ANNUAL REPORT
COMPREHENSIVE RESEARCH ON RICE
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PROJECT TITLE: Development of Shrink Chart for Accurate Rice Quality Assessment

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OBJECTIVES AND EXPERIMENTS CONDUCTED, BY LOCATION, TO ACCOMPLISH OBJECTIVES:

Rice is harvested at moisture that is typically higher than safe storage moisture and needs drying. During drying, part of moisture is removed, which results in reduced rice weight. Shrink charts or formula are normally used by grain dryers to calculate final dried rice weight. In addition to moisture loss during drying, shrink charts also account for the loss in weight due to presence of dockage in fresh samples and invisible losses. Dockage is defined as the proportion of materials other than grains in the harvested rice and commonly expressed as a percentage.

Weight loss due to change in moisture can be determined accurately for rice based on its initial moisture information. But, dockage is typically assumed as 2% of harvested rice at dryers. This number was established long time ago. At present, harvester and handling equipment have, from technological viewpoint, greatly improved and dockage might be significantly lower. Even one percent error in the shrink chart can have significant economic consequence for growers. Therefore, it is vital to precisely determine dockage and update the current shrink chart.

In 2010 rice harvesting season, we embarked on research activities to clarify factors which affect rice dockage. We reported on the impact of rice variety, harvest moisture, harvest day, drying and dropping from certain height and rice growing location on dockage. Based on our previous findings, there was need for a more comprehensive investigation to elucidate impact of additional factors related to prevailing weather conditions and harvesting operations. At the same time, it was necessary to confirm repeatability of results in order to ensure precision of updated shrink chart.

The objectives of this research are as following:
1. Determine impact of type of harvester used on dockage of rice.
2. Determine impact of weather events such as winds and rainfall on dockage of rice.
3. Compile the dockage data from the last two years and make suitable recommendation for updating shrink chart.

To accomplish these objectives we performed several kinds of experiments: dockage of freshly harvested and dried samples of rice harvested with different types of harvesters and dockage of the rice sample during regular weather and odd weather events with strong winds and rainfall. In next section, detailed descriptions of these experiments as well as comparison of dockage results from last year with this year's findings are provided.

MATERIALS AND METHODS

Harvesters

We worked with rice growers and Rice Experiment Station to identify four popular models of rice harvesters with different harvester headers and manufacture years (Figures 1 and 2), including John Deer with stripper header (2011), Case with conventional header (1999), John Deer with conventional header (2007) and Claas Lexion with conventional header (2011). The harvesters were used to harvest rice samples used in this study. In the case of experiments for

evaluating the impact of weather events, the Claas Lexion with conventional header (2011) was used.

Figure 1. Rice harvesters with conventional headers

Figure 2. Rice harvesters with stripper header

Rice samples

Rice of medium grain varieties M104, M202 and M206 were procured from Farmers' Rice Cooperative Sacramento and from specific rice growers with harvesters and farms in Arbuckle and Grimes, CA. Rice obtained from Farmers' Rice Cooperative (FRC) Sacramento CA were only used to study effect of seasonal changes or to confirm repeatability of our last year's result. Rice moisture content at harvest varied from 18 to 26% on wet basis. During rice harvest season, rice samples were collected weekly from each harvester for up to seven weeks. Each rice sample

was divided into two portions. One of the portions was dried while the other remained at harvest moisture. For each of these portions dockage was measured. Total number of rice samples collected in this study was 50. Three replicates were conducted for each rice sample in all experiments.

Dockage testing

Dockage tester is used to mechanically separate various components of rice sample namely grains, chaff and other foreign materials according to their particle size. We measured dockage of rice samples by Carter-Day XT-1 dockage tester (Carter-Day, Minneapolis, MN). USDA FGIS (1997) has developed procedures to determine dockage for short, medium and long grain rice. Based on these procedures for medium grain rice, we used sieve number 31 in top and 27 in bottom sieve carriages.

