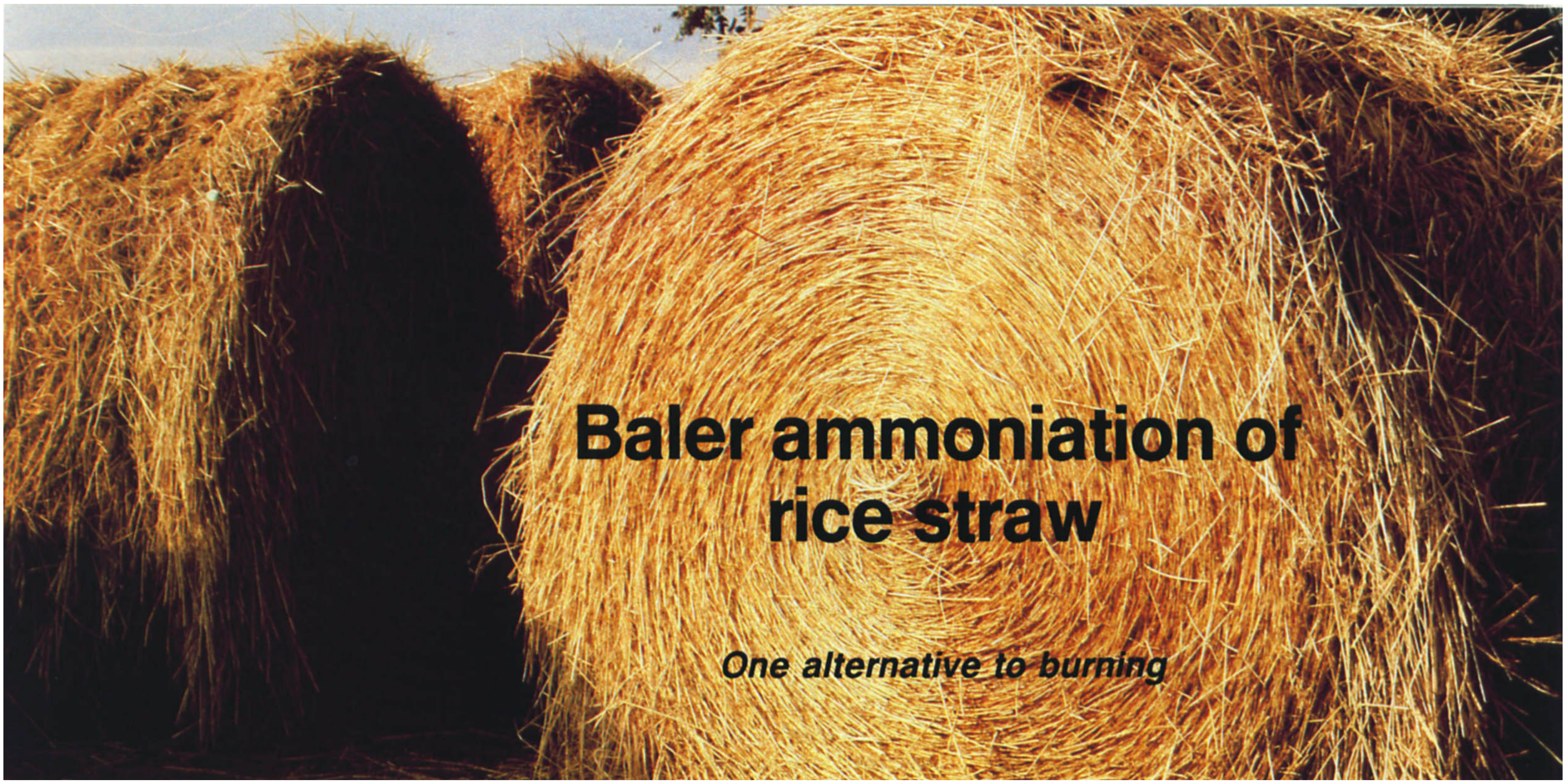

Baler ammoniation of rice straw

One alternative to burning

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Adding anhydrous ammonia to high-density round bales of rice straw improves palatability to cattle and conditions the straw to withstand long periods of outside storage. Uniformity and distribution of ammonia in the 900-pound bales were measured with a special forage sampler. A slight ammonia odor was detectable in treated bales even after six months.

The burning of nearly a million tons of rice straw each year by California's Central Valley farmers has caused public concern about air pollution. With the assistance of the Rice Research Board, we began a project to explore the possibility of baling rice straw and the usefulness of the harvested rice straw as an animal feed.

The California rice paddy is not ideal for the use of standard "off-the-shelf" three-wire balers designed for handling forage. Field floors are often muddy and rutted by the combines. The combines also lay down rice straw in wandering, uneven windrows, leading to choking of the balers. It is very difficult to rake the typical rice straw windrow with the standard rakes for better uniformity or to combine windrows for greater volume.

