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COMPOSTING TECHNIQUE OF THE LIVESTOCK'S EXCREMENT

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I. FOREWORD

A tremendous quantity of wastes, especially livestock excrement, garbage, and sewage sludge, is processed locally because of social trends and has recently been restudied not only as simple soil recovery, but also as a soil improver or fertilizer. Therefore, a system which composts wastes by volume composting processing under a erobic conditions is in greater demand than ever before.

The purposes of composting is to make unclean and unsenitary waste, as quickly as possible, to be detoxificated, decreased in volume and stabilized as soil improver, fertilizer, and other resources.

To achieve this objective, we have accumulated development of vertical multi-stage digesters and systems and have now delivered a 50t/d fowl excrement composting facility to the Miyasaki Prefecture Agriculture Development Public Corporation. The scale and capacity of this facility are the highest in the country and it has been widely acclaimed by the livestock industry.

This vertical multi-stage digester has unheard of superior features and is applicable to a wide range of organic wastes, including sewage sludge, and garbages.

The road of development of composting techniques by Fuji Electric and a description based on the 50t/d facility delivered to the Miyazaki Prefecture Agriculture Development Public Corporation are given below.

II. PROCESSING OF LIVESTOCK EXCREMENT

In recent years, the livestock's namber in our country has been increased by an increase in the consumption accompanied by dietary improvement, specialization of livestock management and higher capitalization, there is also a trend toward multi-head breeding. The actual conditions are shown in *Table 1*. Since the amount of excrement from these livestock is tremendous and a large volume is produced at one place, environmental pollution of the region has become a major social problem. Present livestock excrement processing is outlined below. However, since fowl excrete urine and dung together, this mixture is the processing objective.

Cattle and pigs, although they excrete urine and dung separately, become the objective of mixture processing depending on the method by which they are raised. When dung and urine are separated and collected, the urine is used as night soil or is purified by common sewage processing or soil immersion processing. However, generally, night soil poses such problems as inconvenience of handling and transportation, generation of an unpleasant odor, and securing of storage space.

Moreover, in the sewage processing method, activated sludge process for example, the increased facility costs and maintenance management are problems. In the soil immersion method, the land procurement and secondary pollu-

Table 1 Transition of the number of livestock farmers and livestock for various livestock

Year	Dairy cattle			Beef cattle			Pigs			Layers			Broilers		
	Number of farmers	Number of head	Head/ farm	Number of farmers	Number of head	Head/ farm	Number of farmers	Number of head	Head/ farm	Number of farmers	Number of fowl	Fowl/ farmer	Number of farmers	Number of fowl	Fowl/ farm
1955	254	421	1.7	2,280	2,636	1.2	528	825	1.6	4,508	47,715	10.6	–	–	–
1960	410	824	2.0	2,031	2,340	1.2	930	2,640	2.8	3,839	54,627	14.2	–	–	–
1965	382	1,289	3.4	1,435	1,886	1.3	702	3,976	5.7	3,249	120,197	37.1	20	18,279	914
1970	308	1,804	5.9	902	1,789	2.0	445	6,335	14.2	1,703	169,277	99.4	18	53,742	2,985.9
1975	160	1,785	11.2	467	1,857	4.0	223	7,684	34.5	507	145,743	287.5	12	87,660	7,305

(Ministry of Agriculutre: Livestock statistics, units × 10^3 farmers, × 10^3 head) tion of water are problems. Uring and dung mixture and dung separately collected are processed by drying, burning, burying, composting, etc., but if a large volume of excrement which can be expected to have a soil improvement effect is temporarily used, it hinders growth of crops and has other disadvantages. Burning requires high energy cost and is economically disadvantageous. Burying involves acquisition of land and generation of odor and harmful insects, pollution of underground water, and other secondary pollution problems.

With composting, on the other hand, processing is comparatively simple and cheap and can be said to be the processing method with the best prospects based on the social background previously mentioned.

