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 are much 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 important to determined dockage and update the shrink chart.

The objectives of this research are as following:

1. Determine dockage of rice samples with different harvest moistures from different rice growing regions in California.
2. Determine impact of drying on dockage.
3. Determine impact of dropping rice from different elevations on dockage.
4. Update the shrink chart.

To accomplish these objectives we performed three kinds of experiments: dockage, drying and dropping tests. Dockage was determined for freshly harvested rough rice samples and dried rough rice samples, with and without dropping at selected heights. In next section, detailed descriptions of these experiments are provided.

MATERIALS AND METHODS

Rice Samples

In 2010 harvesting season, we collected rice samples weekly, from three drying facilities that were located in Colusa, Butte and Yolo counties. We selected these three facilities so that we can get samples from majority of rice growing areas and determine if geographical differences affect dockage of rice samples. Each week, we collected 3 to 5 samples from each facility. Each of these rice samples was grown by different farmers. Total number of rice samples used in this study was 51. In this study, we used medium grain rice varieties only. Among the 51 rice samples, 3 were M104, 6 were M202, 19 were M205 and 23 were of M206 variety. Harvest moisture of rice varied from 14 to 26% on wet basis with majority of them between 18% and 25%. Three replicates were conducted for each rice sample in all experiments.

Each rice sample was divided into two portions. One of the portions was dried while the other remained at the harvest moisture. For each of these portions dockage was measured before and after dropping 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:

$$Dockage = 100 \times (Weight\ of\ larger\ materials + Weight\ of\ fine\ materials) / (Weight\ of\ rice\ sample)$$

Moisture content of each of the three fractions was determined after dockage testing 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 130 ℃ 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 (25 ℃) to about 14±1 % moisture (on wet basis) in lab-scale box shaped column dryer (Figure 1). Depending upon initial moisture, samples took 6 to 16 hours of drying to reach the targeted final moisture. Moisture of different rice fractions was measured by either of these two methods: commercial Dickey john moisture meter or hot air oven method.

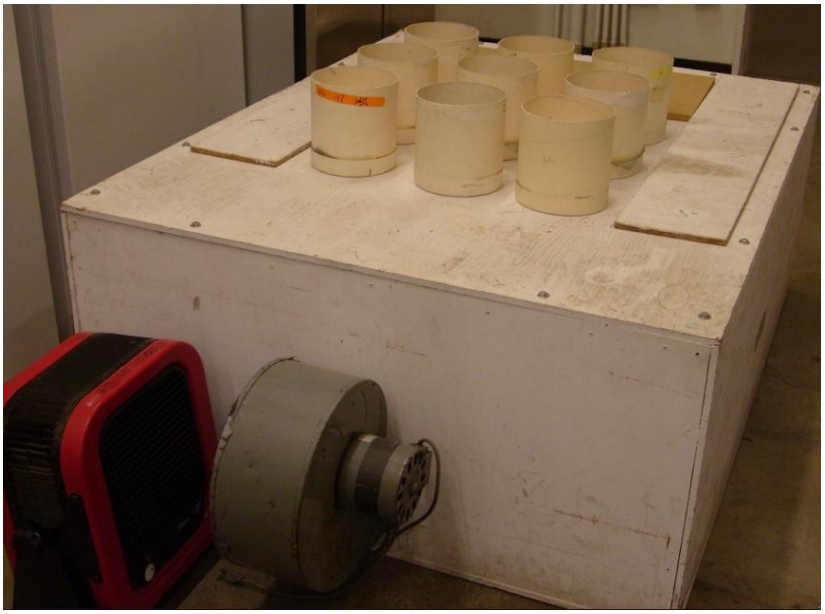

Figure 1. Lab scale air drying of rice samples

Dropping Experiments

During many post-harvest operations such as drying and storage, rough rice is dropped from some height. This dropping may affect its dockage. To determine such impact on dockage quantitatively, we dropped rice samples from 15 feet height multiple times and measured dockage. In experiments, rice samples were dropped once and five times, separately.

