Historical Development of Composting Technology during the 20th Century

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SUMMARY. **Although composting has been practiced for thousands of years, it was not until the 20th century that controlled scientific studies were published illustrating the benefits of compost use in crop production. These studies helped to spur increased interest in composting and compost use, and gave way to the development of commercial composting facilities that supply finished compost products to horticultural producers. Increasing composting activity and compost use encouraged the formation in the late 20th century of trade organizations, such as the U.S. Composting Council and similar organizations in other countries, that support research and applications work to determine ways to improve quality control of commercial compost products.**

The technology of composting and compost use for growing plants is believed to be as old as agriculture itself. While the earliest known written reference to composting is found in clay tablets dated to the Akkadian empire, approximately 2300 B.C. (Rodale et al., 1960), it was not until early in the 20th century that the results of controlled studies on both compost making and compost use to increase crop productivity were first published (Howard and Wad, 1931). Prior to this, the reported benefits of using compost for crop production were anecdotal. During the 20th century, numerous research projects were conducted and results published that firmly established the usefulness of compost in improving production of horticultural crops (Stoffella and Kahn, 2001). Beginning in the 20th century, another important development in compost product use in agriculture was the emergence of organized business enterprises that make, but do not use, compost products. These enterprises earn money by accepting organic waste materials from a variety of sources that pay disposal fees to the composting business, and by selling finished compost products. There are no complete records indicating the first commercial compost marketers, but one of the earliest ones, still in business, was Kellogg Supply Inc. in Carson, Calif., which was marketing compost products as early as 1927 (Kellogg, 1985). Prior to this development, composting had been strictly a farming and home gardening activity. Growers who wanted to use compost had to make it themselves from organic materials available to them, or get it from other farms that had surplus.

The development and proliferation of commercial composting facilities during the 20th century enabled growers to purchase finished compost products for use in crop production.

Composting technology prior to the 20th century

During the 20th century, there were significant technological developments in composting. The earliest composting systems did not employ mechanization, but rather relied on hand labor. Records of the very earliest composting systems are mostly anecdotal, but historical composting systems have been reported in contemporary literature. One example is the composting system built in 1787 at his Mount Vernon, Va., estate by George Washington (1732–99), the first president of the United States (Higgins, 2001; Pogue and Arner, 1997). Although Washington spent a large amount of time between 1775 and 1797 away from his home due to his duties first as a member of the Continental Congress, then as commander in chief of the Continental Army, and later as a member of the Constitutional Congress and as president of the United States, he kept a diary and regularly corresponded with his Mount Vernon staff. Written records indicate that he directed his farm manager to construct a facility to compost stable waste in a pit approximately 15 ft wide, 30 ft long, and 4 ft deep (4.6 × 9.1 × 1.2 m). It was enclosed by a wooden roof, and had brick walls and a cobblestone floor (Fig. 1). Washington referred to this facility as a "dung repository" or "stercorary." Situated close to the stables, wagons would deliver the manure and bedding and laborers would shovel the material into the pit and, later, remove the finished compost from it for use in adjacent fields.

There are numerous other records of both famous and not famous composting projects prior to the 20th century. While there is considerable diversity in size and scope, they were all similar in that they were part of overall farming activity and that the perceived benefits of compost use were not supported by data from scientific studies. Commercial composting activity and scientific studies detailing the benefits of compost use did not occur until the 20th century.

20th century composting systems

INDORE COMPOSTING SYSTEM. The scientific basis for the development of modern composting systems can be traced to the work of Sir Albert Howard (1873–1947). A British government scientist knighted in 1934 for his contributions to agriculture, he spent the bulk of his career in the colonial service in India, first (1905–24) as an economic botanist at the Agricultural Research Institute at Pusa, and later (1924–31) as the director of the Institute of Plant Industry at Indore (Hershey, 1992). The composting procedure developed by Sir Albert, known initially as the Indore method and, later, after additional improvements, the Bangalore method (Gotaas, 1956), employed layered mixtures of high carbon to nitrogen ratio (C:N) feedstocks like leafy plant material with low C:N materials like animal manure in an approximate 3:1 ratio.

