Roughage Wafering Techniques in Japan

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The dairy in Japan has developed steadily in the past ten years up to 1975. The pattern of development was that the number of farm households keeping livestock was decreased by nearly 50% to 180,000, while the number of livestock kept per farm household was increased three times, reaching 11 heads in an average. Such a trend of increasing size of livestock keeping has caused a difficult situation that even the minimum quantity of roughage for dairy cattle would not be available, particularly in suburban dairy areas lacking roughage self-supporting bases. To ensure the availability of roughage by dairy farmers, development of a series of techniques related to the marketing of roughage has become an important problem.

There are two types of roughage merchandise to be marketed widely: baled hay and wafered hay. In Japan, the wafered hay is considered to be advantageous from the viewpoint of securing enough quantity as well as of transporting, storage, feeding or the uniformity of quality. In 1970, as a part of the Roughage Marketing Rationalisation Programme, an experimental model plant with imported dryer and wafering machine was first set up, and by 1975 the number of plants has increased yearly to a total of 20, of which 2 plants were made up with domestic facilities only.

Results of examinations and researches carried out centering these plants will be presented in this paper.

Roughage drying and wafering plants

The most important work to be done prior to the wafering of roughage is the drying. Of the two methods of drying, natural drying and artificial drying, the wafering system based on artificial drying of roughage, mostly pasture plants, is adopted in these plants with the purpose of assuring good quality under the adverse climatic condition with rains every 3 days at the roughage harvesting time.

The plants are grouped as stationary plants and mobile plants which are movable and work with engine as the power source. As the working process is almost similar for both groups, an example is shown in Fig. 1. In these plants, the evaporative capacity per hr of dryers is largely within a range of 2.2–5.5 tons, and the capacity of wafering per hr ranges from 0.6 to 2 tons, being matched with the capacity of dryers.

1) Dryers

As wafering machines well fitted to the capacity of dryers are installed, the performance of the dryer is required to be able to dry the material to an extent most suitable for wafering and to supply at a constant flow.

All of the dryers installed in the plants are rotary drum dryers of single pass type or three pass type, both equipped with scooping blades inside the drum, as shown in Fig. 2. Materials are scooped up by the blades to a certain height, and then flow down. During the flowing-down, they lose their moisture by

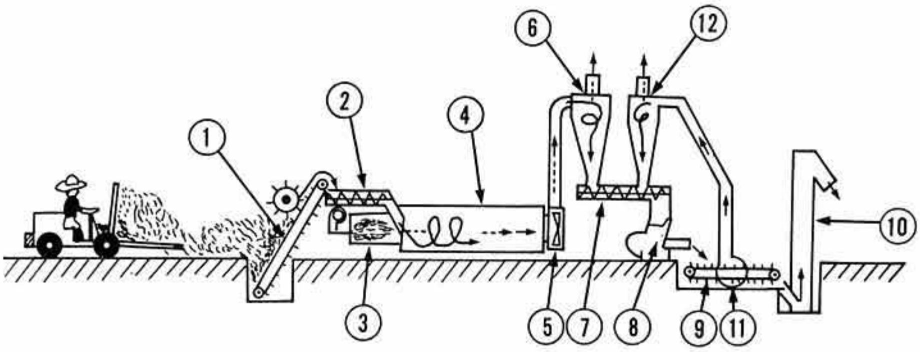


Fig. 1. Operating process diagram of a roughage drying and wafering plant

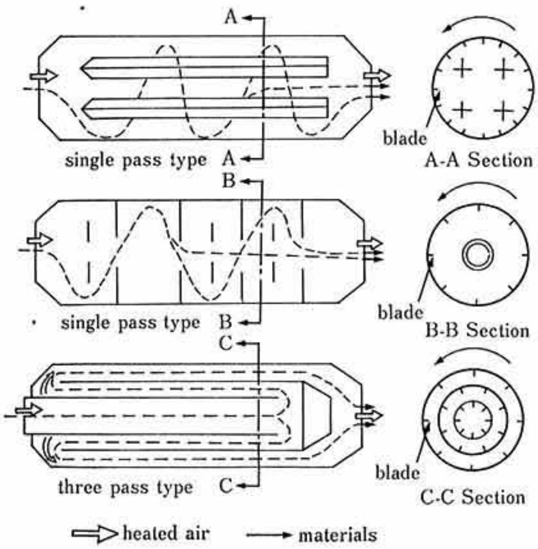


Fig. 2. Schematic diagrams of rotary drums

being contacted with heated air, and become lighter in weight. They are forced to proceed to the outlet of the drum along the flow of heated air. Kerosene or heavy oil is used as fuel. Heated air temperature is 600–900°C at the inlet of the drum, and 110–120°C at the outlet. Holding time in the drum is 2–3 min; a quick drying by high temperature heated-air is the characteristic of this method.

