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REVIEW

Development of the Roll Baler for Chopped Materials

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Abstract

This is a self review about the development of a roll baler for chopped material that can form chopped maize into a roll bale and a bale wrapper that can load and wrap fragile roll bales. These machines were developed for family managed dairy farms in Honshu district to reduce heavy labor and to minimize the work force in maize harvesting. Through the development and examination of the test machines, we found some points that need improvement for practical use. A practical baler and wrapper were developed based on the test machines. Practical tests evaluated the machines at 10 different fields throughout Japan. In these tests, 2 or 3 workers could manage almost all work from harvesting to wrapping, and the silage had good fermentation qualities and could be stored satisfactorily for a long time. These machines have been on the market since 2004. Subsequently, the technology obtained through the development of these machines could be applied for large-scale dairy farmers or contractors.

Discipline: Agricultural machinery
Additional key words: forage harvester, labor saving, maize, minimal work force, wrapped silage

Introduction

Maize is regarded as one of the most suitable forage crops in Japan because of its high nutrition, high yield, and good absorption of nitrogen. However, 5 to 6 people are required to carry out harvesting and ensiling work efficiently. Furthermore, silo stacking has to be done by hand and often in hot weather and is very hard work. In addition, harvesting and ensiling efficiency are lower in major towns because fields are small and scattered. Thus, the planted acreage of maize has been decreasing in recent years; some 35,000 ha have been lost in the last 10 years. Increasing self-sufficiency in feed will not be easy without increased maize planting, and therefore labor saving in harvesting and ensiling is urgently required.

In grass production, the arrival of the roll baler and the bale wrapper enabled just 2 workers to perform the work efficiently. Moreover, the roll baler and bale wrapper have eliminated the need for manual silo stacking and have thus become very popular in Japan. There have also been enquiries about using the roll baler in maize harvesting and ensiling work. However, it was difficult to form chopped maize into a roll bale with little loss because chopped maize could not intertwine.

This is a self review of a roll baler that handles chopped maize and the corresponding bale wrapper, which were developed by the authors for family-managed dairy farms with 30 to 80 cows in Honshu district, in order to reduce heavy labor and to minimize the work force in maize harvesting.

1. Development of the test machine

The test baler and wrapper were developed in the following order: determining problems by investigating previous documents, constructing the test baler, and evaluating the performance in a maize-harvesting test[3,4]. In addition, we developed a bale wrapper corresponding to a roll bale made of chopped maize so that harvesting and

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ensiling work could be done efficiently with 2 workers. We then discussed the operation system that constituted the test baler and wrapper[6].

(1) Document investigation

A technique for wrapping a container bag that had been crammed full of chopped maize by a bale wrapper was developed at the Tottori Prefectural Animal Husbandry Experiment Station. It succeeded in producing high-quality silage reducing loss that was incurred during harvesting and ensiling. In addition, secondary fermentation didn't begin until a few days after the wrapped silage was opened. The report pointed out that this technique could be applied to the traditional working system, but that simplification of the work process and minimization of the work force were needed[2].

A maize-harvesting technique employing a small roll baler that had a 50 cm diameter forming chamber was developed for small-scale dairy farmers at the National Agricultural Research Center for the Western Region (e.g. Shikoku National Experiment Station). However, the document reported that the produced bale was very fragile and approximately 10% was lost due to the impact of discharge when using twine to bind a bale of maize cut to lengths of 3 cm[1].

The investigation determined that forming a high-density bale, binding it so as to keep the density after discharge, and a forming chamber that prevents material from falling were important keys for forming chopped material into a bale because chopped maize couldn't be expected to preserve the bale forming characteristics by intertwining like grass.

(2) Development of the test baler and wrapper

The test baler that we developed consisted of a 90 cm-diamter forming chamber, an 85 cm-wide chamber; a hopper for receiving chopped material from a forage harvester; a conveyer that conveyed chopped material in the hopper to the forming chamber; and a net binding apparatus. The test baler employed a rod-link chain forming chamber with a belt attached to tight bars to prevent chopped material from falling (Fig. 1). The bale edges were wrapped and protected with a net that was 1.2 m wide and wider than the width of a bale, decreasing the loss produced when a bale was discharged. The test baler was evaluated on maize harvesting. The test results demonstrated that the test baler operated reasonably smoothly. When moisture content of maize was 65 to 74%, the loss produced at discharge was 1.6% on average, and the validity of net binding was confirmed. A bale made of chopped maize had high density, a mass of 422 kg (average), and dry matter density of 208 kg/m^3 (average). A view of harvesting by the test baler is shown in Fig. 2.

In addition, the test baler was able to harvest wilting grass by employing an attached forage harvester pick up unit[5].

