Project No. RS-5

COMPREHENSIVE RESEARCH ON RICE
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PROJECT TITLE: Residue Utilization--Packaging and Handling Rice Straw for Use as Feed, Fuel, or Fiber

PROJECT LEADER AND PRINCIPAL UC INVESTIGATORS:

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LEVEL OF 1981 FUNDING: $20,184

OBJECTIVES AND EXPERIMENTS CONDUCTED BY LOCATION TO ACCOMPLISH OBJECTIVES:

1. Objective: Analyze and evaluate new potential systems for packaging and handling rice straw, particularly cubing and the large rectangular bale.

   Experiments:
   a) Time and motion study of Hesston Big Baler, bale forwarding, and bale transport operation, Bayliss, CA.

   b) Observation of Vermeer Big Roll Baler operating in rice straw, Bayliss, CA.

   c) Special cuber dies from Warren & Baerg Mfg. Co. tested on the University of California's Animal Science Feed Mill Cuber, Davis, CA.

2. Objective: Evaluate the storage and marketing potentials of cubes and large bales.

   Experiments:
   a) Observation of large rectangular and big roll bales in storage, Orland, CA.

   b) Discussions with growers, researchers, and utilities concerning marketing potentials, various locations.

SUMMARY OF 1981 RESEARCH (MAJOR ACCOMPLISHMENTS) BY OBJECTIVE:

1. a. HESSTON BIG BALER TEST IN RICE STRAW

A Hesston Corporation Model 4800 BIG BALER with model 4820 Bale accumulator was obtained for testing by Rob Lowman of Gates Machinery Company, Willows, CA.

Observations were made of the baler while operated by Glenn County Farm Advisor Don A. Toenjes in windrowed rice straw on Daryl Alberico's property outside of Bayliss, CA. Toenjes was testing the baler to determine its performance in producing bales of ammoniated rice straw for cattle feed. Time and motion studies were also conducted on the bale roadsiding (forwarding) operation and bale transport.

Baler performance data was taken on October 16 and 17, 1981. The first rainfall in the area occurred September 24 and rain appeared at about one week intervals up to the dates data was obtained. The baler was operating in a saturated silt loam soil with an average cone-index of about 70 psi at 6-8 inches depth. Average straw moisture content at time of baling was 31% wet basis.

The rice stalks had been cut fairly close to the ground (within 3"-4") over most of the checks because of lodging. The straw was windrowed behind the combine. Average windrow width was five feet. Straw averaged an estimated 2.5 dry tons per acre.

The Hesston Big Baler is a tractor drawn baler requiring 180 pto horsepower. A four wheel drive Case Model 2470 tractor supplied by Gates Machinery Co. was used to pull the baler. Both the length and density of the bale can be varied. During the tests, bales of 97" length and 80" length were produced. The 97" bales are ideally suited for transport, although maximum baler capacity was reached while making 80" bales, conceivably because bale density tended to decrease as the bale was shortened. 97" bales averaged 2300 lbs (28% moisture content wet basis) while one 80" bale weighed 2040 lb (36% moisture content wet basis). Nominal bale cross section dimensions were 48" by 50". Bales are tied with six twines.

During the trials of October 16-17, only two bales were produced without having to stop the baler to correct some problem. Most of the problems were due either to baler maladjustment or wet straw conditions. A bale left in the bale chamber during a rainstorm became so heavy that when baling was continued three days later, the bale accumulator could not function properly but straw continued to be compressed into the bale until the pto drive shear pin finally failed. The final weight of the bale was 3670 lbs at 52% moisture content wet basis. Other problems related to wet conditions included straw wrapping on the header cross augers and plugging of the header. Once the baler feed system became plugged, two charges of straw might be fed into the stuffing chamber of the baler resulting in failure of the stuffing finger drive shear pin. Because the stuffing finger drive could not be reversed, the only solution to a jammed stuffing chamber was to keep replacing shear bolts in the drive until the straw was finally compacted tight enough to run the fingers through to the next cycle and restart baling. Often, as many as five shear pins might be required to accomplish this. Observations of this baler and a big roll baler have showed that for rice straw, particularly under wet conditions, the header drive should be made reversible.

Bales made with the Big Rectangular Baler require all six twines to maintain their integrity. Bales in which only five or four ties were completed because of knotter maladjustment usually broke apart when coming off the baler or when picked up for roadsiding.

Bale density control is very important. A number of problems were probably aggravated by improper bale density. Heavy bales, broken bales, accumulator malfunction, and shear pin failure were probably often a result of the bale density control being set too high. More experience with the baler would have improved baler performance.

