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Decomposition of Potato Processing Wastes in Soil[1]

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ABSTRACT

Solid filtered or centrifuged potato processing wastes were obtained from three potato processors in Idaho. The waste samples were dried and ground to pass a 2-mm sieve and added to soils at rates of 0, 2.5, 10, and 25 g/kg. The 100-g samples of Portneuf silt loam soil containing the waste material was incubated at 26 °C and decomposition of the added wastes was determined by measuring CO_2 evolution in a flowing air stream passing over the soil in the incubation flask. Each increment of added organic waste material increased the amount of carbon evolved during the 12-week incubation. The waste materials contained 6.8, 20.4, or 65.5 g N/kg waste. However, these differences in N did not change the amount of CO_2 evolved at the 12-week incubation, although the evolution curves were shaped somewhat differently during the 12 weeks. Regression analyses of the cumulative carbon resulted in highly significant R^2 values being obtained for each potato processing waste material. Decomposition of the solid waste materials ranged from 24 to 92% depending upon the source and application rate. The rapid decomposition of the solid wastes verified field research indicating that potato wastes have not more than 1 yr residual fertilizer value. The organic waste is not likely to accumulate in the field.

Additional Index Words: **waste disposal, carbon content, nitrogen content, food processing waste.**

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Application of food processing wastes and wastewaters to agricultural land for treatment and disposal has become a preferred practice (Bolton, 1947; De Haan and Zwerman, 1972; Mayer, 1974; Norum, 1975; Shannon et al., 1968; Smith, 1976; Smith et al., 1977; and Smith et al., 1978). Agricultural land is an effective medium for treatment of food processing wastes because microorganisms in the soil decompose most of the organic constituents without serious environmental pollution hazards. Some of the organic and inorganic constituents of food processing wastewaters have been tabulated by Smith and Peterson (1982). The organic constituents are readily decomposed by soil microorganisms releasing the nutrients for use by growing crops. Smith (1974) showed rapid decomposition in soil of waste soybean and palm oils that were used for cooking potato products in the processing plants. The major potato processing wastewater organic and inorganic constituents were reported by Smith et al. (1978), with organics averaging about 1600 mg/L after clarification. In the primary treatment process, the wastewater is usually passed through a clarifier in which some of the organic solids settle to the bottom. The solids are removed by pumping to a vacuum filter or centrifuge where they are further concentrated. These solids are usually fed to livestock but are occasionally applied to agricultural land for disposal. The dissolved solids in the wastewater are applied to agricultural land by irrigation. The experiments reported here were conducted to determine the decomposition rates of the waste potato solids in soil in the laboratory.

MATERIALS AND METHODS

Potato processing filter or centrifuge cake (Table 1) was obtained from two potato processors, oven dried at 60 °C, ground to pass a 2-mm screen, and mixed in Portneuf silt loam (coarse-silty, mixed, mesic, Durixerollic Calciorthids) at rates of 0, 2.5, 10.0, and 25.0 g/kg air dry soil. The dry potato waste solids were analyzed for C by dry combustion at 900 °C and for total N including NO_3^- by a Kjeldahl procedure (Carter et al., 1967). The 100-g soil samples containing the potato waste solids were placed in half-liter bottles, wetted with 18 mL distilled water each, plus 1 mL water for each gram of potato waste, and incubated at 26 °C. The moisture content represents about 80% of 33 kPa tension. The flasks were continuously aerated with CO_2 free air with the air passing over the soil. The CO_2 was removed by bubbling the air through a 60-cm column of NaOH solution and then through a distilled water column for moisture saturating the air for soil moisture maintenance. Carbon dioxide generated by decomposition of the added potato waste and soil organic matter was captured in bottles containing standard NaOH solution. The NaOH solutions were removed from the incubator, treated with 10 mL 0.5 *M* $BaCl_2$ solution, titrated with standard H_2SO_4 solution, and CO_2 evolution was calculated. All treatments were replicated three times. An air blank was used to determine the small amount of CO_2 in the air source. The flow of air through the sample flasks was regulated with calibrated capillary tubes in air lines running to each incubation flask.