III. FACTOR OF COMPOSTING TREATMENT OF LIVESTOCK EXCREMENT

Generally, if a large quantity of raw dung and dry dun is used temporarily, the disintegratible organic matter decomposes quickly and a large amount of decomposition gas is generated. This decomposition gas has an harmfull effect on the initial growth of crops. Since livestock excrement contains a large amount of disintegratable organic components, excrement having a low carbon content, such as fowl excrement, must be handled with care because the initial microorganism activation appears suddenly. Therefore, disintegratible organic components should be decomposed and composted beforehand.

Composting is achieved by fermentation processing using the decomposing action of microorganisms. At the initial stage of the fermentation process, the amino acids, proteids, and other disintegratable organic components, including the dissoluble sugars, in the livestock excrement are decomposed and consumed with the growth of the microorganisms. Next, the hemicellulose and cellulose are decomposed, but decomposition of lignin and other hard disintegratible organic components takes a fairly long time. These fermentation processings are often performed under aerobic conditions, that is, they often use aerobic bacteria. In this case, whether environmental conditions are suitable to the growth of aerobic bacteria or not are maintained becomes a vital question.

Before developing the high speed composting system, we made laboratory studies on the conditions under which microorganisms grow rapidly, that is, the ideal fermentation conditions, and then conducted batch tests with a 1t/d machine and confirmation tests with the actual 10t/d system. Some of the high speed composting conditions clarified during these tests will be introduced here.

1. Initial Moisture Content

The moisture contents of livestock excrement depends largely on the kind of livestock and the breeding method. For example, the water content of layer hen excrement is about 70 ~ 80% and the excrement of broilers is a mixture of chips and planar and has a water content of about 20%.

The initial water contents has a large effect on fermentation. A water content of 60% or greater causes aeration to worsen, resulting in a local anaerob state and a water contents of 40% or less causes an insufficiency in the water content required for microorganism growth and satisfactory fermentation processing cannot be expected.

2. Effect of pH

To study the effects of pH on fermentation processing, we observed the fermentation conditions by adding acetatic acid and phosphoric acid to layer excrement. Without pH adjustment, pH = 8.5 was initially obtained and with acetic acid added, pH = 8.1 and with phosphoric acid added, pH = 7.0. *Fig. 1* shows the influence for fermentation by initial pH under these conditions and shows that the rise of the fermentation temperature tends to be slow based on a low initial pH. Moreover, in all cases, the pH rises as fermentation progresses and approaches 9.0 toward the end of fermentation. From this, slightly alkali conditions were judged to be suitable for fermentation processing of fowl excrement.

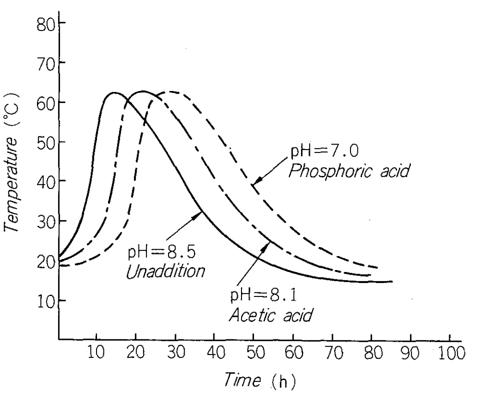


Fig. 1 Influence for fermentation by initial pH

3. Aeration

When organic matter is decomposed by aerobic microorganisms, carbon is necessary for the microorganisms to breath and grow. However, greater aeration than necessary reduces the internal temperature and suppresses activation of high temperature bacteria. Moreover, since a temperature sufficiently high to kill viruses and the eggs of parasitic insects cannot be obtained, care is required. During the confirmation tests with the actual 1t/d system, the aeration needed for fermentation was very small and was about 200 ~ 500l/min/t.

