Mechanical treatment of vegetable waste for animal feed[1)]

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1. Introduction

The waste treatment becomes difficult problem to solve all around the world. The fresh vegetable should be supplied to the human beings as a vital food everyday. The vegetable waste has been produced large amount at farm and intermediate market every day in Korea. The most popular method to remove the waste is to transport it to a garbage dump. But the volume of vegetable waste is such a large amount that the expenditure for the transportation is quit high. Also the valuable energy sources become just a trivial trash on a dumping ground. To save the transportation cost and accelerate the fermentation in a field, t[1)]he vegetable waste should be treated mechanically and reduced the volume.

Especially in Korea, as the forage field is small compare to the required area for animal feed production, most of the forage and grain for animal feed is imported from foreign country. The utilization of agricultural by-product for animal feed can solve the shortage problem on forage supply and was studied by many researchers(NRC, 1989, West etc., 1993, Macgregor, 1989, De Boer and Brickel, 1988). But the agricultural by-product has a characteristics of high moisture and also biased nutrition value included as a feed. So for the utilization of the agricultural by-product, the method how to supply and store material as a feed should be studied for a specific agricultural by-product.

The objective of this research is to develop the treatment system of the vegetable waste. Specifically the process for the treatment system of vegetable waste was determined, and for the system a method for volume reduction of vegetable waste was developed, and also the characteristic of treated waste was analyzed for animal feed.

2. Treatment system

The process for the treatment of vegetable waste could be as follows (Fig. 1).

2.1 Washing and separating equipment (Kim etc., 1995)

For the animal feed, the vegetable waste should be cleaned and separated. The soil, newspaper and plastic can be separated from the vegetable waste during washing in a water tank. A pick up conveyor was developed to supply the washed vegetable to the next processing unit.

2.2 Volume-reducing equipment

The maceration method can be used to reduce the volume of vegetable waste. From the macerated vegetable waste, the juice can be extracted easily. After extracting juice, the

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macerated vegetable waste have a characteristic of quick drying.

2.3 Juice-extracting equipment (Kim etc, 1995)

To reduce the drying cost, the juice has to be extracted by mechanical method. The developed juice-extracting machine have a shape of screw press.

2.4 Vegetable dryer (Kim etc., 1995)

The dryer for the vegetable waste was designed and constructed. An existing batch-type dryer has problems of low energy efficiency and also produces carbonized surface which reduces drying rate of material. The developed dryer rotates the material in a cylinder and moves the material continuously to the out let without any carbonization.

3. Test material and method

3.1. Volume-reducing equipment

3.1.1. Design of volume-reducing equipment

A prototype of volume-reducing equipment was developed using the operating principles of maceration which can crush a material for volume reduction and for easier juice extraction. The macerating occurred in between two knurled-surface rolls rotating in opposite direction each other with different rotating speed and small clearance(Krutz, 1968). It consisted of two parts, as shown in Fig. 2. The upper part indicates the crusher for size reduction of material and the lower one shows the macerater.

A. Crusher

Since it is very difficult in inletting large material over 30mm in diameter such as a cabbage root and a radish to the macerater, its size should be reduced before macerating. In this paper, therefore, a crusher was developed to reduce over-size vegetable waste. The crusher consists of two cylinders(A and C) of 200mm in diameter with many steel bars (15 x 15 mm) along their surfaces. The shaft of cylinder C is fixed on the frame, and the shaft of cylinder A is connected to the shaft of gear B by steel bar and bearing and is closely contacted to the cylinder A by the spring force. When the large size of material is incoming between the cylinders A and C, the cylinder A moves backward for inletting the material. Then the rotating steel bar crushes the material jammed between two cylinders.

B. Macerater

The macerating method can crush the material easily and continuously with small power. It is to shred and crush the material inletted between two knurled-surface rolls with small clearance of 0.3mm and speed ratio of 1.7:1. In order to increase the efficiency of shredding, the material passes through a pair of rolls four times as shown in Fig. 2. Since the clearance of first pair of rolls is 10mm, it is easy to crush and inlet big material to a pair of rolls. The practical macerating process is done on other three pairs of rolls. One V-belt is used to rotate all pairs of rolls in opposite direction, respectively.

3.1.2. Experimental Method

The experimental material was Chinese cabbage collected from a farmer's market in the morning when those were thrown away. As the performances of the volume-reducing equipment, the rate of volume reduction, the drying rate and the measure of juice extraction were evaluated according to the number of passing through pairs of rolls. Number of passing could be controlled by adjusting the clearance between the adjacent two rolls.

