**ANNUAL REPORT**
**COMPREHENSIVE RESEARCH ON RICE**
January 1, 2006 - December 31, 2006

**PROJECT TITLE**: Enhancement of Forage Quality of Rice Hay

**PROJECT LEADER**:
Glenn Nader - Livestock Farm Advisor for Butte/Sutter/Yuba Counties
142-A Garden Hwy. Yuba City, Ca. 95991
(530) 822-7515 ganader@ucdavis.edu

**PRINCIPAL INVESTIGATORS**:
Peter Robinson - Department of Animal Science Extension Nutritionist
Marta Santos - Department of Animal Science Graduate Student

**COOPERATORS:**
Dr. Kevin Holtman – USDA Ag Research Service, Albany, Ca.

**LEVEL OF 2OO7 FUNDING**: $34,800

**OBJECTIVES**:

***Objective 1 – Dairy demonstrations of rice hay forage in replacement heifer rations.***
The demonstration objectives were:
1. To examine effects of a baler with knives in the pickup that slices the straw (coined by the demonstration as double chop rice straw) on:

   A. Mixing time and completeness of mixing in vertical and horizontal TMR mixers
   B. Sorting and feeding behaviour by the cows

2. Record general experiences of the dairy managers with the double chop rice straw:

   A. Compared to other straws
   B. Compared to previous rice straws
   C. Develop diet formulation experiences

3. Increase exposure of Dairy Owners and Nutritionist to a positive experience of feeding rice straw to increase acceptance and future use in the dairy industry.

***Objective 2 - Improvement of chemical qualities of rice hay forage***

   A. Study impacts of drying on changes in digestibility to determine the critical point where nutritional quality declines.
   B. Coordinate with USDA ARS researcher Kevin Holtman on drying impacts on other chemical constituents.

***Objective 3 – Publication of rice hay information***

   A. Publish information on the procedures to that rice farmers need to secure use in different straw markets

B. Publish past information in a peer reviewed journal to build on the scientific knowledge of livestock uses of rice straw.

## EXPERIMENTS CONDUCTED:

***Objective 1 – Dairy demonstrations of rice hay forage in replacement heifer rations.***

Five dairy nutritional consultants were identified that cover the southern San Joaquin Valley. Each identified a progressive dairy producer that was provided one truck load (22-23 tons) of double chop forage quality rice hay to feed replacement heifers. No instructions of how to use the straw were given and each operation designed their own ration. Each operation was toured during the feeding period and both the dairy manager (and/or feeder) and the nutritionist were surveyed.

The results of the survey of the Dairy Managers is in Table 1. If the answers were the same at all the dairies, they are only place in the form once, or summarized.

# Figure 1- Dairy Manager or Feeder Survey Answers

| ***Dairy number*** | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| **Number of dairies feeding for the first time RS** | 3 | | | | |
| **General experience of the two dairies that had fed RS before** | Did not mix properly in the TMR because of the balls of RS resulting in large sort by cows | Tough material, fed about 1.5 lb/day and no problems | | | |
| **Opinions after look at the double chop RS** | Looks good, soft texture and looks more palatable then wheat straw and has better aroma | **Consistent chop**, fine stem, **short cut and broke up well, good length** | | | |
| **Type of TMR** | 2 dairies Horizontal and 3 Vertical feed mixers, | | | | |
| **Forage replacement** | 4- wheat straw (3-4 lbs/hd/day) one replaced 1 lb wheat silage, one replaced 3 lbs alfalfa hay | | | | |
| **Mixing properties** | RS broke up easily no chunks of straw | Comparable with wheat straw at this point | Easy to mix, did not increase mixing time | | |
| **Classes of animals fed** | Pregnant heifers, dry cows and in one dairy breeding bulls | One dairy used for 2 days in lactating cows (middle lactation) but they did not eat the RS | | | |

| | | | | | |
|---|---|---|---|---|---|
| **Number of pens and time fed** | 8-17 pens | 2 weeks | | | |
| **Initial amount fed (lb/head/day)** | 20% of the diet | 0.5 | 2 | 3.5 | 1.5 |
| **Changes in proportion** | - | 3 | 3 | 2.5 | - |
| **Reasons for change** | | Good acceptance and no problems | Good acclimation | Poor mixing | - |
| **Sorting behavior** | There was no significant sorting behavior | | | | |
| **Main differences comparing RS with other straws** | Wheat straw mix easier and has faster break up | RS appearance is better and mixing performance is similar | Very similar | | |
| **Opinion concerning to feed RS to lactation cows** | No, because RS has lack of nutritive value | One dairy fed but they did not eat it | | | |
| **Possibility to feed more with shorter length** | 2 dairies don't think that this is possible | 3 dairies think that could be possible | | | |
| **Maximum** | 4 lbs | | | | |
| **Same price and same nutritive value as wheat straw- Preference** | No | Maybe | Wheat straw but only because of mixing problems | Yes | Don't know |
| **On a scale of 1-10 concerning to the overall experience** | 7 | 6 or 7 | 9 or 10 | 8 | 8 or 9 |