The general procedure for the Indore system is: 1) the placement of a

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Fig. 1. Site of the composting pit built in 1787 at the Mount Vernon, Va., estate of George Washington (1732–99), located about 300 ft (91.4 m) southeast of the main house (shown in inset). Arrow points to a plaque that reads: "Dung Repository. A building, known as the 'Repository for Dung' was located here from 1787 until it was torn down sometime after 1830. It was used to compost manure and other organic materials to make fertilizer for use in nearby gardens and fields. Mount Vernon archeologists have uncovered holes that held the posts used to support the wooden building, a partial brick foundation that enclosed the 'manure pit' where dung was composted, and the stone-paved floor of the pit. It was unusual in the 18th century for such a large building (30 × 15 ft) to be devoted to this special purpose, testifying to George Washington's commitment to improving his crop production." (30 × 15 ft = 9.1 × 4.6 m) Photos by G.E. Fitzpatrick.

layer of brush on the ground to provide a base for the compost pile; 2) then the compost feedstocks are applied in layers to form a compost heap approximately 5 ft (1.5 m) high, 5–10 ft (1.5–3.0 m) wide, and of variable length; 3) the first layer is a 6-inch (15.2 cm) thickness of green matter, such as crop wastes and leaves; the second layer is a 2-inch (5.1 cm) thickness of animal manure, which is covered by a very thin layer of topsoil and crushed limestone; 4) additional material is added in consecutive layers as above until the pile reaches a height of 5 ft. The pile is turned at approximately 6-week intervals and the total composting time is approximately 4–6 months.

A prolific writer as well as a gifted scientist, Sir Albert published numerous papers in both British and Indian journals, and authored two books that summarized his shorter journal publications (Howard, 1943; Howard and Wad, 1931). As a result of Sir Albert's work, numerous other composting projects were established during the 1920s and 30s, including the work of J.M. Moubray in Southern Rhodesia (now Zimbabwe) (Moubray, 1943), J.P.J. Van Vuren in South Africa, J.W. Scharff in Malaya (now Malaysia), and J.C. Scott in China (Gotaas, 1956).

Sir Albert's influence was also felt in Europe and America, but compost project development in the mid-20th century in the industrialized nations had greater emphasis on mechanized composting technologies, rather than the manual labor-intensive projects in Asia and Africa.

Beccari composting system. One of the earliest mechanized composting systems was the Beccari composting system, developed in Italy by Giovanni Beccari in the 1920s. During the 1920s and 30s, over 50 such systems were built in Europe and five were operated in the U.S. While it was a successful early mechanized system, it has been supplanted by more efficient systems and there are no currently operating Beccari systems (Gotaas, 1956).

VAM composting system. The N.V. Vuilafvoer Maatschappij (VAM), a nonprofit utility formed by the Netherlands government, began composting municipal refuse in 1932 in Wijster, Netherlands (Gotaas, 1956). This system was an adaptation of the Indore system, with modifications including the use of mechanized equipment, such as trains that delivered the composting material and grappling hooks that removed the finished compost material from the open compost bins. This system is noteworthy as one of the earliest that composted municipal solid waste, rather than just agricultural crop residues. Numerous VAM systems were operated in northern Europe, but this technology was supplanted by more efficient systems; the last VAM plant was closed in 1989 (Haug, 1993).

Rotary drum composting systems. The first rotary drum composting system was developed in the U.S. by Eric Eweson in the 1940s. Influenced by Sir Albert Howard's belief that anaerobic fermentation at the initial phase could materially accelerate the composting process, Eweson traveled to Great Britain, consulted with Sir Albert, and then designed a composting system in which the compost material is anaerobically fermented in a large rotary drum for a period of 3–6 d, followed by windrow composting. The Eweson system is currently owned by the Bedminster Bioconversion Corp., which has built numerous composting facilities and has licensed this technology to other companies. Unlike many of the early mechanical composting systems, the rotary drum system has been very successful and there are many such systems operating throughout the world at the current time (Fig. 2).

Contemporary composting systems

Most contemporary descriptions of composting technology make major distinctions based on the relative level of technology used in the composting process and on whether or not the facility is within an enclosure or in the open.

Windrow composting. Windrow composting is an example of an open composting system that uses relatively low-level technology. Compost materials are placed in rows and turned periodically, usually by mechanical equipment like tractor-mounted front-end loaders. Windrow systems are popular because they generally

Fig. 2. Rotary drum composting system, Al Ain, United Arab Emirates. Photo by G.E. Fitzpatrick.

do not require dedicated specialized equipment. Farmers and others who have large amounts of organic material suitable for composting typically have general purpose farm equipment that can be used for compost turning and handling.