In each test, we used 1000 grams (2.2 lb.) of rough rice sample. After the test, we obtain three fractions, separated based on size: chaff and larger non-grain items (top collector), grains (middle collector) and fine particles including dust (bottom collector). For convenience of explanation, we are describing these fractions in the report as larger materials, grains and fine materials, respectively. Dockage is described in percentage and can be calculated as follows:

Dockage = 100× (Weight of larger materials + Weight of fine materials) / (Weight of rice sample)

Moisture content of each of the three fractions was determined after dockage test using hot air oven method. ASABE standards (2006) report methods of MC determination of unground grain and seeds. However, there is no mention of oven temperature and heating time for moisture measurement for rice. For wheat, they report sample size of 10 grams, oven temperature of 130ºC and heating time of 19 hours. We used the same procedures for moisture measurement of different components of rice sample. We considered this method sufficient because using longer heating periods did not provide higher accuracy in measurement.

Drying experiments

Rice was dried by slow ambient air drying (25ºC) to about 14±1 % moisture (on wet basis) in lab-scale box shaped column dryer (Figure 3). Moisture of different rice fractions was measured by either of these two methods: commercial Dickey john moisture meter or hot air oven method.

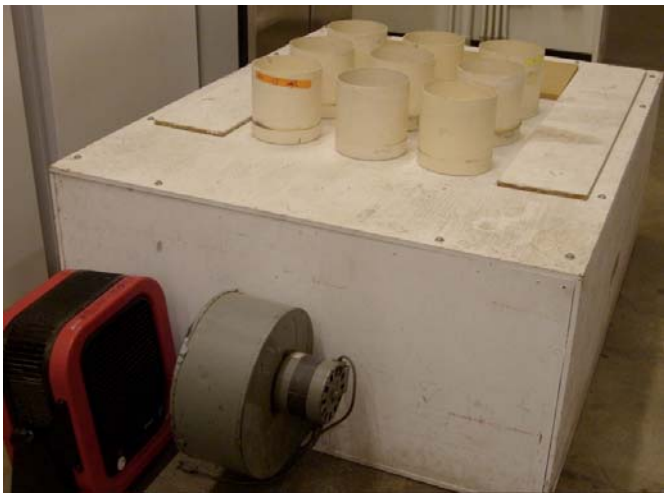

Figure 3. Lab scale air drying of rice samples

Rice sampling during strong winds and rainfall event

Weather conditions were monitored during rice harvesting season to capture specific days with notable magnitudes of rainfall and strong winds. We collected rice samples for 3 and 4 days continuously after the onset of strong winds and major rainfall event respectively. All the rice samples collected were harvested with Claas Lexion with conventional header. Dockage tests for freshly harvested and dried rice samples were conducted and results compared with normal weather conditions. Table 1 summarizes days of rice sample collection and corresponding magnitudes of weather events during sampling duration.

Table 1. Time of sample collection and magnitudes of weather events (* indicate that harvesters were unable to operate due to bad weather events)

Weather event	Sampling number	Date m/d/y	Temperature (°F)	Wind speed (mph)	Precipitation (in)	Remarks
Wind	1	10/30/2011	64	6	0	
	*	11/1/2011	64	28	0	Onset of strong winds
	2	11/2/2011	60	17	0	
	3	11/3/2011	54	16	0.11	Rainy
	4	11/4/2011	46	9	0	
Rainfall		11/5/2011	44	17	0.38	Onset of strong rains
		11/6/2011	49	9	0.16	Rainy
		11/7/2011	48	6	0	Foggy
	1	11/8/2011	47	6	0	
	2	11/9/2011	49	5	0	Foggy
	*	11/10/2011	51	7	0	
	3	11/11/2011	50	8	0.12	Rainy

SUMMARY OF 2011 RESEARCH (major accomplishments), BY OBJECTIVE:

Impact of type of harvester on rice dockage

The type of harvester model used had a significant effect on rice dockage for both freshly harvested and dried rice as shown in Figures 4 and 5. Lower dockage (0.5%) occurred in the case

of harvester equipped with stripper header compared to conventional header (up to 1%). The reason for low dockage was because the stripper header comb rice out of the rice head and leave whole stocks still standing unlike the conventional header which gathers the stalks plus any other chaff, making separation and cleaning more demanding and thereby creating more dockage.

Rice dockage also differed among different harvester models using same header configuration. It is likely that header dimensional aspects, age as well as cutting, feeding, threshing, separating and internal cleaning mechanisms, which are unique to each harvester, may affect dockage. In general, on drying rice samples, dockage reduced compared to that of freshly harvested rice for all the harvesters studied. Considering average dockage of freshly harvested and dried rice for the entire 2011 rice harvesting season and the combination of harvester and headers tested, John Deer with stripper header performed best followed by Claas Lexion with conventional header, Case with conventional header and finally John Deer with conventional header (Table 2).