Before the operation of the dryers, temperature of heated air, rate of flow of supplying materials to rotary drums, etc are set up according to the kinds, characters and moisture contents of materials, and then the operation is started. After necessary conditions are fulfilled, automatic control units detect the rise and fall of temperature inside rotary drums, and regulate automatically the fuel oil consumption and rate of flow of supplying materials to maintain the optimum drying condition during the operation.

Items so far made clear with the dryers are as follows:

Evaporative capacity: When the optimum operation is made with materials of about 80% in moisture content, evaporative capacity of about 1.5 kg per 1,000 kcal of calorific value of fuel oil can be expected. To carry out such an operation, however, empirical judgements of operators are needed.

Moisture content: As the moisture content of materials becomes lower, the drying efficiency becomes lower, but the fuel oil consumption per 1 kg of dried material becomes less, almost in proportion to the amount of water to be removed. Therefore, pre-drying by natural drying etc is very effective in saving fuel consumption. But it often causes varying moisture contents and uneven moisture distribution of materials to be supplied to the plants, making the operation quite difficult.

Table 1. Designation of compressed roughages and compression devices

Pellet	: An agglomeration of individual ground ingredients, or mixture of such ingredients, commonly used for animal feeds.	*Pelleting machine*
Wafer ← Briquette, Biscuit, Wafer, cube, Pellet	: An agglomeration of unground ingredients in which some of the fibers are equal to or greater than length of the minimum cross-sectional dimension of the agglomeration:	*Wafering machine* ← Compression unit, Waferer, Wafering machine, Cuber, Cubing machine, Pelleting machine

Wafer configuration	Size of wafer	Machine for wafering
Column-Shaped wafer	50～80φ mm×30～60 mm	Plunger-type
Cube-shaped wafer	30～40□ mm×40～80 mm	Roller-die-type

Cut length of materials: Allowable length (adaptable to dryers) is less than 5 cm. The shorter the length, the higher the drying efficiency, due to an increased surface area of the material.

Operating hour: Since a total of about 3 hrs is required for preheating at the start and cooling at the end of operation, the short time operation causes adverse effects on time and cost of operation. Therefore, a 24-hr running is desirable, but techniques for temporary storage of high moisture materials have to be developed to make the over-night operation possible.

2) Wafering machine

It is desirable to have the machine which can produce efficiently the wafered roughage which has the hardiness appropriate for feeding purpose, but not easily be collapsed during the handling. Wafered roughages are called by various names. A refined terminology is given in Table 1, and hereafter the wafered roughage is referred to wafer, and the machine to wafering machine. The wafering machine has two types, as shown in Fig. 3.

Roller-die type: Materials supplied onto the die with many compression chambers are pressed by a roller into the chambers and wafered. Imported hay cube-shaped wafers are produced by the wafering machine with square compression chambers shown in Fig. 3-a, which is used exclusively for leguminous forages. The wafering machine of the type given in Fig. 3-b was imported and used at an early date, but the following disadvantages were pointed out by surveys and studies:

1) Too small compression chamber, and allowable cut length of material is shorter than 2 cm. Materials are crushed during the wafering, giving too short fiber length as a roughage.
2) Low efficiency in filling compression chamber, and the product is apt to be very hard.
3) Not easy to change the volume of compression chambers depending on conditions of materials.

For these reasons, the plunger type had come to be regarded as more suitable for obtaining long crude fiber length. Since then this type was adopted in most plants.

Plunger type: A reciprocating plunger forces the material supplied in front of it into a cylinder. By selecting an adequate length of the cylinder, and the degree and direction of taper of inner surface, the material is pressed in the cylinder and comes out as a wafered product. The machine of this type alone, being not combined with the dryer, is also used for wafering rice straw. Structure of the commercial plunger-type machine is shown in Fig. 4.