4. C/N Ratio (Carbon Ratio)

To investigate the influence of the C/N ratio, we observed the fermentation process of layer hen excrement with sawdust added by using the actual 10t/d system. Generally, the C/N ratio of layer excrement is about 10 and became about 12 with 20% sawdust added. However, this had

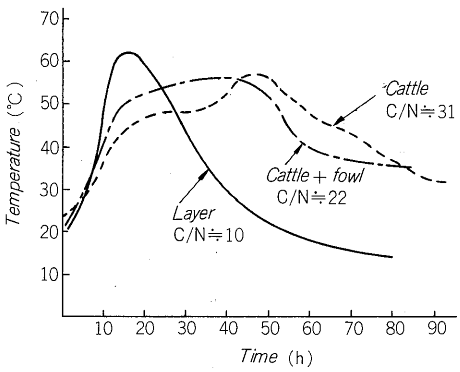


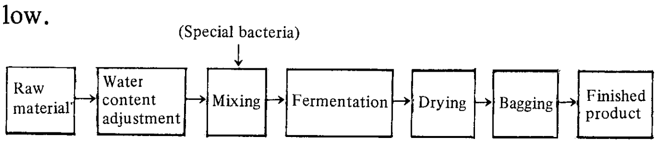
Fig. 2 Influence for fermentation by C/N ratio

no notable influence on the fermentation state and a change in the C/N ratio within this range is considered to have no influence on fermentation processing.

However, if the C/N ratio is approaches 20, such as that of cattle excrement, the fermentation time becomes longer. This is shown in *Fig. 2*.

IV. FUJI HIGH SPEED COMPOSTING SYSTEM AND ITS FEATURES

A block diagram of the composting process is given below.



Each process and its features are outlined below.

1. Water Content Adjustment

As shown in *Table 2*, livestock excrement generally has a large water contents and is not suitable for direct composting. Therefore, preprocessing which adjusts the water content up to the compostable water content (normally, 50 ~ 60%) is necessary.

Table 2 Composition of livestock excrement

(Units %)

	Water	Organic matter	Carbon	Nitrogen	Phosphoric acid	Potash
Fowl excrement	77.5	72.9	42.2	4.6	8.6	2.3
Pig excrement	81.1	80.9	41.5	3.9	4.8	0.7
Cattle excrement	84.3	72.6	41.4	1.8	2.7	4.0

Composition is dry base.

There are various method of adjusting the water contents, such as sunlight or heat drying, machine dehydration, drying by fermentation action, return of dried products, addition of sawdust, chaff, or other water content adjusters, etc. However, avoiding mechanical dehydration that requires water separation processing and the use of a water content adjuster and employment of the compost recircu-