**<u>Figures 1, 2 and 3 below illustrate the difference pictures from last year's demonstration and this year to illustrate what was learned.</u>**

***Figure 1 – 2006 flail chopped rice straw with a unmixed rice straw in the circle***

***Figure 2 – 2007 baler sliced rice straw evenly mixed in the ration***

***Figure 3 - Wheat Straw Rice Straw***

Summary of the Demonstration findings

The double chop rice straw broke up when the bales were opened. The previous year the bales needed to be broken apart with the bucket of the loader before loading into the TMR mixers. This year, the double chop rice straw mixed without problems in both vertical and horizontal TMR mixers without any increase in mixing time. There was low sorting by the cows and most ate the TMR as mixed all day. Most of the dairies used the double chop rice straw as an intake limiter with heifers that were fed ad lib. One dairy used it to replace alfalfa, as his heifers were gaining too fast, at a dramatic savings in feed costs. Surveys of five dairies using this product found, that when properly baled so that the double chop rice straw mixes in the ration, it was equal to or preferred to wheat straw with the overall score of 7 to 9 out of 10 (perfect) indicating that the dairy producers had very good experiences feeding this double chopped rice straw. The rice grower working in the demonstration project was able to expand his rice straw market to dairies by 5500 tons. We believe with greater exposure, and extended drought and tight forage conditions, that use of double chop rice straw by dairymen can provide a large market with nearly a million dairy replacement heifers in California. Conversely, some long stem unchopped rice straw was fed at a nearby dairy outside of this project and was breaking chains on the mixer and not mixing regardless of mixing time. Given dairy owners management time requirements for operation of 2000 to 5000 cows, and all the corresponding infrastructure, they do not have the time or interest to investigate how to fix the problem, but will just not buy rice straw again.

***Objective 2 - Improvement of chemical qualities of rice hay forage***

Based on past physical manipulation rice straw studies (i.e., maceration, flail chopping, rotary harvester) demonstration of the inability of these approaches to increase intake or animal performance, we now believe that the focus of study should be re-directed to chemical alterations during dry down. This will focus on chemical changes during dry-down and possible interventions to mitigate the dramatic forage quality loss.

**A. Impact of drying on changes in digestibility**

Rice forage samples were collected from two varieties (M401 & M202) starting two weeks before harvest. Samples were replicated in two checks along a 50 foot linear transect. At harvest, a 25 square foot sample at each linear transect location (2 transects, 3 locations) for both varieties. They were kept separate and taken to UC Davis Animal Science facility and sampled from simulated windrows as the straw dried. Samples were analyzed for gas production by a rumen fluid method. At each sample time period, a paired sample of fresh samples were equally divided and one was analyzed and other was frozen at $0^{o}$F. This will allow for analysis of the impact of freezing as compared to fresh cut and, if there is no difference in digestibility, it will be assumed that chemical changes that impact forage nutrient quality have not occurred. Freezing will allow for more intense sampling during the drying period in future years because the biological analysis takes 48 hours to conduct.

The results from this year's biological gas analysis are below. Figure 3 shows the gas production for two varieties (M202, M401) at 4 hours and 4-24 hours along with the dry matter (DM) for each. The 4 hour data indicates the soluble sugars and pectin that are available for digestion. The 4-24 hour data represents the digestion of the fiber portion of the plant. During the preharvest periods, the gas values for rice straw were near that of low quality alfalfa, but at the end of the 48 hour drying period dramatically dropped to a very low quality forage.

**Figure 3 - Gas Production of Rice Straw from Preharvest to Day 33 after Harvest**

Figure 4 shows that the most dramatic of the loss of forage quality occurred from harvest time to 48 hours post harvest. A small amount of forage quality loss occurred from day 5 to 33. In all cases the M202 straw selected for this study provided better digestibility than the M401 straw.

**Figure 4 - Gas Production of Rice Straw During Three Periods**

**B. Coordinate with USDA Ag. Research Service researcher, Kevin Holtman on drying impact on other chemical constituents.**

