* (1967) had produced similar results.

Field trials confirmed the high reactivity of carbonation lime, showing a sharper rise of pH values in a brown loess soil, compared with pulverized burnt lime (Table 9/17).

The good solubility of carbonation lime makes its calcium and magnesium highly mobile, allow-
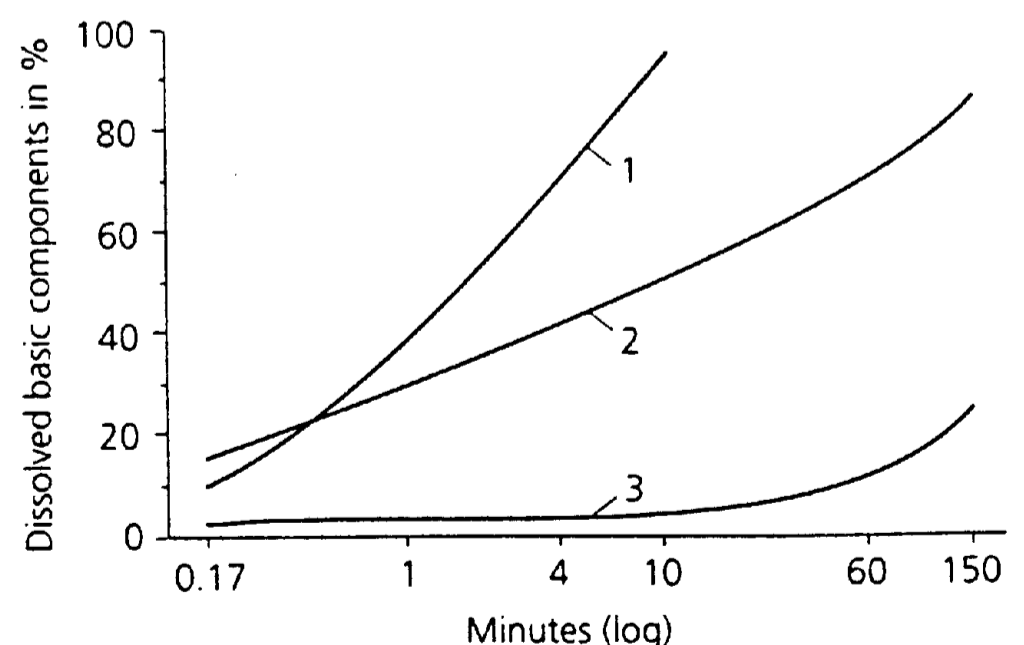
Figure 9/66: Solubility rates of different forms of lime in HCl, pH = 4 (*Deller* and *Teicher* 1980)
1 Carbonation lime; 2 Calcium carbonate; 3 Magnesium calcium carbonate (dolomite origin)

Table 9/17: Effect of top dressing of lime for sugar beet on the pH value of brown loess soil – applied 2 April 1981 (*Amberger* and *Gutser* 1982)

Soil layer	Loess soil pH-values (CaCl₂)				
		1 t CaO/ha		2 t CaO/ha	
Date	Control	CL	BL	CL	BL
0–8 cm					
11 May 1981	6.1	6.7	6.4	7.0	6.5
0–25 cm					
27 Oct. 1981	5.6	6.4	6.2	6.8	6.3

CL Carbonation lime; BL Burnt lime

Table 9/18: N effect of carbonation lime on rye grass. Pot trial: loamy sand, pH (CaCl₂) = 5.2. N dose: 150 mg N per pot trial or about 6 t CaO/ha (*Gutser* 1983)

Dressing	Yield in g d.s./pot	N uptake in mg/pot
Carbonation lime	16.5	315
Calcium carbonate without N	11.5	191
Calcium carbonate + NH₄NO₃	16.8	306
GD₅%	0.8	14

ing targeted improvement of the Mg supply to plants and more rapid amelioration of the lower-level soil reaction. On the other hand, more Ca and Mg leaching, by comparison with other fertilizers, is to be expected in shallow soils (*Gutser* 1983). Thanks to its high reaction capacity, carbonation lime is also a suitable material to stabilize the structure of soils which are prone to puddling.