We developed a test wrapper that could pick up and wrap loose cut bales so that harvesting and ensiling work could be done efficiently by just 2 people. The test wrapper was a tractor-mounted turn table, and could pick up a bale without breaking it by using side arms that pinched both ends of the fragile bale after the turn table was dumped (Fig. 3). We checked its performance and found that the first test wrapper could wrap the cut bale promptly with an average wrapping loss of 0.3%, which was quite low. The power requirement was only 1.6 kW for picking up and only 0.7 kW for wrapping. This was low enough for a 22 kW class tractor. Figure 4 illustrates wrapping work by the test wrapper.

The test baler pulled by a 44 kW four-wheel tractor with a one-row forage harvester was combined with the test wrapper connected by a rear three-point link hitch of a 22 kW four-wheel tractor and tested on the maize har-

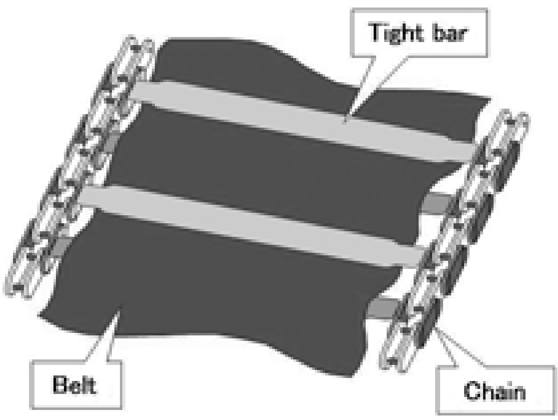

Fig. 1. Construction of forming chamber of the test baler

Fig. 2. Harvesting work by the test baler

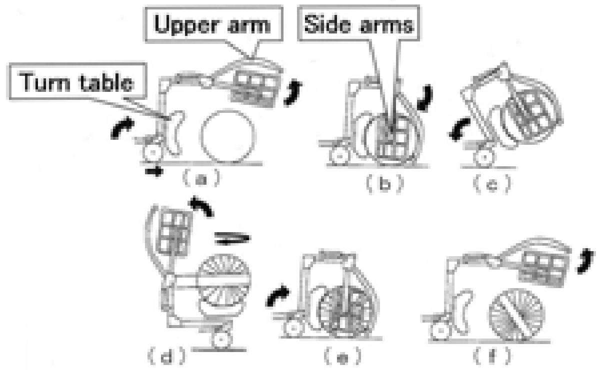

Fig. 3. Working procedure of the test wrapper

Fig. 4. Wrapping work by the test wrapper

Fig. 5. Construction of forming chamber of the practical baler

Fig. 6. Harvesting work by the practical baler

Fig. 7. Wrapping work by the practical wrapper

Fig. 8. Static work by the practical baler

vesting and ensiling at 25 a field. With this combination, 2 workers could sufficiently manage almost all work from harvesting to wrapping. The work efficiencies of the test baler and the wrapper were both 9.3 a/h.

To make it more practicable, the test baler would require improvements in operation, strength and work efficiency, as well as some additional improvements so that it could form better bales with more consistency. For compatibility with traditional harvesting in which a forage harvester is attached to the rear and a covered wagon or a loader bucket is attached to the front of the tractor, it is necessary to enlarge the hopper so it can receive packs from the hood wagon or the loader bucket. These improvements will be necessary for widespread application of the new machine. It also became clear that the wrapping time of the first test wrapper should be shortened.

2. Development of the practical machines and on-site proof tests

We discussed the problems encountered in test machines and developed a practical baler and wrapper, which were improved in many points. We checked these machines at 10 different fields throughout Japan under various weather conditions, field scales and work conditions, in order to verify practical use of the machines[7,8].

(1) Development of a practical baler and wrapper

In the practical baler, a suitable amount of chopped material was first stored in the hopper so that it could form better bales with more consistency and then sent to the chamber. The hopper capacity was increased from 0.9 m^3 to 2 m^3. The chamber was made 80 cm in diameter and 85 cm in width so that the bale mass was approximately 350 kg, which a bale glove for a small tractor could handle. In addition, the forming chamber was redesigned to have closely placed flat tight bars in order to simplify the structure (Fig. 5). The baler could then support static use, in which the baler received material from the loader bucket, and was subsequently modified to run side-by-side with the forage harvester.

The practical wrapper was improved by adding two sets of wrap film in order to shorten the work time. Figures 6 and 7 depict the baler and wrapper.