Analyzed results of proportions of large and fine fractions of dockage in freshly harvested and dried rice resulting from using the studied harvesters are shown in Figure 6. All the harvesters produced more large fraction of dockage than the fines. The proportion of large fractions of dockage was least in case of rice harvested with stripper header. Based on our previous results for freshly harvested rice samples, larger materials have the highest moisture while the finer materials have the lowest moisture. During drying, these fractions of rice undergo different amount of moisture loss. Due to the highest moisture loss in larger materials, dockage of dried rice samples decreased slightly in most rice samples.

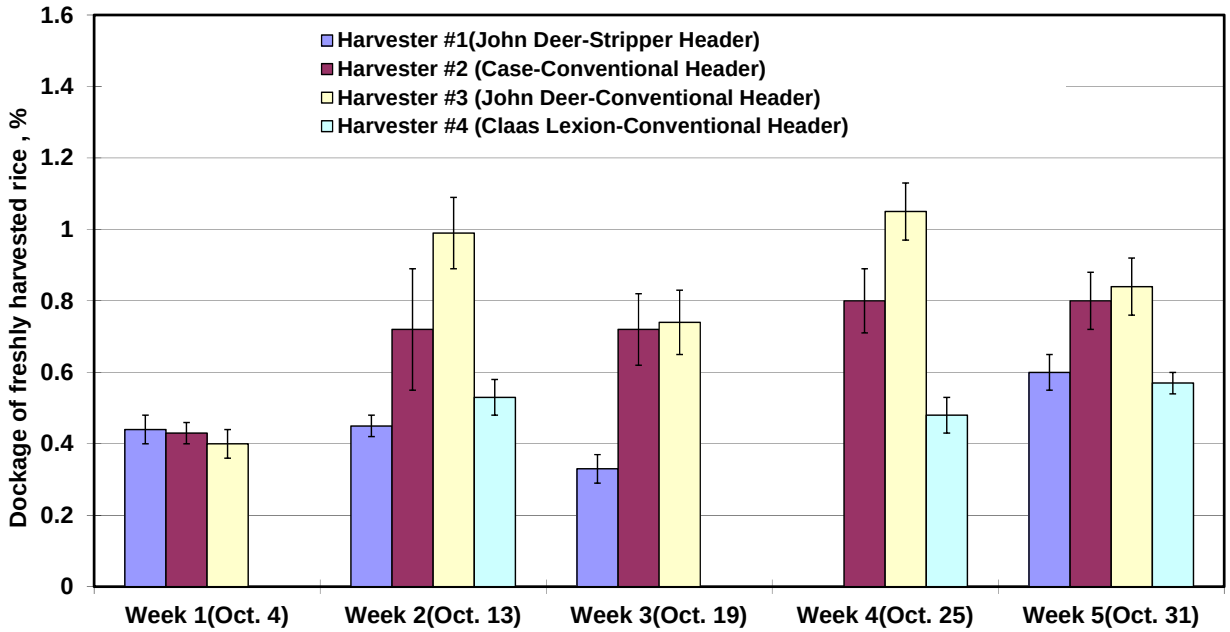

Figure 4. Impact of harvester and header type on dockage of freshly harvested rice samples