Evolved CO_2 was removed from the receiving flasks at weekly intervals for 12 weeks. The air blank was subtracted from all samples and C evolution was calculated. The soil samples were removed after 12 weeks, oven dried at 60 °C, extracted and analyzed for NO_3^- using a NO_3^- specific ion electrode. Regression analyses were run on the C evolution data.

RESULTS AND DISCUSSION

The potato waste solids used in this decomposition study were obtained from three potato processing plants in southern Idaho. They were separated from the waste water streams of the processing plants by filtering or centrifuging the settled solids from the primary clarifiers. The dried potato waste solids had a wide range of N percentages ranging from 6.8 to 65.5 g N/kg of dry solids. This provided an opportunity for evaluating the decomposition rates of the waste materials in soil as well as the influence of different N percentages on N mineralization and immobilization.

Potato processing waste solids cumulative decomposition showed increasing C evolution with each increment of added waste solids from the two Simplot and one French waste solids (Fig. 1, 2, and 3). Regression analyses of the plotted curves for C evolution shown in Fig. 1 through 3 showed highly significant R^2 values for all sets of data (Table 2). The regressions were run on the data for the first through 12th weeks but did not include the zero time. Therefore, the intercepts in the regression equations do not pass through zero but the curves are drawn in the three figures to pass through zero.

The C evolved from untreated soil was used as a control for the other treatments, but was not subtracted

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Table 1. Carbon and nitrogen content of potato waste solids.

Source	N	C	C/N
	g/kg		
J. R. Simplot Co., Heyburn, ID	6.8	406	60
R. T. French Co., Shelley, ID	20.4	422	21
J. R. Simplot Co., Caldwell, ID	65.5	464	7

from the data plotted in Fig. 1, 2, and 3. Net C was calculated for each treatment as the difference between total C evolved and C evolved from untreated soil. Decomposition percentages were calculated as net C divided by total C in the added solid waste (Table 3).

Decomposition of Simplot, Heyburn (SH) solid waste is shown in Fig. 1. The potato waste material applied at the rate of 2.5 g/kg soil decomposed about 63% in the first week of incubation, continued at a high rate the second week, then decreased to a very low rate for the last 9 weeks, totaling 92% (Table 3). The 10 and 25 g/kg soil additions of SH solid waste also decompose rapidly in the first week, but totaled 25 or 26% of the added solids. During the following 11 weeks, decomposition was much slower than the first week, with a total of about 47% of the added solids decomposed. In the early stages of decomposition, the low N (6.8 g/kg) content solid potato waste at higher application rates, caused N deficiency in the soil and limited decomposition rates below the rate of the low addition. With the low application rate, the soil supplied enough N to allow rapid decomposition that was not limited by N immobilization. The maximum daily decomposition rate was calculated to be about 200 kg/ha.

Decomposition of the French, Shelley (FS) solid waste is shown in Fig. 2. The potato waste that contained 20 g N/kg decomposed 44% in the first week for the 2.5 g/kg waste addition rate. In 12 weeks, the total decomposition was 79% with most of it occurring in the first 5 weeks. Both the 10.0 and 25 g/kg FS potato waste additions decomposed 13% for the first week. Decomposition for the following 11 weeks was slower than the first week and totaled 37 and 48%, respectively, for the two waste addition rates for 12 weeks. The maximum daily decomposition rate for the 25 g/kg waste addition in the first week was 1000 kg/ha.

Decomposition of the Simplot, Caldwell (SC) solid potato waste is shown in Fig. 3. The 2.5-g/kg addition

Table 3. Decomposition of potato waste during first week of incubation.