SUMMARY OF 2010 RESEARCH (major accomplishments), BY OBJECTIVE:

Dockage of freshly harvested rice samples

The moisture content of the freshly harvested rice samples ranged between 14 and 26% on a wet basis. For all the freshly harvested rice samples dockage was measured. Dockage varied between 0.2 and 2.0%. Distribution of dockage with harvest moisture of rice is shown in

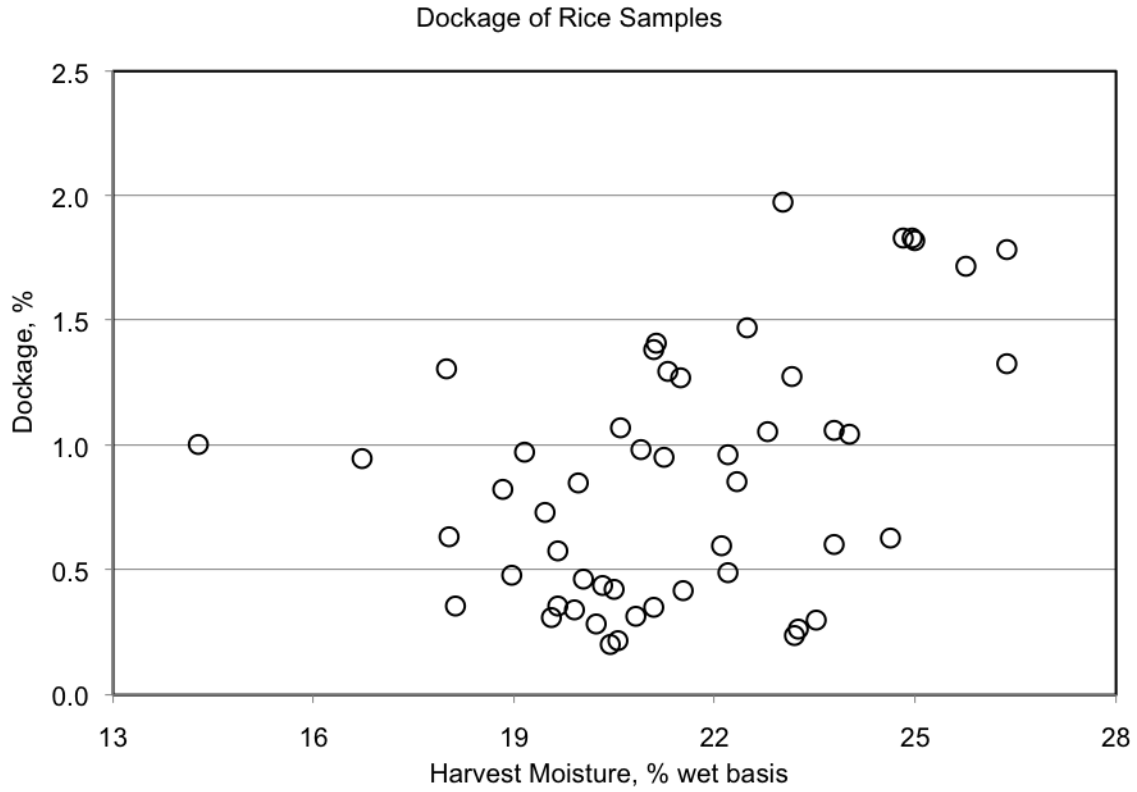

Figure 2. No definite trend was observed between dockage and harvest moisture. Dockage of rice samples harvested at higher moisture (> 25%) was generally high.