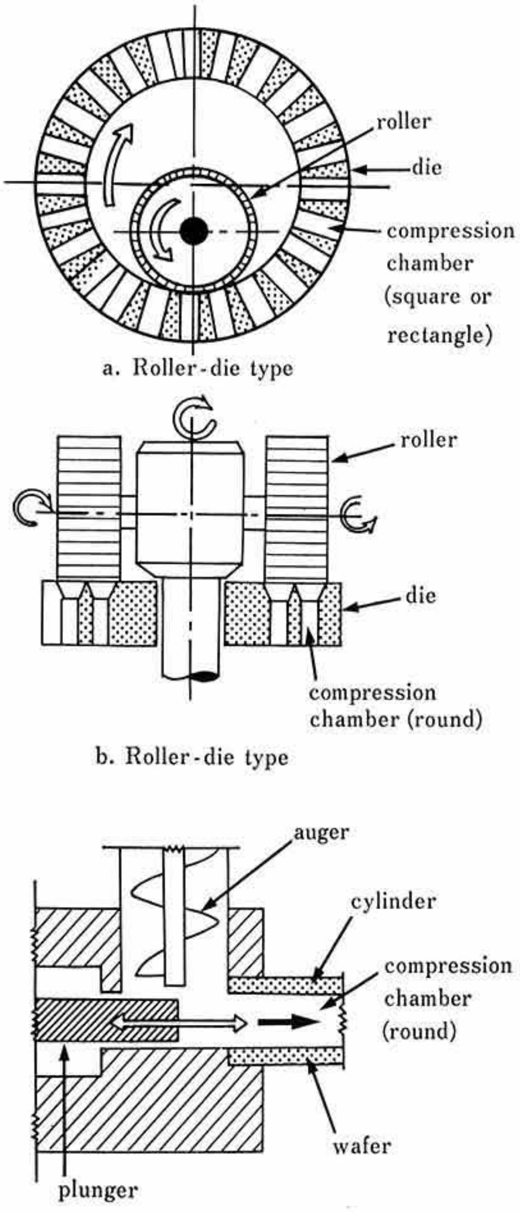
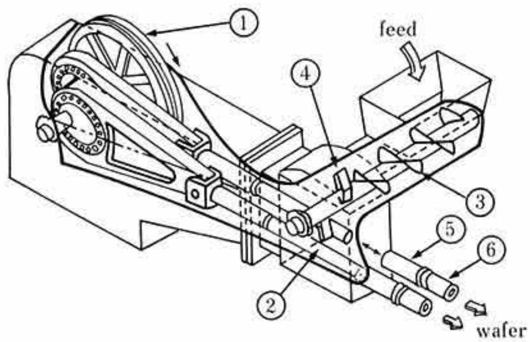


Fig. 3. Schematic diagrams of wafering machines

With this type of machines, the followings were made clear as factors affecting waferability:

Moisture contents: Moisture contents of materials at 16–18% are desirable, but moisture contents of the products have to be below 14% to avoid fungal infestations during



① input V-shaped pulley
② plunger
③ auger
④ compression paddle
⑤ main cylinder
⑥ extension cylinder

Fig. 4. Schematic diagram of the commercial plunger-type wafering machine

the storage. If the wafering is attempted under a condition outside of this range of moisture content, for example, below 10% the material will be scorched, and above 20% the wafered product will be spouted and scattered from the cylinder.

Cut length of materials: Short cutting causes an increased flow of product, but the product becomes liable to collapse. Cut length of 2–3 cm is adequate from the viewpoint of performance of machines and feeding animals.

Kind of materials: Legumes have better waferability than grasses. With the same kind of forage, the waferability decreases from the spring first cutting to the last cutting, showing that the earlier cutting is better. Many other materials such as silage of pasture plants, straws like rice and barley straw, beettop, canetop, sorgo etc can be used for wafering.

Temperature of materials: Materials still keeping the temperature of pre-heating, like the materials immediately after the artificial drying, are better in the waferability than materials naturally dried.

Compression pressure of plunger and wafer density: Specific density of wafers of 0.6–1.0 g/cm^3 is adequate from the points of durability during handling and of feed intake. In this case, the bulk density of wafers is about 60% of the specific density. To get the product with such specific density, the compression pressure of around 500 kg/cm² is required. The capacity of machines of this type is about 15 kg per hr-hp in the rate of flow of the product. Thus, the machines are of high-pressure and high-horsepower.

Problems and countermeasures

Under a serious situation that the marketing of wafers produced in Japan may not develop unless their market price is competitive to that of imported roughages, it is a great problem how to reduce the cost for wafering in drying and wafering plants. In existing plants, an increase of production brought about by extending the running hours throughout a year will result in a cost reduction, as demonstrated by an economic principle. However, the present situation is that the annual production in the plants, equipped with dryers having an evaporative capacity of 2.5 tons per hr, is only about 200 tons per year, far away from the designed target of more than 1,000 tons. To secure the necessary quantity of roughages available for wafering is a critical problem, and to reduce the cost of facilities may also be an important future task of research.

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