In addition to the mechanical problems, heavy dews severely limit the length of time that rice straw can be harvested at conventional baling moistures of 10 to 18 percent. Heavy dews also promote the growth of molds, which can produce substances toxic to livestock, reduce palatability, and possibly contribute to the destruction of feed energy. Of real concern is the presence of *Aspergillus flavus*, a fungus that produces the highly toxic aflatoxin, which has been detected by other investigators. Other scientists also found that rice straw packaged in the standard three-wire bale placed in roadside stacks did not weather well through the winter.

Previous research at the Univeristy of California, Davis, by William Garrett and co-workers has shown that feeding value of rice straw could be significantly improved by ammoniation. Baler-ammoniation studies in Glenn County with two- and three-wire balers also demonstrated the fungicidal activity of ammonia when applied in sufficient quantities. Arizona researchers showed that ammoniation could detoxify toxins produced by the *Aspergillus flavus* organism. The potential for quality improvement of the rice straw became a major factor in our study.

In 1980, we selected a Vermeer 504F PTO baler for study. The baler produced a 4- by 5-foot dense cylindrical rice straw bale weighing 800 to 1,300 pounds, depending on the moisture level of the straw. We mounted ground-powered crowd wheels on either side of the 4-foot-wide windrow pickup, which "folded" in the edges of the 5½-foot-wide combine windrow and were major contributors to the uniform density of the bale. Dual tires were added to increase flotation.

In 1981, we used a Vermeer 605F round baler (5- by 6-foot base) and a Heston 4800 baler (4 by 4 by 8 feet) in the study. The 605F baler, modified similarly to the 504F, was unable to produce a dense uniform bale of rice straw. The Heston 4800, to which crowd wheels were added, had severe choking problems that required hours to unplug. All balers were power take-off (pto) powered. Between 350 and 400 bales were produced during the two-year study.

For ammoniation, we fitted a 200-gallon anhydrous ammonia pressure tank on the front of a four-wheel-drive Versatile 500 tractor. Ammonia from the tank was metered through a flow control valve, entered the USS Cold-Flo reactor chamber, was liquefied, and passed through a splitter that divided the flow into four equal parts. The ammonia outlets were 6 inches from the sides of the windrow pickup. All ammonia outlets were 1 foot apart.

On the second day of the tryout baling, we modified the distribution manifold, increasing the number of liquefied anhydrous ammonia outlets to eight, arranged 6 inches apart across the surface of the windrow pickup. This change more evenly distributed the liquefied ammonia. Manifold outlets for the 605F and Heston 4800 were increased to 13.

Baling

Baling took place under various weather conditions and moisture levels. In 1980, we successfully baler-ammoniated and stored rice straw six hours after combining at straw moistures of 40 percent, but average moisture for baler-ammoniation ranged between 22 and 30 percent. On the average day during our two-year study, moisture levels in windrowed rice straw remained above 20 percent until 10:00 or 11:00 a.m., then dropped; moisture built up again at 4:00 or 4:30 p.m.

High-moisture rice straw bales could not be dumped from the 504F baler in the conventional manner. Bales with 30 to 40 percent moisture had to be removed with hydraulic jacks if they stopped rotating. Later, we found that, if we dragged the baler along the rice paddy levees, the high center would force the high-moisture bales from the machine.

Choking was a frequent hazard with all balers. In the first year of the study, power was provided by the 4-wheel-drive Versitile tractor, in which pto speed could be maintained while ground speed was reduced. The problem of choking was minimized once the tractor driver learned to compensate. In the second year, a Case 2470 was used and pto speed could not be maintained when the tractor slowed. In the second year, there also was more lodging in the field, requiring a closer cut, and there was more clumping of windrowed rice straw presented to the Heston 4800 and the Vermeer 605 balers.

Bales produced by the 504F, using the crowd wheels, had a number of desirable characteristics not shared by those produced by the 605F or 4800. Only a faint ammonia odor, and that at a distance of 1 foot, could be detected coming from the 504F bale immediately after it was dropped from the baler. Ammoniated bales dropped from the other two machines appeared to be "smoking," and they could not be approached from downwind for several minutes. The 4800 bale accumulator had difficulty transferring the tied high-moisture rice straw bale to the dropping point and then transferring it to the ground without breaking twine ties. Ties often broke several minutes after the bale was dropped.

Ammonia, at the rate of 5 pounds of anhydrous ammonia per hundred pounds of dry matter, was distributed across the width of the incoming windrow. We measured uniformity and distribution of ammonia in the 504F bale at various depths with a Penn State Forage Sampler within hours after baling (table 1). Another method was to cut the bales with a chainsaw. We took samples from locations within the bale parallel to the axis and at varying distances from the axis in an attempt to test a cross-section of the windrow as it was wrapped into the bale (table 2).