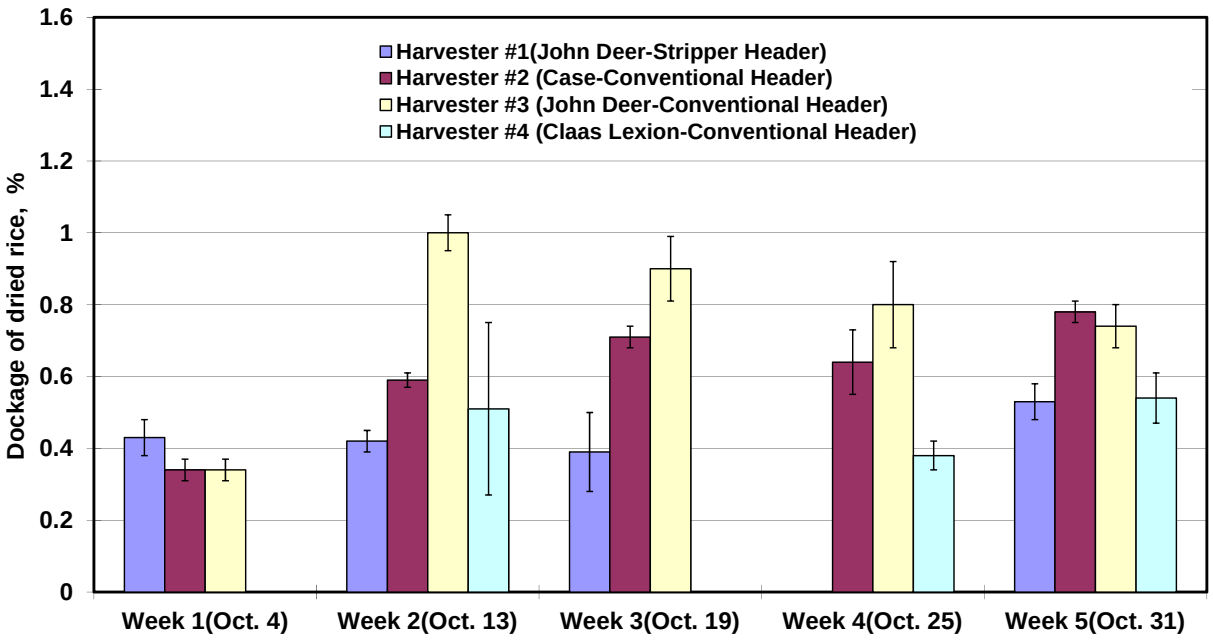

Figure 5. Impact of harvester and header type on dockage of dried rice samples

Table 2: Average dockage of freshly harvested and dried rice from different harvesters

	John Deer with stripper header	Case with conventional header	John Deer with conventional header	Claas Lexion with conventional header
Dried Sample	0.44±0.06	0.61±0.17	0.76±0.25	0.48±0.09
Raw Sample	0.46±0.11	0.70±0.15	0.80±0.26	0.53±0.05

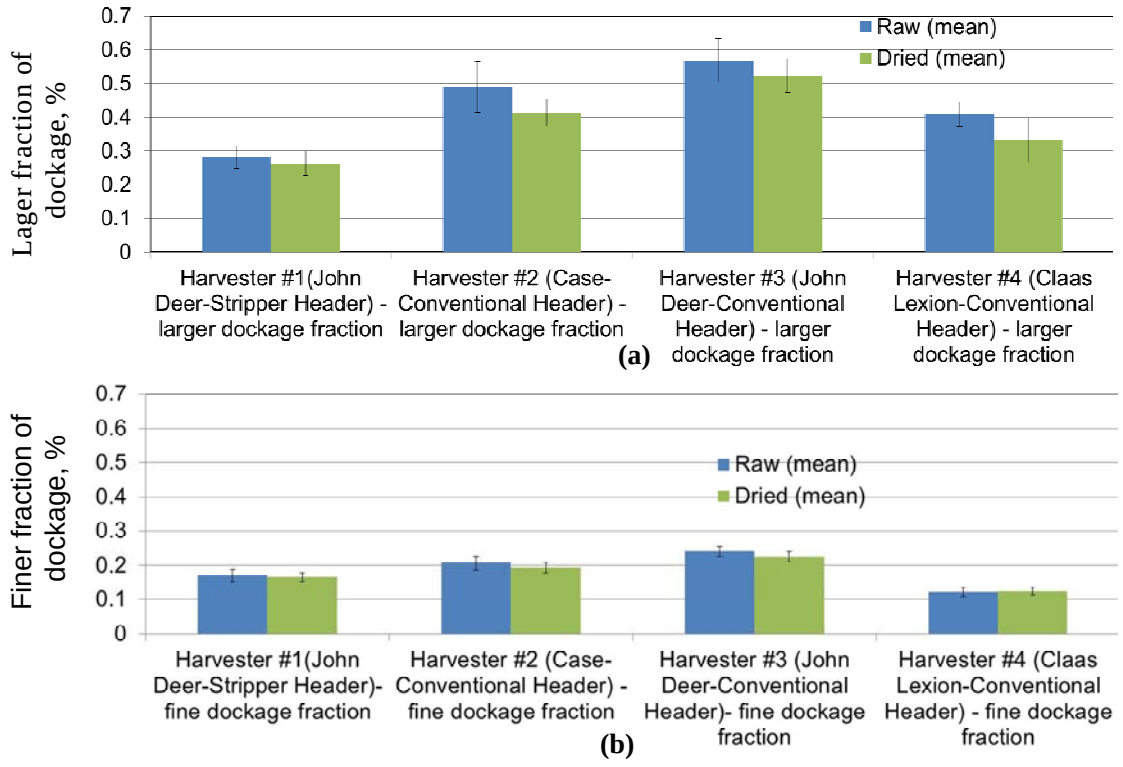

Figure 6. Proportion of (a) larger and (b) finer fractions of rice dockage resulting from using different harvesters and headers

