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Whey

Cheese production in the United States exceeds 2.5×10^6 tons (2.3×10^6 metric tons) per year. Each ton of cheese requires the use of about 10 tons of milk and produces about 9 tons of whey as a by-product. The result is a total annual production of more than 5.3×10^9 gal (2×10^{10} liters) of whey. Whey comprises the water, milk proteins, milk sugars, and nutrients remaining after the butterfat and proteins are removed during cheese manufacturing.

Production. Some cream and cottage cheeses are made by coagulating milk with phosphoric acid. The rest, and all hard cheeses are made by coagulating the milk proteins and butterfat with various bacterial cultures. The residues from the two processes are referred to, respectively, as acid and sweet whey.

Whey is primarily used directly as livestock feed, is concentrated or dehydrated for use in human and animal food manufacture, or is disposed of by land application. Large cheese processing plants are able to concentrate or dehydrate sweet wheys into marketable by-products economically. Smaller plants and plants that use the phosphoric acid process find the high energy costs of removing water from the whey prohibitive.

Temporary conditions may arise in the larger plants when animal feeding, dehydrating, or concentrating whey is not possible as a disposal choice, such as during periods of process malfunction. In such instances land application is usually the method of whey disposal.

The chemical composition of whey is such that whey not only is a nutritious human and animal food supplement (see **table**), but, when properly applied, an enhancer of soil fertility and physical properties. Its disadvantages for use on soils are that it must be removed from the cheese plants on a daily basis and that it possesses a high water-to-nutrient ratio. Like any fertilizer or soil amendment, improper or excessive whey application has the potential of producing environmental problems.

Use as fertilizer. Land-applied whey at a rate of about 53,000 gal per acre (500,000 liters per hectare), which is equivalent to a 2-in. (5-cm) application depth, will supply nitrogen at a rate of 53–107 lb per acre (60–120 kg/ha), phosphorus at a rate of 27–53 lb per acre for sweet whey (30–60 kg/ha) or 160–220 lb per acre (180–250 kg/ha) for acid whey, and potassium at a rate of 80–135 lb per acre (85–150 kg/ha). Whey can be applied up to about 3 times this rate if it is applied over the growing season and the site is properly managed.

The nitrogen is primarily in the amine form as part of the milk protein, and consequently it will become available to plants as the soil organisms decompose the whey. The phosphorus in whey also occurs primarily in organic compounds in the sweet whey. In this form, it is more mobile than in the orthophosphate form, and can move deeper into the soil. Most of the phosphorous in acid whey is present as orthophosphate from the phosphoric acid. Most phosphorus fertilizer is applied in the orthophosphate form. The potassium is primarily in the mineral form, and it is readily available to plants. Whey also contains the essential micronutrients for plant and animal growth in organic forms, and these are readily available to plants as the whey decomposes in the soil.

Sodic soil reclamation. A parameter known as the saturation extract electrical conductivity is used to assess soil salinity; it is obtained by measuring the electrical conductivity of a solution made from a soil sample. Soils with saturation extract electrical conductivities less than 4 decisiemens/m and sodium absorption ratios greater than 13 are classified as sodic. In sodic soils, high pH (>8.3) and high sodium concentrations cause the soils to become dispersed, which leads to reduced air and water entry, poor tilth, and excess surface crusting. To reclaim this soil, it is necessary to lower the pH, temporarily increase the soluble salts, and replace the exchangeable sodium with other cations. Low-sodium wheys, particularly the acid wheys, contain sufficient calcium, magnesium, and potassium along with the low pH (due to the phosphoric acid) to flocculate the dispersed clay in the sodic soils. Thus, soil aggregates form and infiltration increases, allowing leaching of the unwanted sodium from the soil. Sodic soils not affected by a high ground-water level can be reclaimed with 2–5 in. (5.0–12.5 cm) of acid whey followed by leaching with good quality irrigation water or 20–30 in. (50–75 cm) of rain. For best results, the whey should be applied in 2-in. (5.0-cm) increments with irrigation or rain following each treatment. The main obstacle to this sodic soil reclamation method is the transportation cost if the whey must be hauled an appreciable distance.