The rate of volume reduction could be determined by measuring the density of material before and after the maceration. And the measure of juice extraction was expressed as the moisture content of material which squeezed by a tire-roll press developed in Kangwon National University(Kim etc., 1995). To obtain the drying rate of treated material, two methods of drying were used. The temperature and moisture controlled chamber setting on 30℃ of temperature and 40% of relative humidity was used for simulating the natural drying in a field, and the dryer oven setting on 60℃ or 110℃ was used for simulating the commercial dryer.

3.2. Evaluation of Feed Value

The material was largely outside leaves of chinese cabbage of which moisture content was 92% to 94 % (w.b.). The composition of the vegetable waste treated by volume-reducing equipment was analyzed by the method of AOAC(1984).
The treated vegetable waste was stored in experimental silo with three levels of initial moisture content, 50%, 70%, and 90% in wet base. The quality of fermented vegetable waste of different initial moisture contents was evaluated by pH meter and the method of Flieg. NDF and ADF contents of the material was analyzed by the method of Goering and Van Soest (1970). Digestibility of vegetable silages was evaluated in a stomach of ruminant cow with 200 mesh nylon bag. Dry matter, crude protein and NDF digestibility were obtained.

4. Results and discussion

4.1. Volume reducing equipment

4.1.1. Rate of volume reduction and juice extraction

Table 1 represents the rate of volume reduction of experimental material by the number of passing. Even though there was no difference among the number of passing, their volumes were reduced 1/6 in average. The rate of volume reduction reached at 1/10 when the material was squeezed by the tire-roll press. Since the volume of vegetable waste directly affect the cost of transportation in case of the simple land filling-up, this volume-reducing equipment can contribute much for reducing the cost of transportation. For reducing the vegetable waste only in volume, the number of rolls could be one pair because the rate of volume reduction was not affected by the number of passing.

As shown in Table 2, the measure of juice extraction was affected by the number of passing when the macerated material was squeezed by the tire-roll press. But there was not different among the number of passing when the material was treated by the maceration only. The moisture content of macerated and pressed material was typically 85.1% when it was macerated through three pairs of rolls. No juice extraction was occurred during the macerating process.

4.1.2 Drying rate

Fig. 3 shows the drying rate of vegetable waste according to the number of passing in the temperature and moisture controlled chamber. Compared to the drying rate of never treated vegetable waste, the drying rate of macerated vegetable waste increased remarkably. Especially, the number of passing surely affected the drying rate of macerated vegetable waste.

Also, when the macerated vegetable waste was dried in a dryer oven, the drying rate varied similar to that in a temperature and moisture controlled chamber. Compared to the drying rate of control plot, the drying rate of macerated vegetable waste increased by 4 - 7.7 times, and the drying rate of the macerated and pressed vegetable waste increased even more by 20 - 50 times after 30 minutes' passed. This fact was directly related to the drying cost. Especially, in case of drying macerated material in low temperature around 60℃, the drying rate increased by the number of passing. Therefore, it was concluded that the method of 3 times maceration would be proper as a design factor for the drying as a livestock feed and the method of one time maceration for volume-reduction only.

4.2 Evaluation of feed value

As the vegetable waste tested was chinese cabbage of which moisture content was high over 90%(w.b.), it was very difficult to store more than 3 days without treatment even during winter. The content of crude protein was 18.2% which is higher than Timothy and Orchard grass (NRC, 1989). And the contents of NDF and ADF were 43.5% and 28.6% which were quit low compared to rice straw which is major feedstuff for cow in Korea.

The silages method to store vegetable waste was simple and easy to use at farm without big investments. The silages from high moisture content material (90%, w.b.) was not adequate for feed. But low moisture material (50%, 70% in w.b.) produced good silages for feed with low lactic and butyric acid. The digestibility of silages in a stomach of ruminant cow shows that the dry matter digestibility of low m.c.(50%, 70%) material was higher than that of high m.c.(90%) material. The crude protein digestibility also improved with low m.c. material.

In the aspect of fermentation characteristics of silages, it is essential to maintain less than 70% of moisture contents in vegetable waste silages.

5. Conclusion

The vegetable waste has been produced large amount at farm and intermediate market every day in Korea. To save the transportation cost and utilize renewable source, the vegetable waste should be treated mechanically and reduced the volume.

The objective of this research is to develop the treatment system of the vegetable waste. The process for the treatment system of vegetable waste was determined(Fig. 1). A method for volume reduction of vegetable waste was developed, and also the characteristic of treated waste was analyzed for animal feed.

