

RESEARCH-SCALE DRYING OF ROUGH RICE USING SILICA GEL

G. O. Ondier, T. J. Siebenmorgen, A. C. Wiedower

ABSTRACT. After harvest, most rough rice research samples are dried using ambient air, the temperature and relative humidity of which oscillates. Fluctuations in environmental conditions produce variation in the final moisture contents (MCs) of samples, yielding inconsistent functional properties. The goal of this study was to develop an alternative method for drying small rough rice samples using silica gel that would be capable of yielding accurate and precise final MCs while maintaining grain quality. Drying experiments incorporated a combination of 1- and 5-g moisture-permeable packets of silica gel, mixed with rough rice samples in plastic bags. The average adsorptive capacity of the packets in closed rough rice samples was established as 25% to 27% (i.e., 0.25- to 0.27-g water / 1-g silica gel). A desired final MC (12.5%) was achieved for silica-gel-dried rice samples within four to five days, and the milling quality of samples dried to 12.5% MC, expressed as head rice yield, was not significantly different from that of control-dried samples.

Keywords. Drying, Desiccant, Silica gel, Rice, Adsorptive capacity, Equilibrium moisture content.

In Arkansas, rice is typically harvested at moisture contents (MCs) ranging from 14% to 22% (All moisture contents are reported on a wet basis.). The MC must then be reduced to levels safe for storage (usually below 13%), effectively minimizing microbial growth and respiration. Research-scale samples of rough rice are typically dried with ambient air. Because ambient air temperature and relative humidity (RH) fluctuate, final sample MC can also vary, introducing variability in milling quality and subsequent functional property measurements. Laboratory-scale driers with temperature and RH controls are available but are often expensive to purchase and operate. It would therefore be beneficial to develop an effective and inexpensive method for drying research-scale rice samples of varying initial MCs to levels safe for storage, while simultaneously minimizing sample-to-sample final MC variation and maintaining grain quality.

A potential drying method for such samples is sorption drying, whereby a desiccant adsorbs moisture from high-MC grain. Several studies have investigated the potential of using desiccants to dry high-MC grain. Danziger et al. (1972) demonstrated superiority in product quality when corn was dried at ambient temperature using desiccants. Sturton et al. (1983) and Graham et al. (1983) found that drying corn, wheat, and oats using desiccants was promising based on drying kinetics and seed quality. Zhanyong et al. (2002) reduced the MC of soybeans to levels safe for storage by

using intimate mixtures of soybean and silica gel in static beds. Ghate and Chinnan (1984) successfully used desiccants to dry in-shell pecans.

Silica gel is inert, has a high absorbency, and can be regenerated easily using high temperatures (>100°C) without significant reduction in adsorptive capacity (Koh, 1977). As such, this desiccant may be useful for drying research-scale samples of rough rice. Silica gel is available in various-sized packets, as small as 1 g, making it ideal for drying small samples. Packets also reduce separation costs and risk of product contamination.

The overall goal of this study was to develop an alternative method for drying research-scale samples of rough rice, and specifically, to investigate the potential of silica gel for such drying applications. The objectives were: 1) to develop an effective drying procedure utilizing silica gel packets, 2) to measure the adsorptive capacity of silica gel packets in closed samples of rough rice, 3) to determine the effectiveness of using these packets for drying small rough rice samples at varying initial MCs to a desired, final MC of 12.5%, 4) to determine the duration required for sorption drying, and 5) to assess the effect of sorption drying on rice milling quality.

MATERIALS AND METHODS

Two lots of the long-grain rice cultivar, Wells, were harvested from the Rice Research and Extension Center near Stuttgart, Arkansas, in the fall of 2008 and 2009 at 18.1% and 19.6% MC, respectively. The lots were cleaned immediately after harvest using a dockage tester (XT4, Carter-Day Co., Minneapolis, Minn.). Rough rice MCs were determined after cleaning using an oven method [The oven method for moisture content determination consisted of drying duplicate, 20-g sub-samples in a convection oven (1370 FM, Sheldon Inc., Cornelius, Oreg.) for 24 h at 130°C (Jindal and Siebenmorgen, 1987)]. The lots were stored in sealed plastic bins at 5°C prior to experimentation. Rough rice MCs were

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again determined at the beginning of experimentation using an oven method.

Rough rice samples were dried using silica gel packets (Aridien Inc., Belen, N. Mex.). The purported initial MC of the silica gel packets was 0.05%, and the adsorptive capacity was 30%. However, unless otherwise noted, silica gel adsorptive capacity was estimated as 26.6% (0.266 g H₂O/g silica gel), based on preliminary experiments. This value, which is less than the purported 30% free-water adsorptive capacity, accounts for intra-kernel resistance to moisture migration. Unless otherwise noted, silica gel packets were intimately mixed with rice samples.