The results indicated that ammonia levels did not equalize between layers within the dense rice straw bale produced by the 504F. Bales split after six months of outside winter storage still contained a detectable free ammonia odor.

After 54 days of 504F bale storage, differences in *in vitro* dry matter disappearance, which is an estimate of digestibility, were highly significant statistically. Means of untreated rice straw dropped from 31.2 percent to 28.7 percent and means of the ammonia-treated straw dropped from 40.4 percent to 34.6 percent. Differences in *in vitro* dry matter between baler ammoniated straw and control were highly significant.

Total solubles remaining after enzyme extraction, which indicate changes in cellulose fractions, showed a significantly increased level in ammonia-treated straw. The mean for the untreated control was 33.6 compared with 42.1 for baler-ammoniation.

Total nitrogen, as a percentage of straw dry matter, was significantly higher in baler-ammoniated than in untreated bales. Storage for 54 days significantly decreased nitrogen in both groups. Levels in untreated straw dropped from 0.752 to 0.641 percent, and in baler-ammoniated straw from 1.354 to 1.158 percent.

Moisture levels in bales changed little between the 54-day sampling periods, but levels were much higher in ammoniated bales than in untreated bales. Differences between untreated and treated means were highly significant with untreated at 22.4 and 22.6 percent, and baler ammoniated at 29.5 and 29.7 percent.

Treated and untreated bale weights as fed did not change similarly over 54 days. Treated bales were significantly heavier than untreated bales. Untreated bales initially averaged 780 pounds and decreased to 689 pounds; treated bales averaged 913.9 pounds initially but slightly increased to 956.5 pounds.

Ash, as a percentage of dry matter, was significantly lower in ammoniated straw, and there was a highly significant change over 54 days. Averages of untreated bales rose from 14.99 to 16.95 percent; levels in ammoniated bales dropped from 14.86 to 14.36 percent 54 days later.

Ether extract levels were not significantly different between treatments, nor were they affected by 54 days of unshel-

TABLE 1. Nitrogen (N) retention of baler-ammoniated rice straw (Vermeer 504F baler) at five depths in plastic-covered bales

Sampling site	Dry matter	Total N in H_2SO_4	NH_3-N in H_2SO_4	N undried	N dried
	%	*g/kg*	*g/kg*	%	%
Center	86.7	6.51	4.44	1.26	1.32
6" from center	85.3	8.40	6.10	1.37	1.36
12" from center	79.8	10.16	7.10	1.33	1.26
18" from center	83.8	9.85	7.05	1.45	1.30
24" from center	85.2	10.44	7.60	1.43	1.42
LSD .05	—	2.22	1.85	NS	NS

NOTE: Cores sampled with a Penn State Forage Sampler, then placed immediately in rubber-stoppered glass bottles containing 1N sulfuric acid (H_2SO_4) to fix the free ammonia.

TABLE 2. Results of sampling ammoniated rice straw, 4- by 5-foot round bale

Sampling site	Extract NH_3-N	Extract total N	Sample size	Dry matter
	9m/kg	*9m/kg*	*gm*	%
Bale 296				
Center	1.22	1.50	25	81
7" from center	5.21	6.10	23	81
14" from center	4.00	5.80	32	81
21" from center	3.38	4.90	43	81
30" from center	0.56	1.90	31	81
Bale 380				
Center	3.83	4.40	13	74.8
6" from center	3.05	3.50	19	74.8
12" from center	1.89	2.30	17.5	74.8
18" from center	2.26	2.80	26	74.8
24" from center	2.36	2.90	30	74.8

NOTE: Bales cut in half, layers sampled from end to end. Samples immersed in 1N sulfuric acid, 3/18/81. Temperature in mid-50s (°F), scattered showers.

tered storage. Average levels in untreated straw went from 2.45 to 2.39 percent, and in ammoniated straw from 2.38 to 2.20 percent. Potassium levels were significantly reduced over the 54-day storage, but no significant differences were measured between untreated and ammoniated straw. Levels in untreated straw dropped from 1.44 to 1.35 percent, and in treated straw from 1.41 to 1.20 percent.

Levels of crude fiber, calcium, and phosphorus, at 35.9, 0.27, and 0.09 percent, respectively, were unaffected by time or treatment.

Cattle feeding study

Fifty Hereford heifers were weighed and randomly split into two groups to be fed similar diets for 100 days (table 3). Loomix commercial feed mix preparations, treated or untreated roughage, salt, minerals and some graze were available free choice. Amounts of lime and rice bran were restricted.

Heifers fed ammoniated rice straw ate more of the straw, less Loomix, and slightly more mineral, averaging about 1½ pounds more total feed per day than the control heifers. Both groups ate about 4½ pounds of dry matter, less than predicted by the UC least-cost grain computer program.