Windrow composting has traditionally been popular with small- and medium-scale compost operations, because it does not require complex technology or dedicated, specialized turning or handling equipment. However, one significant drawback of the windrow system is its inability to supply sufficient aeration to excessively moist compost feedstocks. This problem can be managed to some degree by mixing moderately wet feedstocks with relatively dry feedstocks and composting the mixture. Extremely wet feedstocks, such as sewage sludge, even when mixed with dry materials, often are difficult to aerate and develop foul odors.

AERATED STATIC PILE COMPOSTING SYSTEM. The U.S. Department of Agriculture Biological Waste Laboratory at the Agricultural Research Center in Beltsville, Md., investigated this problem in the early 1970s and developed the aerated static pile composting system. This system has a superficial resemblance to the windrow system, in that the compost materials are placed into rows, but the windrows are built on top of an air distribution system composed of flexible perforated pipes embedded in woodchips. Fans are used to provide forced aeration into the pile or induced draft aeration from the pile. The aerated static pile system has been successful in providing high levels of aeration to difficult, wet feedstocks and is commonly used throughout the world to make compost from excessively moist, hard to aerate materials.

Composting systems that were designed, built, and operated in the second half of the 20th century were of two general types: 1) systems in which the composting took place in the open air, called nonreactor systems; and 2) systems in which the composting took place inside enclosures, or reactor systems.

NONREACTOR SYSTEMS. The common types of open air composting systems include the windrow and aerated static pile systems. Windrow systems are common in on-farm composting operations (Rynk, 1992), and are the most popular technology for yard trimming composting facilities. In the U.S. in the latter part of the 20th century, their numbers increased from a total of 651 active yard trimming composting facilities in 1988 to a total of 3846 in the year 2000 (Kaufman et al., 2004).

REACTOR SYSTEMS. A large number of reactor systems were introduced in the latter 20th century. The rotary drum system developed by Eweson in the 1940s remains popular. Other noteworthy contemporary reactor systems include rectangular agitated beds systems and silo systems.

In the rectangular agitated beds system, composting takes place between walls that form long, narrow channels referred to as beds. Sets of rails, on the top of the beds, support and guide a compost turning machine (Fig. 3). Feedstocks are placed at one end of a bed, and as the compost turning machine moves on the rails, it turns and mixes the compost, moving the compost mass forward with each pass toward the end of the beds. Rectangular agitated bed systems have "user friendly" feed and withdrawal systems (Haug, 1993), and most are constructed with aeration pipes

Fig. 3. Rectangular agitated beds composting system, West Palm Beach, Fla. Photo by G.E. Fitzpatrick.

Fig. 4. Silo type composting system, Lake Buena Vista, Fla. Photo by G.E. Fitzpatrick.

recessed within the floor to enable maximum air movement through the compost mass.

Silo systems. In silo systems the compost material is added to a large cylindrically shaped vessel (Fig. 4). Internal augers turn and mix the feedstocks, and finished compost is removed from ports in the center. Aeration systems blow air up from the base through the composting materials. In many silo systems, initial composting is followed by a curing period to allow the compost to achieve the desired level of maturity.

Trends in composting and compost use

If the development and use patterns of composting technology during the 20th century are an indication, it can be expected that compost making and compost use in horticulture in the 21st century will continue to grow. U.S. Environmental Protection Agency (EPA) records indicate negligible composting activity, as a percentage of total waste product generation, for the years 1960, 1970, and 1980 (EPA, 2000). However, beginning in 1990, EPA data indicated a steady increase in composting activity: 4.2 million tons (3.81 million t) in 1990, 9.6 million tons (8.71 million t) in 1995, 13.1 million tons (11.88 million t) in 1998, 14.7 million tons (13.34 million t) in 1999, and 16.5 million tons (14.97 million t) in 2000 (EPA, 2000). If the figures for the total amount of municipal solid waste (MSW) composted per year are expressed as percentages of total MSW generated per year, 2.1% of the total amount of MSW generated in the U.S. in 1990 was composted as compared to 7.1% in 2000 (EPA, 2000), indicating a steady increase in the amount of composting in the U.S. If these trends continue, composting and compost use in horticulture should be expected to increase in the 21st century.

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