(2) Performance of the practical machines

Validation tests were carried out in Hokkaido, Fukushima, Gunma, Mie, Okayama, Ehime, Kumamoto and Miyazaki in cooperation with public experiment stations and farmers. The practical machines exhibited better performance than the first one. For example, loss at discharge was 1.2% on average, loss at wrapping was 0.2% on average, a mass of a bale was 330 kg on average (when moisture content was 72% on average), the baler's rate of work was about 30 a/h when two row forage harvesters were used, and the wrapper's rate of work was 15 to 36 a/h. The total labor time of the work system with the new machine (one-man operation) was 58% and 47% that of traditional work systems such as bunker silos and stack silos. Farmers evaluated the machine as being

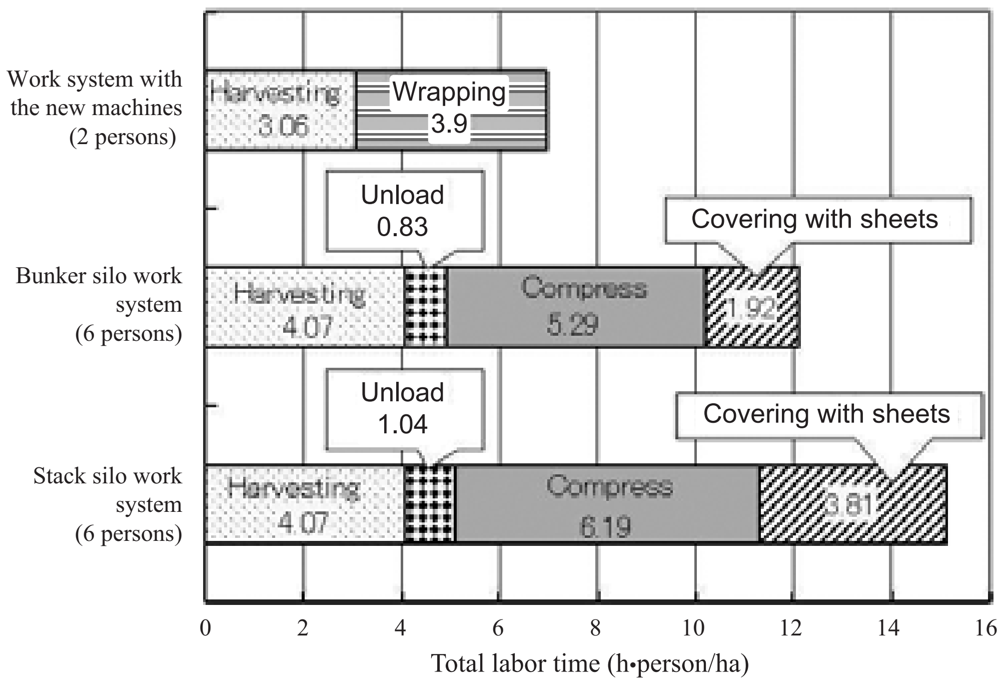

Fig. 9. Comparison of total labor time between developed work system and traditional work system

Table 1. Fermentation quality of maize silage

	Period of storage (month)			
	2	4	6	12
pH	3.7	3.7	3.7	3.7
Lactic acid (FM%)	1.82	1.70	1.69	1.49
Acetic acid (FM%)	0.39	0.39	0.40	0.30
Propionic acid (FM%)	0.11	0.09	0.11	0.00
Butyric acid (%)	0.00	0.00	0.08	0.00
VBN/TN (%)	9.14	9.19	9.20	6.03
V-score	89	89	85	97

clearly quite practicable. Figure 8 depicts static work, and Fig. 9 compares total labor time among the bunker silo system, the stack silo system and the work system with the new machine. The baler required approximately 16 kW of power.

(3) Silage fermentation quality

The silage had good fermentation quality, could be stored satisfactorily for a long time (Table 1), and could be used little by little. Even the high moisture content of 80% did not influence the fermentation quality after 3 months storage, and soil on the bales did not seem to present practical problems. Sorghum silage exhibited both quality fermentation and good long-term storage. The cut bales of rhodesgrass had higher density than the uncut roll bales formed by a currently marketed roll baler, and the fermentation quality was good. However, no difference was observed in the fermentation quality of oats, although the density was almost twice as high. More test examples were deemed necessary.

Future development

The baler and the wrapper have been on the market since 2004. Now we are investigating a self propelled baler, which provides a harvester that can apply to maize, grass and forage paddy by exchangeable attachments. The machine is being developed for contractors in the Honshu area, which are often working at paddy fields that are switched to forage crop fields. Furthermore, investigation of a multi-purpose baler for large-scale dairy farmers or contractors is planned.

Conclusions

We developed a roll baler for chopped material that could form chopped maize into a roll bale and a bale wrapper that could load and wrap fragile roll bales for family-managed dairy farms in order to reduce the heavy labor and to minimize the work force in maize harvesting. The performance and functions of the practical machines, which were developed based on the test machines, were sufficient for practical application. Furthermore, the fermentation quality of the silage was good, so use of the new machines could be expected to spread. The technology obtained through developing the baler and wrapper should be further improved to apply to large-scale dairy farmers or contractors.

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