The gains were not satisfactory for replacement heifers, but those fed baler-ammoniated rice straw gained significantly more than did the control group (table 4).

Volumes

Applying ammonia at the 5 percent level at the time of the study added 90 cents per hundredweight of dry matter to the cost of baling. Tank filling took 15 minutes. Baling cost, which depends on volume and equipment, was difficult to estimate in the second year of the study because of baler choking and other problems.

Only the 504F baler was able to bale high-moisture straw continuously for four hours or longer without problems. Baling rate was one bale per three minutes, or 8 to 12 tons per hour. Baling rates for both the Vermeer 605F and the Heston 4800 were close to 4 tons per hour because of the continuous choking and other problems. Straw yield from the 504F was estimated at 2.5 tons per acre.

The project was over-horsepowered, but the flotation and need to support more than 2,000 pounds of additional weight beyond the front axle required a large tractor. Horsepower requirements listed for the 504F baler are estimated at 50 hp, for the 605F, 60 hp, and for the Heston 4800, 90 hp.

The bales were placed by the roadside with rear-mounted forks and a conventional forklift. A fork mounted on the rear of the modified John Deere M tractor easily managed the round bales with about three to six minutes to deliver the average bale to the roadside, depending on the condition of the field surface and distance. Two bales could have been removed by a tractor with adequate front-end flotation. The large-tired conventional forklift was inadequate for the field conditions encountered.

The 4- by 4- by 8-foot bales were difficult to move when on edge. They were not well supported by the rear-mounted forks and, because the twine ties were often caught by the lifting forks, bales were easily damaged. Baling density for the 4800 was adjusted so that twines would not break once tied. If the 4- by 4- by 8-foot bales of rice straw were on the ground for more than a few days, the bales softened, twines loosened, and they could only be handled easily by a "squeeze lift."

Conclusions

Baler ammoniation of rice straw is feasible, provided a high-density bale is formed. Standard round balers need modification to operate in rice paddies. Modifications should include hydraulic-powered crowd wheels, a more acceptable method to discharge high-moisture bales, reversible windrow pickup, adjustable-height axle, and hydraulic power independent of the tractor's system. The development of a self-propelled baler would give the operator better control and conceivably speed up baling.

The tractor should be able to support an anhydrous ammonia tank, and the operator should be able to slow the ground speed without reducing pto speed.

TABLE 3. Average daily feed intake as fed

Feedstuff	Control	Anhydrous ammonia
	lb	*lb*
Nonammoniated rice straw	5.69	0.00
Ammoniated rice straw	0.00	7.77
Rice bran	4.40	4.37
Loomix 5R:1R*	1.82	0.00
Loomix 5EE*	0.00	1.14
Hydrated lime	.13	.13
Salt & minerals	.05	.07
TOTAL	12.09	13.48

* Loomix preparations were designed to overcome differences in crude protein levels in the two diets and to supply various vitamins.

TABLE 4. Average weights and gains of heifers fed nonammoniated (control) and ammoniated rice straw

Items	Control	Anhydrous ammonia
No. heifers	25	25
Initial weight (lb)	556	557
Final weight (lb)	592	604
100-day gain (lb)	36**	47**

** significantly different (P<.01).

High-density round bales of rice straw can be stored in the open during winters with 30 inches or more of rain without appreciable loss, provided the round surface faces the prevailing rains and the bales do not touch each other.

High-density round bales of rice straw ammoniated during baling at a level of 5 percent of dry matter will sustain less loss of protein and dry matter, and have less reduction in *in vitro* dry matter disappearance. Ash levels, an indicator of energy loss, increase less in ammoniated bales.

Rice straw formed into low-density 5- by 6-foot round bales and conventionally shaped rectangular bales of 4 by 4 by 8 feet will not withstand outside storage during 25 inches of rainfall or more without molding and decaying, even though they are ammoniated.

Cattle seemed to find untreated rice straw palatable, when it was baled four to five days after harvest, and they consumed it readily as a free-choice supplement to irrigated pasture. Given a choice, cattle selected baler-ammoniated rice straw, consuming as much as 24 percent more and gaining as much as 30 percent more than when fed untreated rice straw. Our results indicated that young cattle should not be fed rice straw as the sole roughage. Rate of gain was the only measurement of response, however; differences in skeletal growth were not evaluated.

Because of the amount of unthreshed grain in rice straw heads, the danger of aflatoxin and other mold-developed toxins is considerable. Rice straw for animal consumption should be packaged at low moisture levels and kept under shelter unless a fungicide such as ammonia is utilized.

Ammonia can be a hazardous compound. In correcting round baler problems without costly delays, we found it necessary to use a breathing apparatus. The tractor operator also required special protection if traveling in the same direction as the wind but at a slower speed.

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