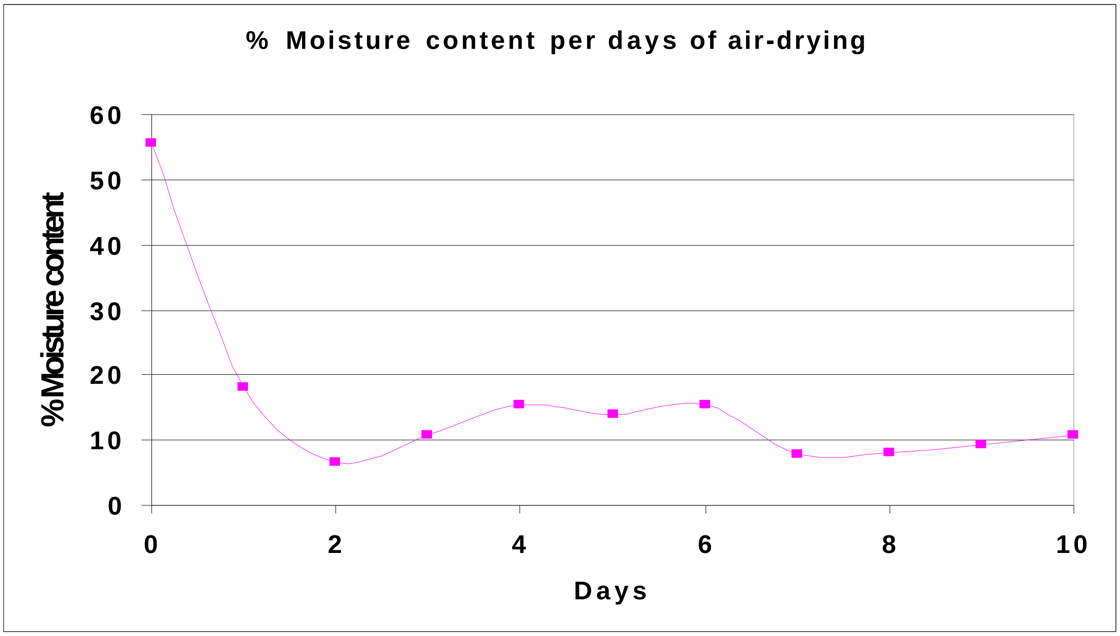
The USDA laboratories in Albany, CA are set up to perform quantitative analysis of cell wall structural components and these techniques were applied to the rice straw during sun-drying. The goal of this work was to ascertain whether changes in the structural components could be detected and, if so, advise what to do to preserve higher forage quality.

Straw was sampled at the time of harvest (9/21/06) and immediately frozen to prevent drying. The straw was then transported while frozen to the Albany laboratory and the straw was placed in Tupperware basins in the sun to dry. A time zero sample was taken and immediately placed in the freezer so as to ensure that no drying would occur. The straw was then sampled routinely at the same time each day for the next 10 days and refrozen after sampling to preserve its initial properties. The straw was immersed in liquid $N_2$ and then ground in a coffee grinder to reduce the particle size prior to analysis. The ground straw was returned to the freezer after grinding.

**Moisture content**

**Figure 5** shows the change in moisture content with drying. Initially the straw after harvest was 55.5 % moisture content and decreased to 10-15 % moisture content by 48 hours of drying. Variation in moisture content is likely related to sampling and/or variation in relative humidity in the atmosphere. Drying is likely to occur at least as fast on the field as the bed of straw is elevated by the cut stalks and this allows for passage of air beneath the straw. Drying in this case was in a Tupperware container and was likely slower.

**Figure 5. Moisture content of rice straw with days of sun drying of rice straw.**



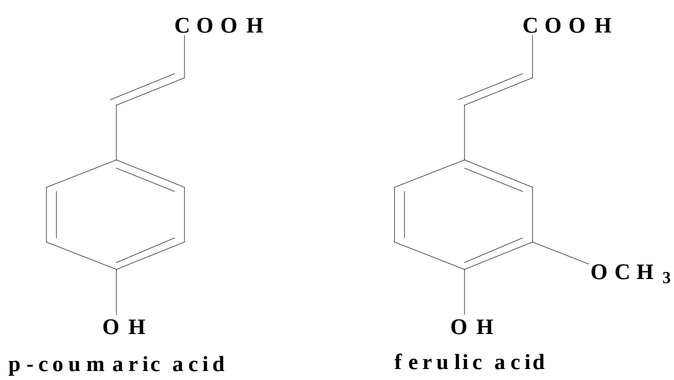

## Cell wall components

The contents of the measurable cell wall components are listed in **Table 1**. As can be seen from the data, lignin and silica content were constant throughout the analysis. Variation was likely due to sampling variability as the analyses were performed on small samples. Lignin content was not expected to vary as deposition of lignin is complete prior to senescence. Any changes in lignin content are likely to be detected prior to harvest.

Monosaccharide contents were consistent throughout the sample set with glucose, xylose, and arabinose around 40, 20, and 5% by weight, respectively. It had been hoped that small changes in these components would be seen with drying as free metabolites would evaporate with a rapidly decreasing moisture content, however this could not be detected.