Impact of weather events

Rice dockage was affected by strong wind and rainfall events as indicated in Table 3. Dockage was higher on windy (0.9%) and rainy (2%) days compared to during normal weather conditions (0.6%). It was also noted that fluctuations of rice moisture occur due to strong winds and rains. At the onset of strong winds, the harvested rice moisture content dropped. On the contrary, moisture contents of rice increased significantly due to rains. It is believed that because strong winds and rains may cause rice to droop or fall down, the harvesting operation is negatively influenced. Especially, rice cutting and feeding efficiency are comprised when rice stalk is fallen. Threshing, separation and cleaning of rice in the harvester are also compromised when the moisture contents are high.

Table 3. Impact of wind and rainfall events on rice dockage

Weather Condition	Number of Samples	Mean Dockage, %	
		Raw samples	Dried samples
Normal	102	0.64±0.24	0.58±0.22
Windy	24	0.89±0.36	0.70±0.33
Rainy	18	1.98±0.73	1.62±0.59

Dockage of different rice varieties

Medium grain rice of M104, M202 and M206 varieties were obtained from Farmers' Rice Cooperative and used to study the effect of seasonal changes on dockage and to confirm repeatability of our last year's result. The study findings are shown in Table 4. Because of changing growers' preferences, we were not able to secure samples of rice variety M205 in this year's research. In accordance with last year's trend, we observed that drying of rice affected dockage. For both 2010 and 2011 rice harvesting seasons, dried rice on average had lower dockage (0.14%) than freshly harvested rice. Rice dockage in 2011 was slightly lower than 2010, although not significantly. There was no significant effect on dockage due to variety differences. In general, results showed that dockage of rice were significantly lower than the currently assumed 2% weight of the freshly harvested rice.

It is worth noting that the mean dockages of rice obtained at the drying sites are slightly higher compared to dockage values obtained when specific harvester types are considered. The reason for this is because during harvesting operation in the field most growers load bankers with rice from different harvesters and the rice that is finally delivered to the drying sites by trucks comes from varied harvesters. Considering both seasons, mean dockage for rice obtained from drying sites were higher, with values of about 0.9% and 0.7% for freshly harvested and dried rice samples, compared to best performing John Deer harvester with stripper header at 0.4% and 0.5% respectively. For both seasons, it was also observed that the rice moisture content decreased as the rice harvesting season advanced and no linear relationship was found between rice dockage and the rice moisture content.

Table 4. Comparison of freshly harvested and dried rice dockage for different rice 2010 and 2011 rice harvesting seasons

Rice Variety	Rice Dockage			
	Freshly harvested 2010	Freshly harvested 2011	Dried 2010	Dried 2011
M104	1.0±0.6	0.65±0.04	0.93±0.54	0.46±0.08
M202	0.9±0.5	0.85±0.10	0.84±0.37	0.74±0.05
M205	0.6±0.4	ND	0.50±0.31	ND
M206	1.1±0.5	0.88±0.05	0.83±0.52	0.74±0.02
Mean	0.92±0.23	0.79±0.13	0.78±0.19	0.65±0.16

Dockage distribution

A significant proportion of freshly harvested rice samples obtained from growers with different harvesters during regular weather (for the whole harvest season) and those sampled during windy weather or collected at drying sites had dockage values below 1% (Figure 7). On the contrary, 100% of the samples obtained after rains had dockage values above 1%. Even after drying, rice obtained after rainfall events still had a considerable proportion (94%) with dockage values above 1% (Table 5). The proportions of freshly harvested and dried samples with average dockage values below 1% as well as the average moisture contents of rice samples used for different categories of the experiments are shown in Table 5.