Phosphorus effect. 10 t of carbonation lime (70% DS) contain on average 90 kg of P_2O_5 (39 kg P). Given the conditions under which it is formed, most of the phosphate is likely to be present in the form of dicalcium phosphate (DCP);
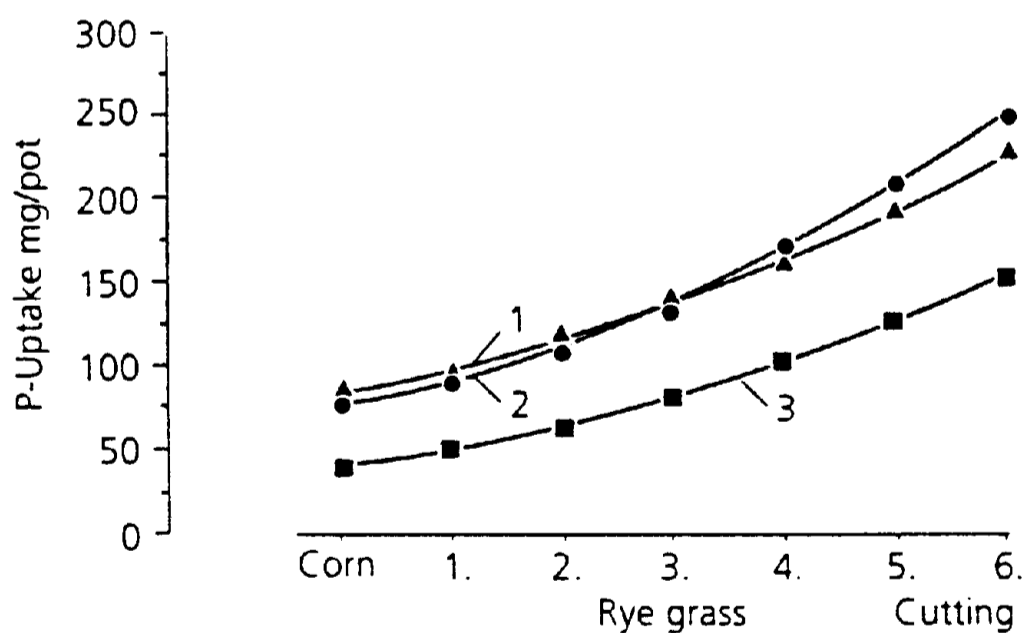
Figure 9/67: Comparison of the effect of carbonation lime with calcium carbonate + dicalcium phosphate and calcium carbonate alone, measured by P uptake by corn and pasture grass. P dose: 306 mg P per pot = 9 t carbonation lime/ha (*Gutser* 1983)
1 Carbonation lime; 2 Calcium carbonate + dicalcium phosphate; 3 Calcium carbonate without dicalcium phosphate

over 90% of the phosphate is soluble in citrate or citric acid (*Werner* and *Solle* 1984).

Despite excessive liming (reduced P mobility), P supplied by carbonation lime had 75% of the effect of DCP in pot culture (seven harvests; Figure 9/67); in smaller doses, it was as effective as mineral DCP fertilizer (*Werner* and *Solle* 1984). The results observed in pot culture are applicable to the field, provided the lime is well distributed.

Nitrogen effect. 10 t of carbonation lime contain 30–40 kg N. For the greater part, this is organic nitrogen which, depending on the temperature, is more or less quickly mineralized in the soil.

Applied shortly before sowing, nitrogen in carbonation lime is practically as effective as mineral N fertilizer (Table 9/18). After stubble liming in the summer or autumn, N may be lost because of nitrate leaching, particularly in sandy and shallow soils. However, this can be effectively countered by plowing in straw (promotion of straw breakdown) and by "catch" cropping (*Gutser* 1983).