A dry matter balance (eq. 1), in conjunction with a total mass balance (eq. 2), was used to determine the mass of moisture that must be removed to dry each rough rice sample to the desired 12.5% MC. The corresponding mass of silica gel required to adsorb this moisture was then calculated based on an assumed adsorptive capacity using equation 3.

$$m_1 \times (1 - MC_1) = m_2 \times (1 - MC_2) \quad (1)$$

$$m_3 = m_1 - m_2 \quad (2)$$

$$m_s = m_3 / \text{assumed adsorptive capacity} \quad (3)$$

where m_1 is the mass of rough rice at moisture content determined after storage and immediately before starting the drying experiment, MC_1 (decimal, wet basis); m_2 is the mass of rough rice at the desired storage moisture content, MC_2 (0.125); m_3 is the mass of moisture to be removed in drying a sample from MC_1 to MC_2 ; m_s is the mass of silica gel required to dry a rough rice sample to the desired MC_2 (When necessary, a combination of 1- and 5-g silica gel packets was used to yield the exact mass of desiccant (m_s) required to dry a rice sample to the desired 12.5% MC; 1-g packets were added when the required silica gel mass was not evenly divisible by 5. These additions minimized over- or under-drying samples.).

Sealable plastic bags with volumes of 946 cm³ (1 qt) or 3785 cm³ (1 gal) and 473-cm³ (1-pt) glass jars were considered as potential drying containers. Designing a drying method for use at ambient temperature is important in minimizing drying costs. As such, drying experiments were carried out in a laboratory with temperatures ranging from 21°C to 23°C, and in chambers maintained at 10°C, 21°C, 26°C, and 47°C. At the conclusion of each experiment, the final MCs of the rough rice samples were determined using an oven method. All statistical analyses were performed using JMP 8.0.1 software (SAS Institute, Inc., Cary, N.C.).

EVALUATION OF PLASTIC BAGS AS DRYING CONTAINERS

Moisture migration into or out of a drying container may adversely affect the drying rate and final MC of a rice sample. It was therefore important to dry samples in a moisture impermeable container. Plastic bags are readily available, affordable, and easy to handle/store, thus their effectiveness as drying containers was investigated.

Four, 200-g rough rice samples from both the 18.1% and 19.6% initial-MC Wells lots were dried by intimately mixing silica gel packets with rice samples; two samples from each lot were dried in 946-cm³ (1-qt) sealable plastic bags and the other two in 473-cm³ (1-pt) glass jars. The mass of silica gel required was estimated by equations 1-3. The samples were

dried for eight days in a chamber maintained at 26°C, after which the MC was determined using an oven method. The drying effectiveness was evaluated by comparing the final MCs of samples dried in the plastic bags to those dried in the glass jars, which were deemed impermeable to moisture.

RICE SAMPLE/DESICCANT PACKET DRYING PROCEDURE

Three drying treatments were investigated for maximizing silica gel effectiveness when drying small samples of rough rice in plastic bags: 1) surface placement (SP) of silica gel packets on top of rice samples, 2) intimate mixing (IM) of rough rice and silica gel packets without agitation, and 3) intimate mixing of rough rice and silica gel packets with agitation (IMA) of the drying container at 24-h intervals throughout the drying duration. The IMA samples were agitated by manually shaking the sealed plastic bags containing the rice samples and silica gel packets for 1 min, thus disrupting moisture stratification of the air within the bags. It was speculated that moisture stratification may slow the rate of moisture transfer from the rice kernels to the silica gel packets. The IM samples were only agitated at the beginning of the experiment. The SP drying method comprised placing silica gel packets directly on top of the rice bulk without agitation.

The effect of increasing rough rice sample masses on each drying method with respect to silica gel drying effectiveness was also investigated. Bulk rice samples from both Wells initial-MC lots were divided into six, 250-, 500-, and 1000-g samples (fig. 1). Samples were dried in duplicate using silica gel packets placed in sealable plastic bags with the desiccant placement treatments (SP, IM, and IMA) applied according to figure 1 [The 250-g samples were dried in 946-cm³ (1-qt) bags while the 500- and 1000-g samples were dried in 3785-cm³ (1-gal) bags.]. Required desiccant mass was determined using equations 1-3. All plastic bags were kept in a chamber maintained at 26°C for eight days, after which the rice MC was determined by an oven method.