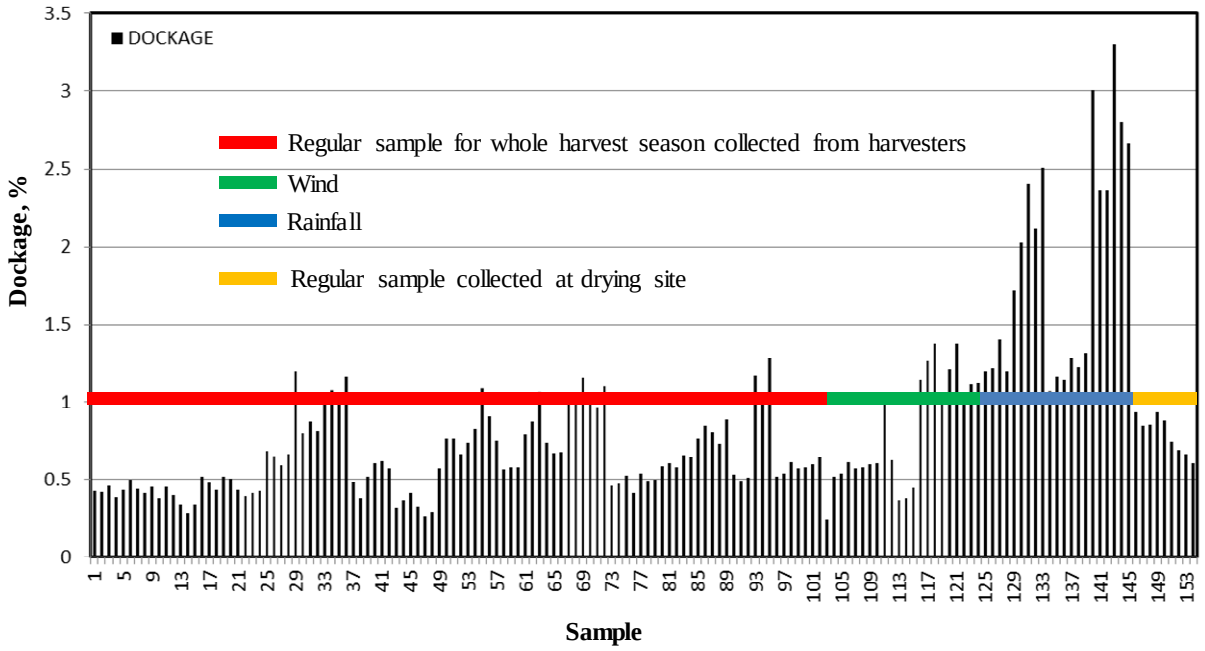

Figure 7. Distribution of sampled dockage values

Table 5. Mean moisture and sample proportion in percentage with dockage values above 1%

Impact Category of Tests	Experiment Samples Used	Mean Harvest Moisture (%, w.b.)	Mean Dockage of Rice		Sample Proportion With Dockage Above 1%	
			Freshly Harvested (%)	Dried (%)	Freshly Harvested (%)	Dried (%)
Harvester type	102	0.22±0.03	0.64±0.24	0.58±0.22	13.73	3.92
Wind effect	24	0.18±0.02	0.89±0.36	0.70±0.33	45.83	12.50
Rainfall effect	18	0.19±0.01	1.98±0.73	1.62±0.59	100	94.44
Variety difference	9	0.24±0.02	0.79±0.12	0.65±0.15		

Recommendation for updating shrink chart

Based upon our research for the past two consecutive years, the average dockage for freshly harvested rice received at the drying site is 0.9%, which is significantly lower than the widely accepted and industrially used value of 2%. Dockage value is significantly low (0.5%) when stripper header is used for harvesting of rice. However, bad weather conditions significantly increases rice dockage.

In the industry, shrink factors account for the reduction in weight due to moisture lost in drying, dockage removal during cleaning and handling operations, and invisible losses. The shrinkage in harvested rice (amount of reduction in weight) is described by shrink factor (*S*, %), which is defined as:

$$S = \frac{W_i - W_f}{W_i} \times 100$$

where, W_i (lbs.) is the weight of rough rice received at dryers and W_f (lb.) is corresponding dried rough rice weight. If shrink factor is known, the following expression can be used to determine the dried rough rice weight:

$$W_f = W_i - W_i \times \frac{S}{100} = W_i\left(1 - \frac{S}{100}\right)$$

The weight loss during drying can be easily calculated using equation based on initial and final moisture contents. If rice with initial moisture M_i (%, w.b.) is dried to moisture M_f (%, w.b.) then shrink factor *S* (%) due to moisture loss during drying can be calculated as:

$$S = 100 \times \frac{M_i - M_f}{100 - M_f}$$

When rice is dried to 13% moisture i.e. $M_f = 13$, the above equation can be simplified to:

$S = (M_i - 13)$ x 1.15

If dockage is *d* (%) and invisible loss is *k* (%) then the final shrink factor will become:

$$S = (d + k) + (100 - d - k) \times \frac{M_i - M_f}{100 - M_f}$$

Invisible losses are due to unknown sources and hence, are harder to determine accurately. Rice drying facilities set value of invisible loss, (*k* %) typically in 1.5 % to 3.5 % range. In this study, we determined that dockage (*d* %) can be safely assumed at 1.0% to update rice shrink chart.

REFERENCES

ASABE Standards. 2006. S352.2: Moisture measurement-Ungrounded grain and seeds. *in ASABE Standards*, American Society of Agricultural and Biological Engineers, St. Joseph, Mich.

USDA FGIS, 1997. Chapter 3: Inspection of rough rice *in Rice inspection handbook*, Federal Grain Inspection Service, United States Department of Agriculture, Washington D.C.

CONCISE GENERAL SUMMARY OF CURRENT YEAR'S RESEARCH

Rice industry needs to develop a universal shrinking chart for precise assessment of effect of dockage and moisture of freshly harvested rice on final weight of dried rice. Weight loss contributed by moisture change during drying can be easily calculated by considering initial and final moisture contents (MCs). Weight loss attributed to dockage and invisible loss are typically assumed at 2% and 1-3.5% of fresh weight of harvested rice, respectively. The dockage value was established long time ago and has certainly been overtaken by recent technological advances in rice farming, harvesting and handling. In addition, weather events including rainfall and strong winds influence harvesting operations which could affect dockage. Even 1% error in dockage estimation has significant economic consequence to rice growers. Therefore, our goal was to clarify and precisely quantify factors which influence rice dockage and update rice shrink chart.

In 2010 rice harvesting season, we embarked on research to clarify factors which affect rice dockage. We reported on the impact of rice variety, harvest moisture, harvesting day, drying and dropping from certain height and rice growing location. This research, performed during the 2011 rice harvesting season, focused on elucidating the impact of harvester type and weather events including strong winds and rainfall on rice dockage. Rice of medium grain varieties M104, M202 and M206 were procured weekly for up to seven weeks from specific rice growers with different harvesters and farms in Arbuckle and Grimes, CA. Rice dockage resulting from using four popular models of rice harvesters with different harvester headers including John Deer with stripper header, Case with conventional header, John Deer with conventional header and Claas Lexion with conventional header was studied. During rice harvest season, changes in weather events were monitored and rice samples were collected from the harvesters to study impact of strong winds and rainfall events on dockage. Additional rice samples were obtained from FRC (Sacramento, CA) in accordance with last year's procedures to confirm repeatability of results. MC of freshly harvested rice used in this study ranged between 18 to 26% (w.b.). A total of 50 samples of rice were used. Reported data represent at average of least three replicates.

Results from our study indicate that dockage of freshly harvested rice with MCs of 18~26% wet basis (w.b.) varied between 0.2% and 2.0%. The average dockage was 0.79% in 2011 rice harvest season, slightly lower than 0.92% in 2010. Similarly, mean value of dockage of dried rice with MC of 14±1% (w.b.) was 0.65% in 2011 and 0.78% in 2010 harvest seasons, again slightly lower (0.14%) than that of freshly harvested rice. There were no significant differences in dockage among studied rice varieties and dockage of different rice varieties used in 2011 were consistent with 2010 results, albeit slightly lower. It was also observed that no significant relationship between dockage and harvest moisture content was found. In particular, wind and rainfall events significantly increased dockage. The results also revealed that type of harvester affected dockage. The type of harvester and header affected dockage with stripper header indicating least dockage (0.5%) compared to conventional header (up to 0.8%).

In summary, average value of dockage for freshly harvested rice was determined to be 0.9%, which is significantly lower than the widely accepted value of 2%. This dockage value can be used to update rice shrink chart. Negative economic consequences related to dockage could be mitigated by proper consideration of among other factors that influence dockage, harvester and header type used as well as prevailing weather events.

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