Typical whey composition and properties

Property	Sweet whey	Acid whey
Water	92%	92%
Milk solids	8%	8%
Chemical oxygen demand (COD)	50,000 ppm	50,000 ppm
pH	3.8–4.6	3.3–3.8
Electrical conductivity	7–12 dS/m	7–8 dS/m
Total nitrogen	0.10–0.20%	0.10–0.20%
Total phosphorus	0.05–0.10%	0.30–0.40%
Total potassium	0.15–0.25%	0.15–0.25%
Calcium	840 ppm	840 ppm
Magnesium	100 ppm	100 ppm
Sodium*	Highly variable	600 ppm
Sodium adsorption ratio*	Varies	3–4
Micronutrients	†	†

* The sodium concentration and the sodium adsorption ratio vary with the amount of salt used in the various cheese manufacturing processes and the fraction that ends up in the whey.
† Concentrations are about the same as in milk.

Erosion control. Under furrow irrigation of row crops such as corn, beans, potatoes, and sugar beets, furrow erosion is often a problem. Up to 98% of this soil loss can be eliminated by treating the furrows with whey after each cultivation. The simplest method is to add just enough whey to each furrow to coat the sides. A second method is to add whey to furrows that have had straw scattered in the row at a rate of about 700 lb/acre (780 kg/ha). A more sophisticated and effective method that uses less whey involves mechanically applying the straw to the furrow and then spraying the straw with whey. The first two methods require about 6000 gal per acre (56,000 liters/ha). The last uses only about 2000 gal per acre (19,000 liters/ha). All three methods essentially eliminate soil erosion from the irrigated fields and at the same time increase water infiltration and soil tilth. The beneficial action is initially due to the stickiness of the whey and subsequently to the decomposition of the milk proteins and sugars by soil organisms. The increased biological activity produces polysaccharides that bond or cement soil particles together.

Environmental concerns. There are several environmental concern involved in land application of cheese whey. First, as with any industrial or food processing waste, whey should not be allowed to enter any surface or subsurface water without proper pretreatment.

Second, whey contains up to 60,000 parts per million by weight of chemical oxygen demand (COD): COD is a measure of the amount of oxygen a material consumes during decomposition in soil or water. The acceptable COD loading rate for a site is affected by soil temperature, moisture, hydraulic conductivity and porosity, application frequency, and the depth to the water table. Exceeding the COD loading rate reduces free oxygen levels and may cause foul odors associated with the free ammonia or hydrogen sulfide. Exceeding the COD loading rate may lead to plant death. Also, iron and manganese may be reduced, solubilized, and leached into ground waters.

Third, whey contains appreciable quantities of soluble salts (40,000–80,000 ppm), and if the salts are applied faster than they are leached from the soil by precipitation or irrigation, the salts accumulate in the soil surface and limit plant growth. High-sodium whey also presents additional problems if not properly managed.

Fourth, the phosphorus in whey that comes from the milk is primarily in organic form, and it is much more mobile in the soil than is orthophosphate. Excessive whey application presents the potential of leaching organic phosphorus below the root zone, before it is changed to orthophosphate by soil organisms, thus allowing it to leach into the ground water.

If no more than an 8-in. (20-cm) depth of whey (216,000 gal/acre or 2 × 10^6 liters/ha) is applied annually in 1-in. (2.5-cm) increments to soils with a dry surface that is not immediately wetted by rain or irrigation, these four factors will not likely present a problem. This application rate is less than the rates set in the United States by most state regulatory agencies. When greater application rates are used, soil and ground-water monitoring should be included as part of the management system.

Nitrogen use by crops and the high carbon-to-nitrogen ratio in the decomposing whey will usually cause sufficient nitrogen immobilization to keep nitrate leaching from being a hazard. Whey is of food-grade quality and will not present a hazard with respect to toxic metals or radioactive materials.

For background information *SEE AGRICULTURAL SOIL AND CROP PRACTICES; CHEESE; EROSION; MILK; SOIL; SOIL CHEMISTRY; SOIL FERTILITY* in the McGraw-Hill Encyclopedia of Science & Technology.

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