Recommendations concerning application. For best results, carbonation lime must be distributed as uniformly as possible. Twin-disk spreaders capable of covering large areas have proved suitable for dewatered carbonation lime of ~ 70% DS (appropriate storage guidelines must be observed). Aqueous lime suspensions are applied with special equipment (tank carts, sprayers). Optimum times of application are in the autumn (stubble liming) and spring (top dressing, partly on winter cereals). Dosage is governed by the lime requirements of

the soil (pH value, clay content, etc.). Maintenance liming takes about 3-5 t (70% DS) per hectare every 3-4 years. Soil amendment dosages range between 10 and 20 t/ha for light and heavy soils respectively.

The amounts of P and Mg supplied with the lime count fully against the quantity of fertilizer to be applied (for instance, 8t/ha lime always covers the P requirement of the following crop). The N effect depends on the time of application and amounts at most to 30 kg N/8 t lime. The N supplied by further N-containing mineral fertilizer should thus be reduced accordingly. Concerning the application of carbonation lime from the practical points of view see also *Irion* (1979) and *Weerth* (1979).

9.4.2 Recalcining of carbonation lime

The concept of recalcining sugar industry carbonation lime has been in existence since the early 1900's. Accordingly the German Imperial Patent No. 101,276 registered in the name of *Wilhelm Baur* from New York already details a two-stage plant using rotating drums (*Baur* 1899): drying of the carbonation lime takes place in the first drum followed by the calcining in the second. These units should be preceded by a disintegrator to reduce the size of the filter cake. *Baur* also refers to *Stammer*'s "Lehrbuch der Zuckerfabrikation" (*Stammer* 1887), which details the pressing of carbonation lime into bricks which is followed by their respective calcining. The Patentee considers this approach as too costly and complicated. The latter process according to *Buisson* was in operation in two Russian factories at the end of the 19th century (*Stammer* 1887). Calcining proceeded there in a way similar to that in a brickyard.

But, todate, this technology has not found broad usage. Five factories in California have at one time reburned carbonation lime (*Daniels* and *Cotton* 1951). Similarly the Kobe refinery started up a multistage kiln for the recalcining of carbonation lime containing large amounts of kieselguhr in 1975 (*Akamatsu* 1976). Of those five factories in California, four have closed and the remaining

factory continues to recalcine carbonation lime quite successfully for 100% of their needs. In contrast, the use of recalcining equipment has proliferated throughout the paper industry since the 1920's (*Kramm* 1972). Such installations in North America alone can be numbered in the hundreds.

One of the primary obstacles to the installation of a recalcining lime process is the capital cost of the kiln and peripheral equipment which can be substantially more expensive than a comparably sized shaft kiln. Furthermore, the CO_2 content of the reburned lime kiln gas is typically 14-16% and this requires a larger gas-conveying pipe and compressor, as well as a larger carbonation tank and gas distributor.

However, environmental and economic circumstances, such as:

- high costs and/or high transportation costs for the limestone, as well as
- high disposal costs for the carbonation lime if other utilization is not possible (section 9.4.1)

may justify such an expenditure. When faced with the replacement or expansion of an existing lime production facility or the building of a new factory, the prospect of lower raw material costs and less carbonation lime to dispose of can be compelling factors in selecting a recalcining process.

Two types of kilns have been used commercially for recalcining: the rotary (section 9.4.2.2) and the multiple hearth kiln (section 9.4.2.3).

Pilot trials. Other processes such as recalcining in a high speed reaction chamber (*Schoppe* et al. 1979, *Schiweck* et al. 1979), in a fluidized bed (*Schiweck* et al. 1983) or in a similar apparatus (*Saiga* et al. 1978) have been operated in pilot plants. Recalcining is preceded by a drying step which may be carried out to give carbonation lime in powdered form in a pneumatic conveyor drier or in granular form in a fluidized bed drier (*Schiweck* et al. 1983). Ground limestone and possibly coal dust/coke is added to the carbonation lime cake prior to granulation in the latter case, to avoid enrichment with undesirable components in the several times recycled carbonation lime.

The Great Western Company selected the same procedures to recalcine small briquettes ($35 \times 25 \times 20$ mm, volume of ~ 18 cm^3) in a conventional shaft kiln. Briquetting of the carbonation

Section 9.4

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Section 9.4

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