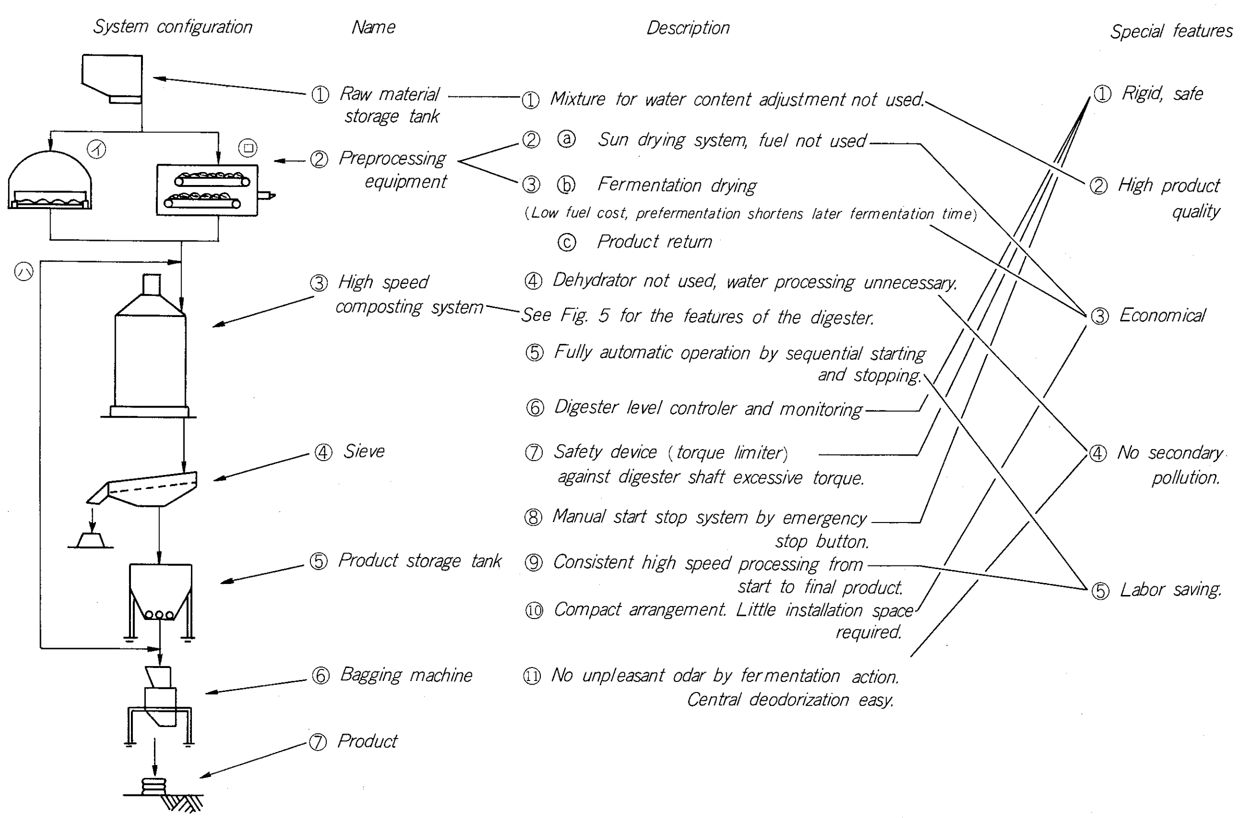


Fig. 3 Special feature of Fuji high speed composting system

lating process in which product return or the fermentation drying process saving fuel expenses are recommended as an advantageous method.

2. Mixing

The raw material and product return for water content adjustment use are made homogenous by mixing them with a fermentation promotoer. The fermentation promoter includes various useful microorganisms and enzymes and its addition promotes the fermentation action.

3. High Speed Digester

With our vertical multi-stage digester ordorless sanitary compost can be obtained from fowl excrement in 1 ~ 1.5 days and from pig and cattle excrement in 2 ~ 4 days. However, in the case of commercialization, accumulation and curing of several days after removal from the digester may also be anticipated.

4. Drying and Bagging

The granules and foreign matter, etc. are removed from the product from the digester by a sieve. The water contents of the product at this time is approximately 40%, and if this is immediately bagged, water vapor and odor inside the bag may cause a drop in the product quality. Therefore, the product should be bagged after the water content has been reduced to approximately 30% or less by drying it in the wind for 2 ~ 3 days or by using a small dryer.

5. Automation of All Processes

Since all processes from feeding of raw material to the final product are automated, substantial labor saving in plant maintenance is obtained.

6. Pollution-free

Since the digester is vertical and compact, the space over which odor is disbursed is small. Furthermore, since it is completely enclosed, collection and deodorization of odorous gas are simple. Moreover, there is no water pollution source and no danger of secondary pollution.

These features are diagrammed in *Fig. 3*.

V. VERTICAL MULTI-STAGE HIGH SPEED COMPOSTING SYSTEM

Microorganisms which decompose organic matter mainly comprise those which are active at the medium temperature region of 30 ~ 40°C and those which increase in activity at the high temperature region of 50~70°C. Meso-phile grow by decomposing and absorbing disintegratable surgars and proteins. Thermo-phile participate in the decomposition of cellulose and grow with the salts decomposed by miso-phile and miso-phile as the nutrient.

The vertical multi-stage digester developed by us forms thermo-phile microoganisms by applying meso-phile at the top stage and thermo-phile from the middle stage to bottom stage and features high speed, efficient decomposition processing by these microorganisms from decomposition of disintegratable sugars and proteins to cellulose and lignin.