	Simplot, Heyburn		
Potato waste added, g	0.25	1.00	2.50
C evolved, mg	66	111	261
C evolved, % of added	63	26	25
Decomposition, kg/ha	3 514	5 880	14 027
	French, Shelley		
Potato waste added, g	0.25	1.00	2.50
C evolved, mg	44	53	132
C evolved, % of added	44	13	13
Decomposition, kg/ha	2 440	2 925	7 375
	Simplot, Caldwell		
Potato waste added, g	0.25	1.00	2.50
C evolved, mg	25	116	261
C evolved, % of added	22	25	22
Decomposition, kg/ha	1 200	5 605	12 600

Table 2. Regression equations for potato waste decomposition shown in Fig. 1 through 3 (R is application rate, T is time).

Regression equations	
Fig. 1 $\hat{Y} = 55 + 5.2R + 1.8R^2 + 15.9T - 0.57T^2 + 14.8RT$	$R^2 = 0.958^{**}$
Fig. 2. $\hat{Y} = 28 + 32.9R + 35.4R^2 + 30.0T - 1.8T^2 + 7.9RT$	$R^2 = 0.970^{**}$
Fig. 3. $\hat{Y} = 32 - 8.2R + 50.8R^2 + 24.7T - 1.5T^2$ 8.7RT	$R^2 = 0.970^{**}$

of SH waste decomposed about 22% the first week (Table 3), declined sharply the next 2 weeks, and almost none decomposed in the following 9 weeks. Total decomposition was about 28% of that added. The 10 g/kg addition of SC waste decomposed about 25% in the first week with very little decomposition occurring thereafter. The 25.0-g/kg addition of SC waste decomposed 22.5% the first week, continued at a rapid rate for the next 2 weeks, after which the rate slowed for the next 9 weeks with total decomposition about 44%.

The rapid decomposition observed in the first few days or weeks of incubating the potato wastes in soil and the relatively slow decomposition occurring in the third through 12th weeks indicates the presence of a soluble, rapidly decomposing fraction, and at least one slower decomposing fraction of the potato waste solid material. This supports Reinertsen et al. (1984) in their observation of similar decomposition patterns with wheat straw.

The 2.5 g/kg potato waste application represents about 5600 kg/ha if the waste material were mixed in 15 cm of soil. This represents an average COD application of 15 kg ha^{-1} d^{-1} for a year, which is a low rate. The highest rate of 25 g/kg in the laboratory study represents 56 000 kg/ha or an average of 150 kg ha^{-1} d^{-1}. The high rate can be effectively treated in the field soil for organic matter reduction, but may cause air pollution with undesirable odors and water pollution by excess NO_3^-. Therefore, the highest rate will probably not be applied for an extended time. About 50% of the organic waste from a potato processing plant pumped to a clarifier is composed of dissolved solids from processed

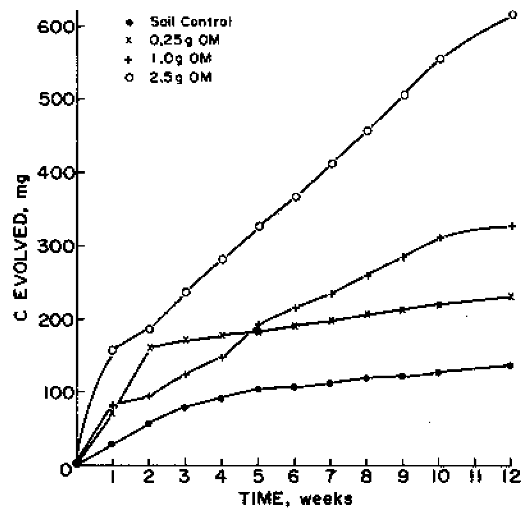

Fig. 1. Carbon evolved during 12 weeks incubation of Simplot, Heyburn potato waste solids.