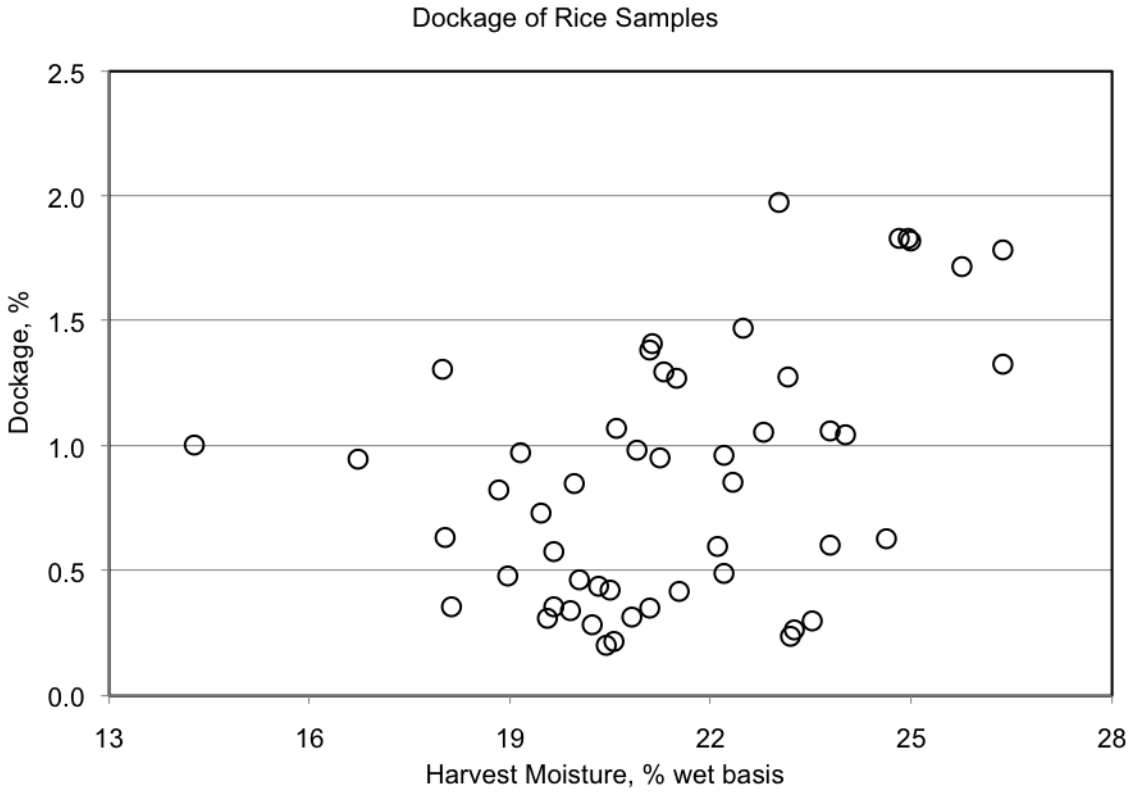

Figure 2. Dockage of freshly harvested rice samples

Among the four medium grain rice varieties considered, no significant difference in dockage was observed (Table 1).

Table 1: Dockage of rice samples of different varieties

Variety	Number of Samples	Dockage, %
M104	3	1.0±0.6
M202	6	0.9±0.5
M205	19	0.6±0.4
M206	23	1.1±0.5

Rice samples were collected on five days spread throughout the harvesting season. Figure 3 shows the impact of harvesting day on dockage. In early harvest days, rice samples have higher dockage which reduced as the harvesting period progressed. From the third week onwards dockage was more or less in similar range. One of the factor that might cause such decline in dockage is rainfall which occurred very often especially after mid October. In this study, impact of rainfall on dockage was not studied and therefore we could not conclusively determine the cause of such decline of dockage.