1. The volume of vegetable waste was reduced 1/6 by developed volume-reducing machine. The rate of volume reduction reached at 1/10 when the material was squeezed by a tire-roll press.
2. The moisture content of macerated and pressed material was 85.1%(w.b.) when it was macerated through three pairs of rolls.
3. The drying rate of macerated vegetable waste was 4 - 7.7 times faster than that of untreated material, and that of the macerated and pressed vegetable waste was 20 - 50 times faster.
4. As the vegetable waste of Chinese cabbage contains high crude protein and low NDF content, it must be the good feed with the high nutritional value for farm animals. The silages method to store vegetable waste was simple and easy to use at farm without big investments. The silages from low moisture material (50%, 70% in w.b.) produced good silages for feed with low lactic and butyric acid.

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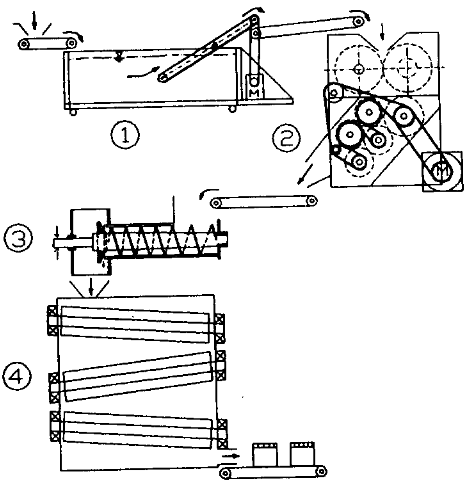

Fig. 1 Treatment system of vegetable waste

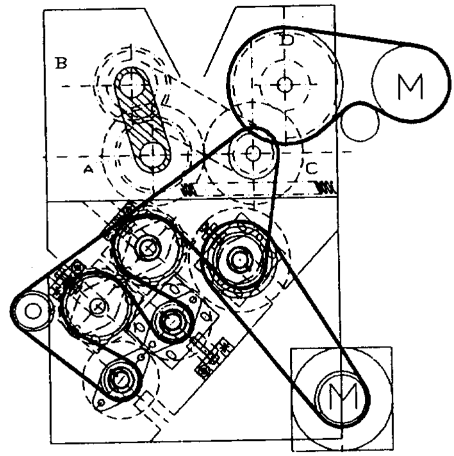

Fig. 2. Volume-reducing equipment

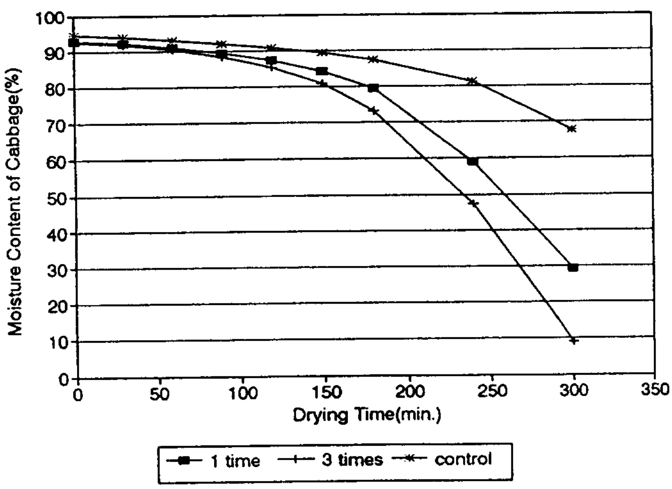

Fig. 3 Drying rate of volume-reduced waste according to the number of passing in a temperature and moisture controlled chamber

Table 1. Effect of number of passing on the rate of volume reduction.

	No. of passing		
	1	2	3
Macerated	17.4%	19.3%	17.5%
Macerated + Pressed	10.3%	11.3%	10.2%

Table 2. Effect of number of passing on the moisture content (w.b.)

	No. of passing		
	1	2	3
Control	94.6%	94.7%	94.0%
Macerated	94.2%	94.2%	93.5%
Macerated + Pressed	88.0%	87.1%	85.1%

Table 3. Composition of vegetable waste (chinese cabbage), %DM

M.C.	Crude protein	Crude fat	Ash	Crude fiber	NDF	ADF
92.4	18.2	2.0	9.2	14.5	43.5	28.6

Table 4 Quality of fermented vegetable waste of different moisture contents

	M.C. 90%	M.C. 70%	M.C. 50%
pH	6.5	5.3	5.7
Lactic acid, %	-	0.23	0.20
Acetic acid, %	0.35	0.37	0.22
Butyric acid,%	0.54	0.21	0.14

Table 5 Digestibility of vegetable silages in a stomach of ruminant cow

	M.C. 90%	M.C. 70%	M.C. 50%
Dry matter	70.1	75.4	73.6
Protein	63.2	68.3	67.8
NDF	58.7	63.4	63.0