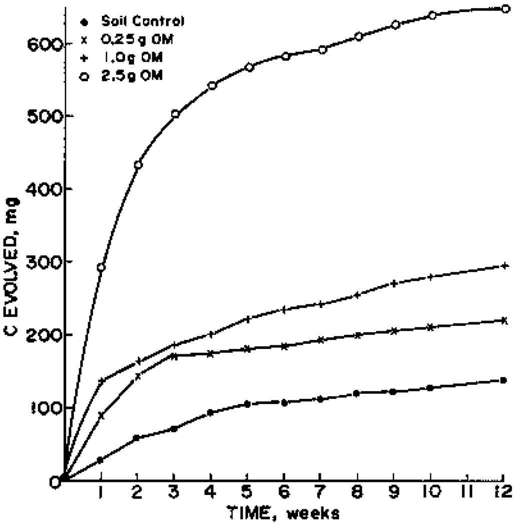

Fig. 2. Carbon evolved during 12 weeks incubation of French, Shelley potato waste solids.

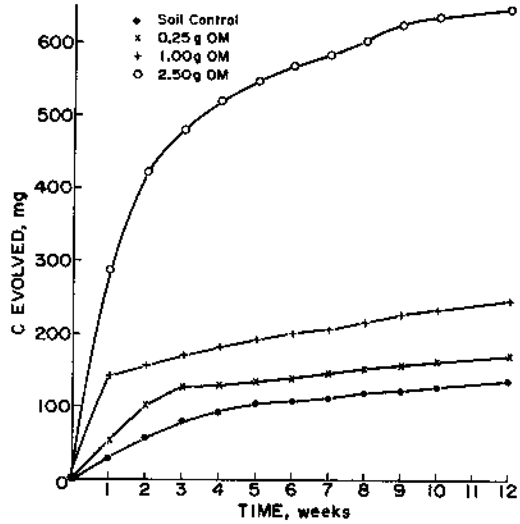

Fig. 3. Carbon evolved during 12 weeks incubation of Simplot, Caldwell potato waste solids.

potatoes. The dissolved organic solids are similar to the starchy waste solids removed from the waste stream by clarification and filtration except that the dissolved organic solids may have lower molecular weight. The dissolved solids should therefore decompose in the field as rapidly as or more rapidly than the filtered solids used in the experiments reported here.

Soil NO_3^- concentrations were measured following the incubation experiment and found to relate fairly closely to the total N content of the waste solids (Table 4). In the SH waste, that contained 6.8 g/kg total N, immobilization of N increased with each increment of added waste material. Soil NO_3^- was 32 mg N/kg in the check soil and the values decreased to 0.3 mg N/kg with the 25 g/kg SH treated soil. With the FS waste, which contained 20.4 g/kg total N, no N immobilization was observed. Instead, each increment of added waste material increased the NO_3^- found at the conclusion of the incubation. With the SC waste, the total N concentration was 65 g/kg and the waste acted like fertilizer with each added increment increasing the NO_3^- concentration even greater than the FS waste. At the end of the incubation, the NO_3^- concentration was 418 mg/kg of soil.

Potato wastes are added to field soils in increments. When waste water is applied by irrigation, the frequency is usually from 2 to 4 weeks. Each addition of waste organic matter, applied to field soil, decomposes rapidly as an original addition in the first weeks similar to the early weeks' results in this experiment. The rapid decomposition observed in this experiment verifies observations by Smith and Hayden (1984) that N applied in potato processing wastewater was utilized by a corn crop or lost by leaching or denitrification within one year of application. Large applications to land of organic wastes in potato processing waste streams, even when applied for several years, would not be expected to accumulate because decomposition is so rapid. Fields irrigated with potato processing wastewater become increasingly fertile and productive with successive years' wastewater irrigation when they are not overloaded with organic wastes or wastewater.

Table 4. Nitrate in soil after 12 weeks incubation with potato solid wastes.

Application	Solid wastes		
	SH†	FS	SC
	NO_3-N, mg/kg soil		
0	32	32	32
2.5	22	36	77
10.0	8	56	210
25.0	0.3	96	418

† SH is Simplot, Heyburn; FS is French, Shelley; and SC is Simplot, Caldwell.

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