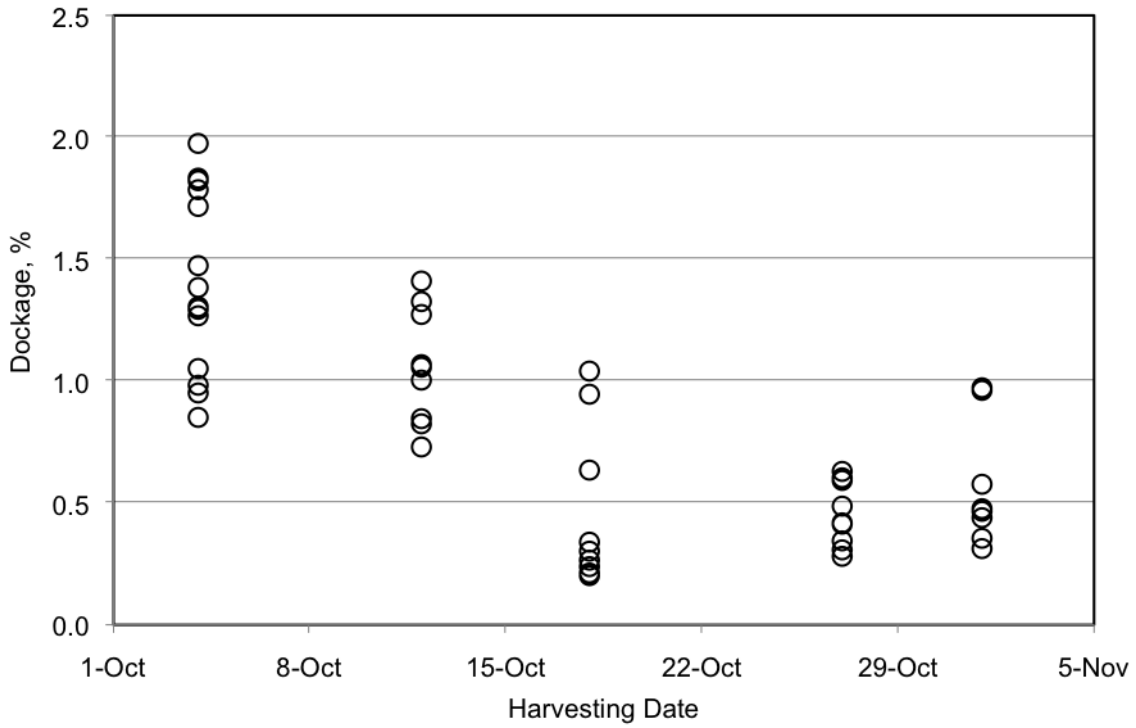

Figure 3. Impact of harvest date on dockage of rice samples

Rice samples were obtained from three drying facilities located in different counties. Typically these facilities get rice from nearby rice fields within a radius of about 10-15 miles. Therefore, samples from these facilities can be considered as representative of the county. As seen in Table 2, location seems to have insignificant impact on dockage.

Table 2: Dockage of rice samples from different location

Dryer location, County	Number of Samples	Dockage, %
Colusa	17	0.7±0.4
Butte	17	0.8±0.5
Yolo	17	1.1±0.6

Impact of drying on dockage

In freshly harvested rice samples, larger materials (composed of mainly chaff) have highest moisture while the finer materials have the lowest moisture among all the three fractions. For example, in first week rice samples, average moisture (wet basis) of larger materials, grains and fine materials were 32.8%, 24.1% and 23.4%, respectively. During drying, these fractions of rice undergo different amount of moisture loss. After drying, average moisture (wet basis) of larger materials, grains and fine materials were 14.7%, 14.9% and 13.8%, respectively. Due to highest moisture loss in larger materials, dockage of dried rice samples decreased slightly in most rice samples. On average (out of 51 samples spread in five weeks), dockage of dried samples was 0.71% while dockage of freshly harvested samples was 0.87%. Dockage of dried rice samples for each week's rice samples are shown in Figure 4. This figure seems identical to Figure 3 because the differences in dockage of individual rice samples in these two figures are very small (0.15±0.27 %).