In the case of livestock excrement, the fermentation action is completed in a short time of 1 ~ 4 days. Moreover, about 0.1% (weight ratio) of special bacteria is added at the inlet of the digester to promote the fermentation action. An arm that rotates at an extremely slow speed is

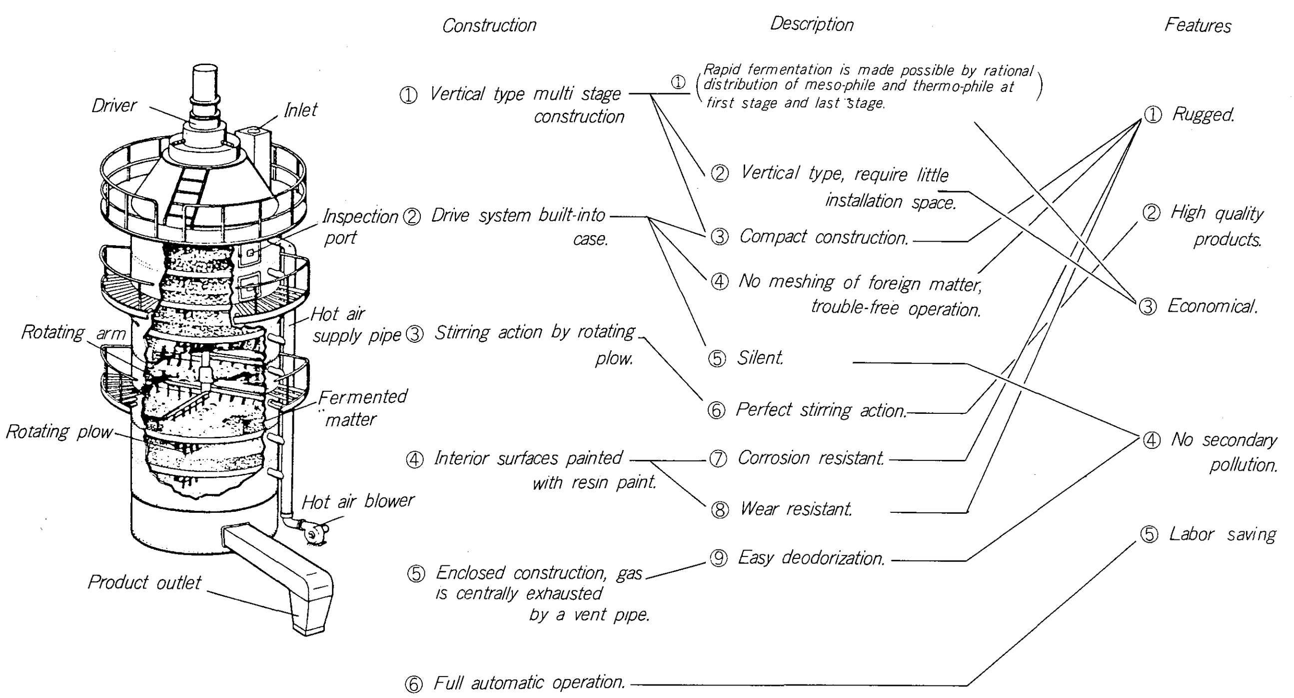


Fig. 4 Special feature of Fuji high speed composting equipment

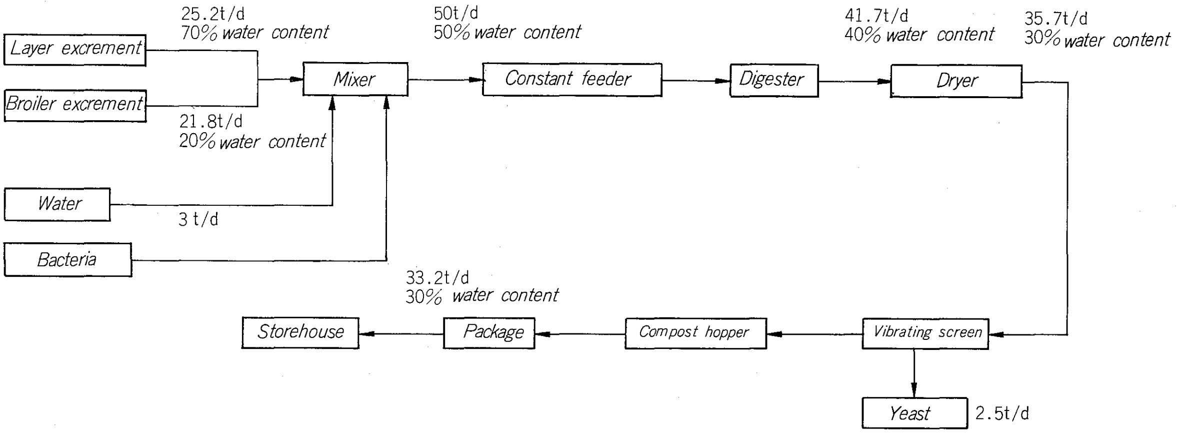


Fig. 5 Balance sheet of the fowl excrement composting equipment for Miyazaki Prefecture

provided inside the digester and a plow is attached to this arm. The raw material that has entered the digester from the top is constantly stirred by rotation of this plow and is converted into fine granules and ample air is simultaneously applied from the circumference and the microorganisms begin to suddenly grow. The number of bacteria inside the tank rises logarithmically from $10^5 \sim 10^6$ to $10^8 \sim 10^9$. After a fixed time has elapsed, the raw material is automatically dropped to the next stage by the plow.

Raw material feed, stirring transfer inside the tank, and removal from the tank are performed continuously. Since different microorganism are distributed at each stage inside the tank, and each requires a different amount of carbon, it is constructed so that the amount of air can be adjusted for each stage.

The features of the digester are diagrammed in *Fig. 4*.