Actual baler capacity during October 16-17 was 5.2 tons per hour or four dry tons per hour (at 0% moisture) over the entire operating period. If all unscheduled down-time is removed from the analysis, the theoretical baler capacity is 14 dry tons per hour (0% moisture). Fourteen tons per hour is close to what Hesston specifies for the baler in alfalfa. Given more experience with the baler, modifications as suggested above (reversing header drive, etc.), straw at 20% moisture content or less, and reasonably good field conditions (a soil cone index rating of 70 psi or greater at 6-8 inches depth), the baler would probably be capable of operating at this high rate. A more likely capacity is 9 tons per hour. For all baling operations, following as closely behind the combining operation as straw drying conditions will allow is recommended. Weathered straw in windrows tends to pack together resulting in baler feed problems. If necessary, turning the windrows to dry the straw would probably pay for itself by increased baler capacity. Roadsiding the bales as early as possible is also recommended. Summary results of the October 16-17 baler tests are shown in Table 1.

Observations were also made of the bale roadsiding operation and bale transport. Initially, Toenjes employed a Hyster forklift to forward the bales out of the field. The forklift worked well with light bales and stable soil conditions. It could not negotiate soft fields while loaded with a bale. A John Deere Model M with rear mounted forks was employed with some success but was not capable of handling heavy bales. A Massey-Ferguson Model 285 wheel tractor with rear mounted forks on loan from Gates Machinery Co. was finally used to roadside the bales. Weights had to be added to the front of the tractor to keep the front wheels on the ground while forwarding heavy bales. The average capacity of the M-F 285 in roadsiding bales in checks 3000 feet long was 8 dry tons per hour (0% moisture). Summary observations are also shown in Table 1.

Bale transport from the field to Orland, California, was done by Martin Bros. of Willows, California, under contract to Toenjes. Bales were loaded two at a time onto the truck trailers with a squeeze loader. This loader worked well with the large bales but required reasonably stable soil. The trucks were regular highway rigs with a 24' front trailer and a 30' rear trailer. The trucks had to stay on solid ground. A total of 28 big bales could be placed on each truck, 12 on the front trailer and 16 on the rear.

Two truck loads observed carried 21.5 tons each. Load was much less with lighter bales. Bales averaging the same weight as those produced on October 16-17 would give a load of 32.2 tons, in excess of legal limits. An average bale weight of 1890 lbs would provide a legal load of 26.5 tons. The average time to load a truck and tie down the load was 52 minutes. 15 minutes were required to unload the truck at the storage site 15 miles from the field. Summary observations are also shown in Table 1.

A preliminary economic analysis by Philip S. Parsons, Agricultural Economist, Emeritus, is included in Table 2. The results show that the Hesston Big Bale concept can be quite economically attractive if the baler capacity can be improved by eliminating unscheduled downtime. At the actual baler capacity of 4 dry tons per hour, total overhead and cash costs amount to $20.91/ton. At 9 dry tons per hour, total costs decrease to $10.26/ton, and at 14 dry tons per hour, to $7.20/ton. The cost of roadsiding the bales with the M-F 285 tractor at 8 tons per hour is $2.61/ton. If capacity is increased to 12 tons per hour, this decreases to $1.74/hour. Martin Bros. stated to Parsons that for the haul to Orland, they would be willing to write a firm contract at $15.00/ton. Total cost to deliver baled rice straw 15 miles from the field would be $38.52/ton with the baler operating at 4 tons/hour, $27.87/ton at 9 tons/hour, and $24.81 at 14 tons/hour. At 9 tons/hour or above, the cost is less than the cost reported by Dobie in 1977 for small rectangular bales of rice straw increased by 50% to account for inflation. The comparable cost for 4' wide by 5' diameter big roll bales reported by Dobie and escalated by 50% is $24.78 per ton.

b. Vermeer 605-F Big Roll Baler Test

Toenjes also obtained a Vermeer 605-F Big Roll baler to make bales for ammoniated straw feeding trials. A few observations were made of this baler on October 26, 1981, while operating on Alberico's property. Only four bales were completed during the observation period. Most of the problems encountered with the baler were the result of the header plugging or uneven feeding of the windrow into the bale chamber. Uneven feeding caused the belts that form the roll bale to slack on one side. When this happened, straw would feed onto the wrong side of the belts. The baler would have to be stopped and manually cleared. Uneven feeding was apparently the result of the header plugging on one side or the pick up tines not having enough stiffness to push the straw into the bale chamber. The project proposed for the coming year includes modifying a roll baler to correct these problems. The theoretical capacity of this baler was estimated at 6.2 dry tons per hour (0% moisture). This compares with Dobie's reported figure of 6 tons/hour for a big roll baler operating in rice straw. The Vermeer baler had a closed circuit bale density control. Bale density could have been increased if the density control had been made active so that the operator could adjust it. Sheet-metal cones placed on the inside of the bale chamber to keep the bale from jamming in the chamber caused the bales to have ragged sides. Other methods for easing bale removal could possibly yield better bales. Work of this nature is also proposed for the coming year.