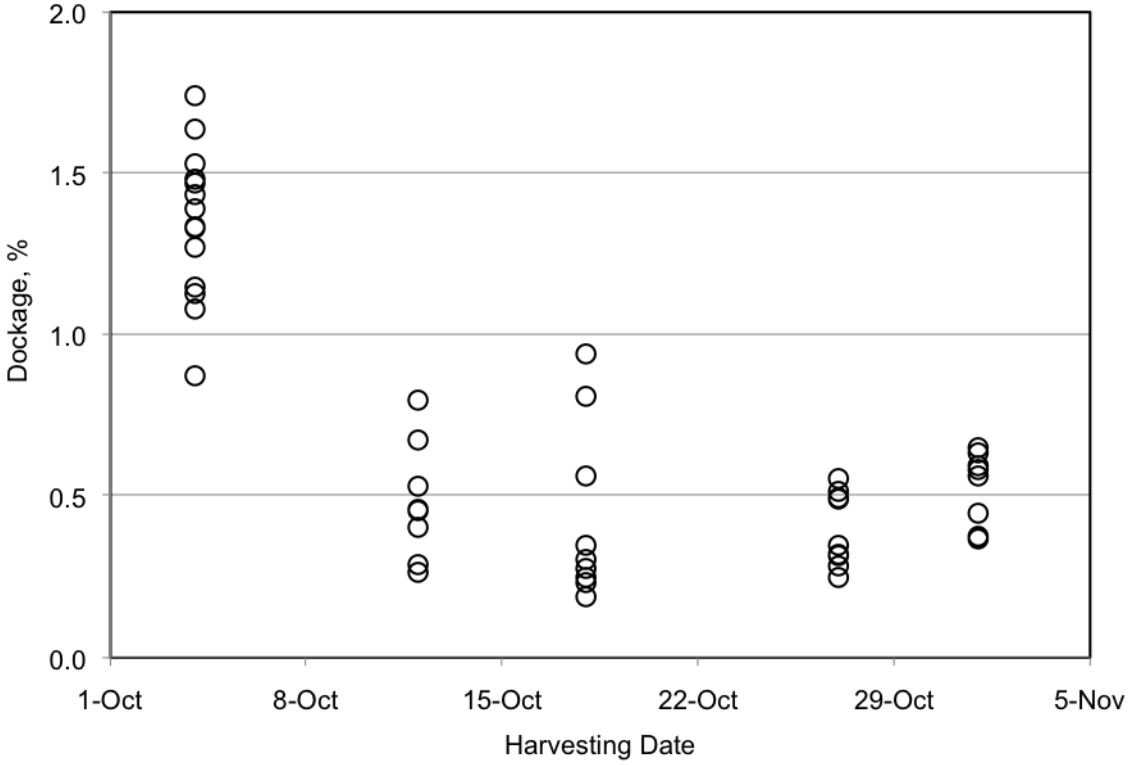

Figure 4. Dockage of dried rice samples

In commercial drying operations, large fraction of chaff and other non-grain materials are removed before drying by blowing air through them. This saves a high amount of heat that otherwise would have been needed to dry these materials. This separation of non-grain materials before drying would lower the dockage of dried rice enormously. In this study, such air-separation was not conducted and hence the lowering of dockage reported here is purely due to differential change in moisture of different fraction during drying.

Impact of dropping rice on dockage

Rice samples were dropped from 15 feet height once and five times. On dropping, some fragile fractions break on impact after the free fall. This results in change in proportions of different fractions in the sample and thus affects dockage. Among the different fractions, amount of larger materials and grains lowered while amount of fine materials increased. Since the change in dockage was very small, from second week onwards, dropping test was performed for only two rice samples each week. Dockage of dropped rice samples was found to be slightly higher (0.03% more) than those samples that did not undergo dropping tests.

Development of shrink chart

On drying, weight of harvested rice becomes smaller. Amount of this reduction in weight or shrinkage in harvested rice 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 received rough rice weight and W_f, (lb) is corresponding dried rough rice weight. Alternatively, if shrink factor is known, following expression can be used to determine the dried rough rice weight:

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

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 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:

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

Based upon this work, we observed the value of d as 0.9%, which is significantly lower than the widely accepted and industrially used value of 2%. 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 were handling small quantities of rice samples and therefore, we could not observe any notable invisible losses in our studies.

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CONCISE GENERAL SUMMARY OF CURRENT YEAR'S RESEARCH

In rice industry, rice is weighted when it is received at dryers, but growers are paid based on the final dried weight. Typically shrink chart or formula is used to determine the final dried weight. Shrink charts take in account the reduction in weight due to loss of moisture, dockage and invisible losses. Weight change due to moisture loss can be computed accurately but individual dryers determine amount of dockage and invisible losses. These numbers of dockage and invisible loss were established long time ago. Due to the advancement in harvester and handling equipment, these numbers may be very different at present. In this research, our goal was to determine dockage and factors affecting it and develop updated shrink chart.

In this research, we collected 51 medium grain rice samples from three different dryers located in Colusa, Butte and Yolo counties on five different days during 2010 harvesting season. Harvest moisture of these rice samples were in 14 to 26% range. We determined dockage of harvested and dried rice samples. We also performed dropping tests where rice was dropped in free fall from 15 feet height multiple times and impact of such dropping on dockage was determined.

Dockage of freshly harvested rice samples varied between 0.2% and 2.0% with average being 0.87%. No significant differences in dockage were found among M104, M202, M205 and M206 rice varieties. Impact of harvest moisture and geographical location of field on dockage were insignificant. In early weeks of harvesting season, dockage was higher than later weeks. During drying, grains and non-grain materials dry differently. Larger materials like chaff present in rice lose more moisture than grains causing dockage to be lower on drying. Average dockage of dried samples was 0.71%, which was 0.16% lower than freshly harvested rice samples.

When rice samples were made to freefall, its impact with solid surface causes some larger particles to break. This was evident as proportion of fine materials (collected from the bottom tray in the dockage tester) increased on dropping. Overall, dockage of rice samples increased on dropping but this increase was very small, approximately 0.03%.

Based upon findings of this research work, average value of dockage was determined to be 0.87%, which is significantly lower than the widely accepted value of 2%. Using this dockage value, shrink charts can be updated. In this year, we determined impact of drying, dropping, harvest moisture, geographical rice field location and variety on dockage. In addition to these, weather events, such as rainfall and wind patterns may affect dockage and requires further investigation. For future research, we need to continue dockage tests for rice samples at even larger scale so that we have robustness and more confidence in our data sets that could be used to make industry wide recommendations.

PUBLICATIONS OR REPORTS
N/A

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