Cinnamic acids are known to limit the rate and extent of enzymatic hydrolysis or rumen digestibility. Cinnamic acids link the carbohydrate polymers in the cell wall directly to the lignin. Cinnamic acids are linked between lignin polymers by ether linkages or between lignin and the carbohydrates via ester linkages. Cinnamic acid ester content can be analyzed by saponification at low temperature with NaOH and cinnamic acid ether linkages can be analyzed by high temperature hydrolysis reactions similar to soda pulping.

**Figure 6. Chemical structures of p-coumaric and ferulic acids.**



Two moieties, p-coumaric acid and ferulic acid (**Figure 6**), are present in the cell wall of rice straw. An increase in either of these contents would indicate that chemical linkage between the carbohydrate and lignin occurs with the drying and subsequent shrinkage of the cell wall. The content of both the p-coumaric and ferulic acids did not change however with drying in **Table 1**. It was interesting to note however that the detectable cinnamic acid contents were lower than expected, around 1 % for all samples tested.

**Table 1. Quantitative results for cell wall components as a function of days of sun-drying.**

| Days sun-dried | % Lignin | % Ash | % Glucose | % Xylose | % Arabinose | p-Coumaric Acid | | | Ferulic Acid | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Ester-linked (%) | Ether-linked (%) | Total (%) | Ester-linked (%) | Ether-linked (%) | Total (%) |
| **0** | 20.2 | 13.3 | 39.8 | 18.3 | 4.6 | 0.47 | 0.06 | 0.54 | 0.24 | 0.16 | 0.40 |
| **1** | 17.7 | 9.1 | 34.3 | 15.3 | 5.3 | 0.54 | 0.01 | 0.55 | 0.28 | 0.13 | 0.41 |
| **2** | 17.0 | 9.1 | 43.8 | 22.1 | 5.5 | 0.52 | 0.05 | 0.57 | 0.28 | 0.19 | 0.47 |
| **3** | 19.8 | 11.1 | 43.1 | 24.1 | 4.8 | 0.52 | 0.0 | 0.52 | 0.26 | 0.13 | 0.39 |
| **4** | 20.7 | 10.9 | 41.3 | 20.1 | 4.8 | 0.42 | 0.08 | 0.50 | 0.24 | 0.19 | 0.43 |
| **5** | 16.8 | 10.3 | 46.7 | 22.1 | 5.4 | 0.62 | 0.02 | 0.64 | 0.30 | 0.19 | 0.49 |
| **6** | 18.3 | 10.3 | 46.7 | 23.0 | 5.1 | 0.43 | 0.21 | 0.64 | 0.21 | 0.28 | 0.49 |
| **7** | 21.5 | 13.6 | 38.5 | 20.9 | 5.2 | 0.44 | 0.07 | 0.51 | 0.23 | 0.20 | 0.43 |
| **8** | 18.3 | 10.4 | 45.1 | 20.1 | 5.3 | 0.47 | 0.06 | 0.53 | 0.25 | 0.20 | 0.45 |
| **9** | 18.5 | 11.0 | 40.1 | 20.0 | 4.2 | 0.49 | 0.08 | 0.57 | 0.26 | 0.20 | 0.46 |
| **10** | 17.5 | 9.7 | 34.4 | 14.6 | 4.7 | 0.51 | 0.12 | 0.63 | 0.26 | 0.25 | 0.51 |

This research showing not significant change during the drying process by Dr. Kevin Holtman has eliminated cinnamic acids, free metabolites (glucose, xylose, and arabinose) as the potential causes for forage quality loss. This will now allow the future research on changes in cellulose and silica during the 48 hour drying period.

***Objective 3 – Publication of rice hay information***

A draft publication has been produced that predominately focuses on producing straw as beef and dairy cattle forage. These require different processes, as beef cattle operators are interested in a higher moisture straw that has some green color, a forage quality test, and stays together in the bale when feed out on the rangeland. In contrast, dairy producers main concern is the rice straw mixing in the total mixed ration (TMR) equipment so that each bite that the dairy heifer takes is the same and that animals do not sort the feed. This requires that the straw be chopped before baling and then baled at the lowest moisture possible. The publication also lightly covers other uses (e.g., erosion control, housing). The draft publication will be reviewed by rice growers that produce rice straw in January 2008. It will then be submitted to the University of California peer review process. It will be published in a limited number of printed publications intended to reach rice farmers, and it will also be put on the UC ANR website as a downloadable publication.

The California Dairy Magazine will be approached again in the summer 2008 on an article of the findings of last year's dairy heifer feeding demonstration. The successful feeding of double chop rice straw will be the focus of the article to help dairy producers understand that properly treated rice straw can be successful in dairy heifer rations. The timing of the article is to stimulate interest based on UC findings for contracting by dairy operation with rice growers during the late summer. Also, a research article on previous three years of rice straw research on the physical manipulation of the straw entitled "The Effects of maceration of rice straw on voluntary intake and performance of growing beef cattle fed rice straw based rations" will be published in Animal Feed Science and Technology in 2008.