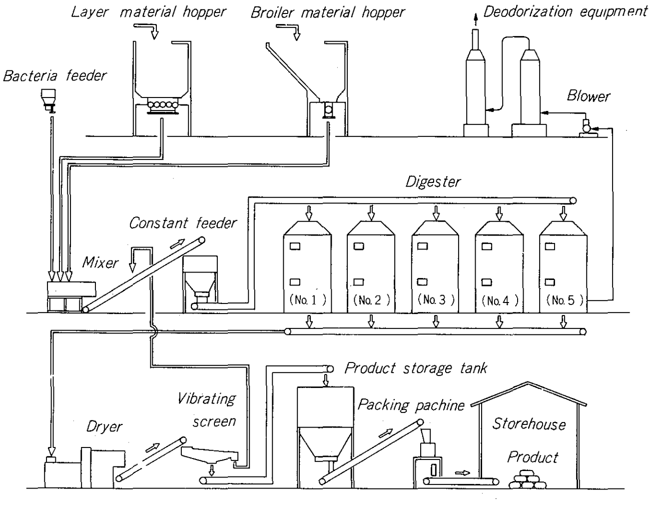


Fig. 6 Flow sheet of the fowl excrement composting equipment

VI. 50t/d FOWL EXCREMENT FERMENTATION PROCESSING FACILITY FOR MIYAZAKI PREFECTURE AGRICULTURE DEVELOPMENT PUBLIC CORPORATION

1. Outline of Plan

The Kyushu area is one of the leading chicken raising regions in Japan. This facility was planned to include prevention of the spread of contagious diseases by fowl excrement and to simultaneously prevent odor, water pollution, and other secondary pollution, in addition to fermentation processing by batch collection of fowl excrement and its use as fertilizer for green houses in the same region as one link in Miyazaki Prefecture agricultural environment adjustment work.

The fowl excrement processing facility is capable of processing 21.8t/d of broiler excrement, 25.3t/d of layer excrement, and 3t/d of added water for a total 50t/d, of mixed excrement having a water content of 50% so that it is capable of processing fowl excrement corresponding to approximately 500,000 chickens raised in the region.

It was planned to permit bagging and shipment of about 30t of fermented fowl excrement per day by operating 6 days a week.

The balance sheet based on the above basic plan is shown in *Fig. 5* and the flow sheet is shown in *Fig. 6*.

2. System and Equipment

(1) The fowl excrement collected by dump car from the chicken farms is placed into separate hoppers for broilers and layers.