c. Cubing Tests with Specialty Dies

A set of special dies reported to improve rice straw cubability were loaned to the University by Warren and Baerg Mfg. Co. of Dinuba, California. Warren and Baerg have reported success with these dies in John Deere cubers which they have modified to handle the increased pressure the die creates. The dies are standard John Deere 1-1/4" square dies with 3 inch long straight extensions welded to the discharge end of the standard die.

In anticipation of obtaining long run times on the dies, the existing cuber feed system was replaced with the standard feed metering, mixing and elevating equipment from Kirby Mfg. Inc. of Merced, California. The system includes a well designed mixing auger and adjustable metering system for adding water and binder to the feed material if desired. Electrical power and water supply modifications were necessary as a result of the new system.

During installation of the special dies from Warren and Baerg, the cuber press wheel was found frozen on its shaft and its edges worn beyond established wear tolerance. A rebuilt press wheel and replacement bearings were installed on the cuber along with the special dies.

The special dies were first tested on tub-ground dry corn fodder, with on-site cooperation by Mr. Bob Baerg of Warren and Baerg. The exceptionally high compression in the dies was sufficient to elevate the material in the dies to pyrolyzing temperatures. The resulting steam and gas pressure exploded the material out of the dies. Cubes were set on fire. The cuber frame was inadequate to carry the increased cubing loads. Several of the die extensions separated because of inadequate weld strength. Several of the extra-hard bolts holding the dies to the die ring were sheared.

This experience resulted in the decision to replace the special dies with standard dies and continue any further work on this cuber by using liquid binders if necessary. Rebuilt standard dies were purchased and installed with new bolts. A binder supply system was built from an on-hand ground rig spray machine. Two to eight tons each of the following materials were cubed:

1. Field chopped cotton stalks without binder.
2. Baled and tub-ground corn stalks without binder.
3. 75% by weight tub ground wheat straw from bales mixed with 25% by weight tub ground corn stalks without binder.
4. Hammermilled (3/4" round hole screen) rice straw from bales with 3 to 4% by weight liquid binder.
5. Tub-ground wheat straw from bales with 3 to 4% by weight liquid binder.

The liquid binder was an equal mixture by weight of Orzan and water. Only the rice straw and wheat straw cubed with the binder made durable cubes, although cubes from all the materials would likely be satisfactory for use in fluidized bed gasifiers.

In December, 1981, another offer was made to Papakube Corporation to obtain a set of their special dies for testing on the University cuber. Papakube maintains that their dies achieve enhanced cubing with little increase in power requirement or die pressure. If the offer is not accepted, no further offers will be made.

2. a. Storage of Cubes and Large Bales

Because few rice straw cubes could be produced due to the failure of the special dies, no assessment was made of rice straw cube storage. Goss made the observation that cubes made with liquid binder should not be stored in deep layers immediately following cubing. Some curing and drying time should be alloted prior to placing cubes in storage. This is consistent with recommendations made for alfalfa cubes.

Large rectangular bales and big roll bales from the baling trials were observed in field storage and in exposed stack storage at the dairy where the feeding trials conducted by Glenn County Farm Advisors, Toenjes and Bell, will take place.

The large rectangular bales do not weather well in exposed storage, stacked or not. They are very similar to small rectangular bales in this regard. Water penetrates the bale because the bale is made in "slices" which provide convenient channels for water migration. Severe deterioration of bales was noted both in the field and in the stack. Broken bales and collapsed stacks were observed. Some of the problem may have been the result of the high moisture content at time of baling even though ammonia was applied as a preservative. However, bales of dry straw made early in the season apparently did not hold up much better than bales of wetter straw after 11" of rainfall on the bales. Large rectangular bales will require covered storage of some kind. For very large numbers of bales, the stack could be made with a triangular cross section and covered with plastic or thatched with loose rice straw. Further research would need to be done to confirm the feasibility of this approach.

Big roll bales fared very well in exposed storage as long as they weren't in contact with other bales. Where such contact occurred, rotting of the straw was the usual result. Roll bales in stacks will probably require cover. Roll bales stored in the field will not. Substantially less dry matter loss is to be expected in roll bales than large rectangular bales for uncovered winter storage.

b. Market Potential

A strong market for either cubes or bales of rice straw does not yet exist. In many cases, the reasons given for not developing markets is the apparent lack of straw collection method. The philosophy is wide spread that no market will develop until straw is reliably available at competitive cost, and that no system for making straw available at competitive cost will be developed until a market exists. Obviously, the two developments must occur simultaneously. Since research is being conducted on collection systems and utilization systems, simultaneous development is the likely outcome.