(2) A constant amount of layer excrement and broiler excrement is fed from the raw material hoppers by a conveyor, mixed with bacteria by the mixer, and sent to the raw material constant feeder. At this time, the water content is adjusted to 50%.

(3) The raw material constant feeder supplies a constant amount of fowl excrement to five digesters. Each digester is capable of processing 10t/d.

(4) The fowl excrement is left in the digesters for $1 \sim 1.5$ days and the fermented excrement is then fed to a dryer.

(5) The fermented fowl excrement is dryed to a 30% water content by a dryer, screened by a vibrating screen, and the product is stored in the product hopper.

(6) The product in the product hopper is bagged for 8 hours and stored in a product storehouse.

Table 3 Main items of composting plant

No.	Machine	Specifications
1	Raw material hopper Broiler excrement Layer excrement	Type : Concrete tank type Capacity : 58 m^3 x 2 46 m^3
2	Mixer	Type : Paddle type x 1 Capacity : 4.5t/Hr
3	Raw material constant feeder	Type : Screw feeder x 1 Capacity : 23 m^3
4	Digester	Vertical type multi stage system 10t/d x 5 units Diameter 3.6 m x 8 stages, 5.5 kW
5	Dryer	Type : Rotary kiln x 1 Capacity : 300 kg H_2O/h (evaporation amount)
6	Product hopper	Type : Sheet steel, screw feed type Capacity : 65 m^3
7	Deodorization equipment	Type : Accid and Alkali washing type x 1 Gas flow : 25 m^3 min

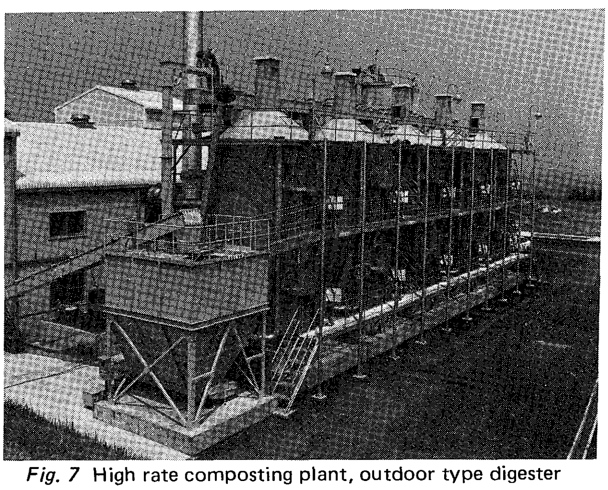


Fig. 7 High rate composting plant, outdoor type digester

(7) The fermentation gas is deodorized by deodorization equipment.

Moreover, the main items of the composting plant shown in *Table 3* were decided to apply to the flow sheet of *Fig. 7*. *Fig. 7* shows the high rate composting plant outdoor type digester.

3. Operating Results

Installation of this plant was completed at the end of March 1978 has been operating normally ever since. The facility is automatically operated in preprocessing, fermentation, and postprocessing block units and is operated continuously 24 hours a day.

1) Processing capacity

The processing capacity and product quality of the digester were both satisfied. When operated continuously for 24 hours, 33t, or approximately 2200 fifteen kilogram bags, can be produced daily. This value exceeds the planned value by more than 10%. An example of the composition of fermented broiler and layer excrement (compost) consisting of planar or chips laid on the floor is shown in *Table 4*.

Table 4 Composition of fowl excrement compost

(Units: % except for pH)

Kind of excrement	Water content	pH	T-C	T-N	P	K	Ig-Loss
Broiler (planar floor) Layer	15	8.0	37	3.0	2.5	2.8	73
Broiler (chip floor) Layer	21	8.3	37	3.3	2.4	3.0	76
Broiler (planar floor)	23	8.4	41	3.6	2.0	2.1	82
Layer	75	8.4	35	3.2	2.7	4.5	79