Discussions with researchers, utility representatives, and growers indicate that there is an awareness of the resource value of rice straw. Goss's research on gasification has indicated a likely market for rice straw in irrigation pumping, power generation, heated air drying, and other energy systems. The work by Toenjes and Bell has shown that rice straw could be used to support an increased cattle population in Northern California, although the amount of straw that can be used in this fashion is not a large share of the total annual production. Traditional markets, such as mushroom culture, should continue to utilize straw.

The deferral of PG&E's proposed 1600 MWe coal fired power plant until the 1990's represents a loss of a major potential market for straw. Cofiring straw and coal in large utility boilers is not a likely near term market. Utility enthusiasm for any type of large power plant has waned in the current economic and regulatory climate. Utility participation in smaller scale cogeneration facilities can be expected to continue for financial and political reasons and these may serve as excellent markets if the appropriate thermal conversion system can be devised and willing entrepreneurs located. The delivered costs for rice straw in bales quoted earlier of around $25/dry ton is equivalent to about $1.80/MMBtu. Within a 15 mile radius one might be able to collect 150,000 tons of rice straw per year. If storage could be accomplished to allow utilization over the year, and a proper facility constructed, a 25 MWe cogeneration plant could be operated. Obviously, substantial work needs to be done before such a goal can be realized. There is at least one market that could lead to such development, however, and there appears to be rising grower interest in it. One grower expressed a desire to build a combustor to burn big roll bales to supply heated air for rice drying. The escalation in cost of purchased electricity and natural gas has many growers considering the use of straw in this fashion. This type of initial small scale development can lead to eventual large scale commercial utilization of the straw. The risks of small scale development are low, and if the attempt is successful, it will serve as a practical demonstration to others. Markets for rice straw cubes and bales appear to be developing.

PUBLICATIONS OR REPORTS:

None (publications in preparation).

CONCISE GENERAL SUMMARY OF CURRENT YEAR'S RESULTS:

Time and motion studies on a Hesston Big Baler in rice straw showed that the baler does hold promise for collection of rice straw. Technical modifications need to be made to adapt the baler to conditions in rice fields. Average capacity of 9 tons/hour can probably be obtained. Cost for baling, roadsiding, and transporting 15 miles are estimated to be about $28.00/ton at 9 ton/hour capacity. The biggest hindrances to the use of large rectangular balers is the need for covered storage of the bales and the rather high initial cost of the machine. Comparison of large rectangular bales and big roll bales showed roll bales to be superior in uncovered storage.

Special dies tested on the University cuber to investigate their potential for cubing rice straw resulted in excessive pressure and overloading of the cuber structure. Use of the dies would require strengthening the cuber. Other types of dies require examination and testing.

Markets for rice straw can be developed simultaneously with developments in collection technology and will probably originate on a small scale before large scale development occurs.

Table 1. Summary Results of Large Rectangular Baler in Rice Straw, October 16-17, 1981, Bayliss, California.

Operation	Equipment Used	Actual Capacity dry tons/hour	Theoretical Capacity dry tons/hour
Baling	Hesston Model 4800 "Big Baler" with model 4820 bale accumulator. Case Model 2470 4-wd tractor.	4	14
Roadsiding	Massey-Ferguson Model 285 wheel tractor with rear mounted forks	8	8
Loading	Squeeze loader on modified Freeman self propelled chassis	24 (21.5 tons per truckload)	24 (21.5 tons per truckload)
Unloading trucks and stacking bales	Squeeze loader	100	100

*Theoretical capacity is actual capacity adjusted by eliminating unscheduled down-time.

Table 2. Preliminary Economic Analysis of Large Rectangular Baler in Rice Straw, October 16-17, 1981, Bayliss, California.

Operation*	Overhead Costs $/dry ton	Cash Operating Costs $/dry ton	Total Cost $/dry ton
Baling:			
4 tons/hour	8.19	12.72	20.91
9 tons/hour	3.64	6.62	10.26
14 tons/hour	2.34	4.86	7.20
Roadsiding:			
8 tons/hour	0.37	2.24	2.61
12 tons/hour	0.25	1.49	1.74
Load, Transport 15 miles, Unload and Stack** (21.5 tons/load)		15.00	15.00

*Refer to Table 1 for equipment used in each operation
**On basis of firm contract