2) Temperature distribution

An example when fowl excrement was fermented with a water content of approximately 50% is shown in *Fig. 8*. Fermentation was completed in about 24 ~ 36 hours.
Fig. 9 shows the measurement examples of the temperature distribution of each stage of the digester of this plant. The digester temperature rises suddenly from 42°C to 66°C from stage 1 to stage 3, reaches a maximum of approximately 70°C at stage 4 and is maintained at about this temperature at stage 5. From stage 6, the temperature gradually falls until is drops to 53°C at the stage 8 outlet and is ex-

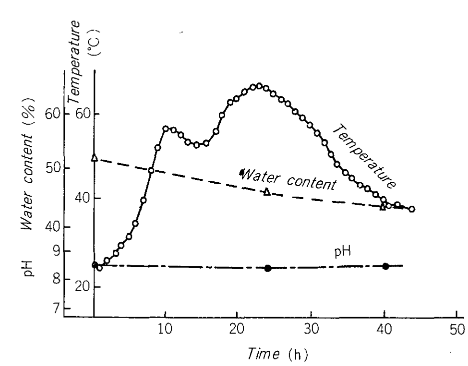


Fig. 8 Fermentation temperature of broiler and layer fowl excrement excrement mixture

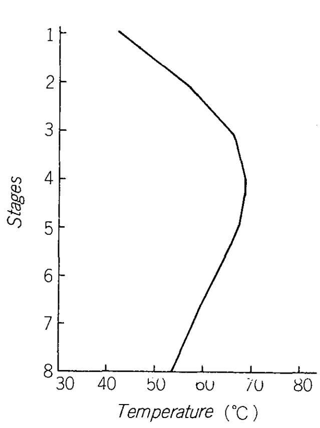


Fig. 9 Temperature curve of the digester

hausted. This temperature distribution accounts for the sporadic distribution of the meso-phile and thermo-phile distribution at each stage of the digester as described in Section **V** and shows that fermentation is just about compelted in about 30 hours.

3) Deodorization

The plant employs a totally closed system. That is, the hoppers, digesters, and conveyors all have an enclosed construction so that there is no odor leakage. The bad odor inside the raw material hopper and the fermentation gas of the digester are combined and sent to a deodorization equipment where they are deodorized. The deodorization equipment employs a two tower type deodorizer consisting of a sulfuric acid tower that removes the ammonia component and a hypochlorous acid soda acid tower that removes the hydrogen sulfide, methyl sulfide, and other unpleasant odors. The density after remove of the odorous gas at the inlet and outlet of the deodorizer is shown in *Table 5*. The result satisfied the limit values. Even when measured at the boundaries of the plant, almost no odor was sensed and the plant is acclaimed as a pollution-free facility.

4) Economy

The production cost of the fermentation system of this plant consists of fuel, electricity, water, deodorizing chemicals, repair, material and other operating expenses, cost of the bags, cost of the bacteria, etc. However, some of these can be eliminated, depending on the system, and costs are on a case-by-case basis. Therefore, production costs also depend on the system and are considered to be about several yen per 1 kg. This value is much lower than that of a machine drying system (for example, the running cost in the case of heat drying processing is said to be 20 yen per 1 kg of dry fowl excrement), and processing by the fermentation method is clearly advantageous.

Table 5 Test results of the deodorization equipment

Component	Inlet (ppm)	Outlet (ppm)
Ammonia	1,500	0.45 or less
Trimenthylamine	0.02	0.007 or less
Hydrogen sulfide	0.35	0.02 or less
Methylmebutane	0.003 or less	0.003 or less
Methyl sulfide	0.07	0.01 or less
Methyl dioxide	0.01 or less	0.01 or less

VII. CONCLUSION

The trend in waste processing is from the simple secondary pollution technology of the past toward the use of waste as a resource. This new plant provides one solution from various standpoints. In the future, the increase in the size of facilities will be accompanied by stipulation of serialization of products and organizations, fertilizing effect for plants, etc. In all events, the numerous factors in the process of physical change are displayed in fermentation and will be clarified both from the standpoint of microorganisms and soil mechanics in the future. We feel that the experience gained in the development of this plant as a large scale processing facility will be a solid foundation from the standpoint of fermentation mechanics.

We wish to express our gratitude to all those who cooperated in the construction of this plant.