ADSORPTIVE CAPACITY OF NEW AND REGENERATED SILICA GEL PACKETS IN ROUGH RICE SAMPLES

The adsorptive capacity of silica gel packets in closed containers of rough rice would be expected to be less than that in a free water environment due to forces holding water inside rice kernels. The in-rice adsorptive capacity is needed for accurate use of equation 3. A method was implemented to experimentally determine the actual, in-rice adsorptive capacity of silica gel packets. In this method, the mass of silica gel required to dry the rice samples was estimated at six assumed adsorptive capacities of 15%, 20%, 25%, 30%, 35%, 40%, and 45%. Duplicate rice samples were dried for eight days using silica gel amounts determined for each adsorptive capacity and final MCs determined. Following a regression analysis (polynomial fit) of final MCs (y-axis) to corresponding assumed adsorptive capacities (x-axis), the adsorptive capacity of silica gel packets that yielded a desired, 12.5% MC, was taken as the actual adsorptive capacity (as illustrated in fig. 4). The procedure was then repeated using regenerated packets, since Koh (1977) showed that silica gel can be regenerated at high temperatures (>100°C); using regenerated packets could potentially reduce drying costs.

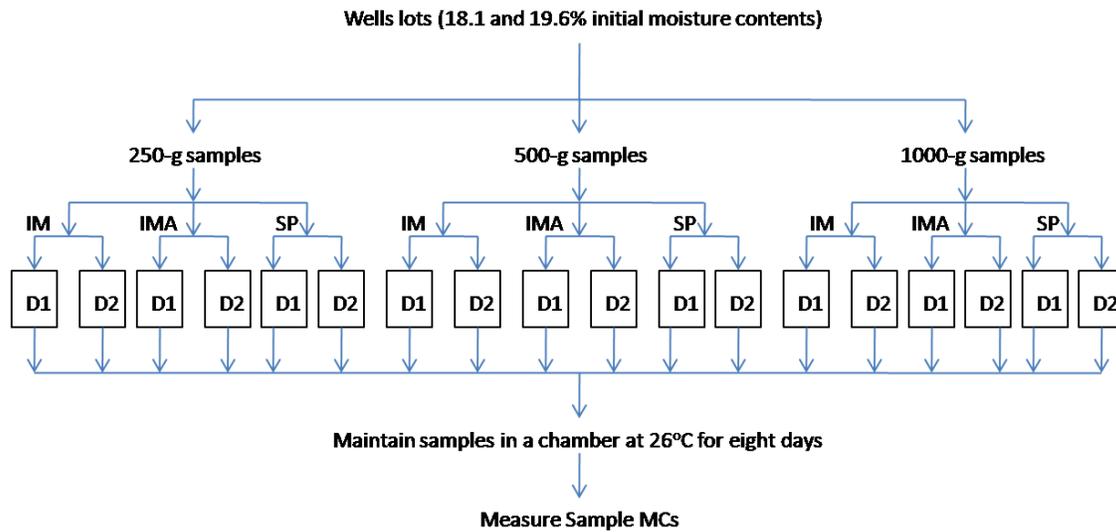


Figure 1. Schematic of experiment to determine the effect of silica gel packet placement method and sample mass on final rough rice moisture content (MC). Packets were intimately mixed (IM), intimately mixed with agitation (IMA), and surface placed on top (SP) of duplicate (D1, D2) rice samples from each indicated initial moisture content lot of Wells rice.

Duplicate, 200-g rough rice samples from each Wells lot were dried using silica gel packets with packet mass determined by equations 1-3, based on assumed adsorptive capacities of 15%, 20%, 25%, 30%, 35%, 40%, and 45% (fig. 2). Samples were dried in quart-size plastic bags and kept in a chamber maintained at 26°C for eight days. The silica gel packets were then regenerated in a convection oven (1370 FM, Sheldon Inc., Cornelius, Oreg.) at 130°C for 24 h and re-used to dry second, third, and fourth batches of rough rice from both Wells lots following the same procedure used in the initial cycle (fig. 2). The change in adsorptive capacity between new, once-, twice-, and thrice-regenerated silica gel packets would indicate possible change in drying effectiveness due to regeneration.

ROUGH RICE INITIAL MC AND DRYING TEMPERATURE EFFECTS

Bulk rice samples from each Wells lot were conditioned in a chamber maintained at 26°C and 55% RH to yield samples with MCs ranging from 17.7% to 12.7% (fig. 5). Six, 200-g samples from each conditioned lot were then dried in chambers maintained at 10°C, 21°C, or 47°C for eight days (fig. 3) to determine the influence of initial MC and temperature on the final MC of the rough rice samples. Duplicate samples were dried at each temperature in quart-size plastic bags using silica gel packets, the mass of which was determined using equations 1-3.

DRYING DURATION TO THE DESIRED 12.5% MC

Sixteen, 200-g rice samples from each Wells lots were dried in quart-size plastic bags for eight days in a chamber

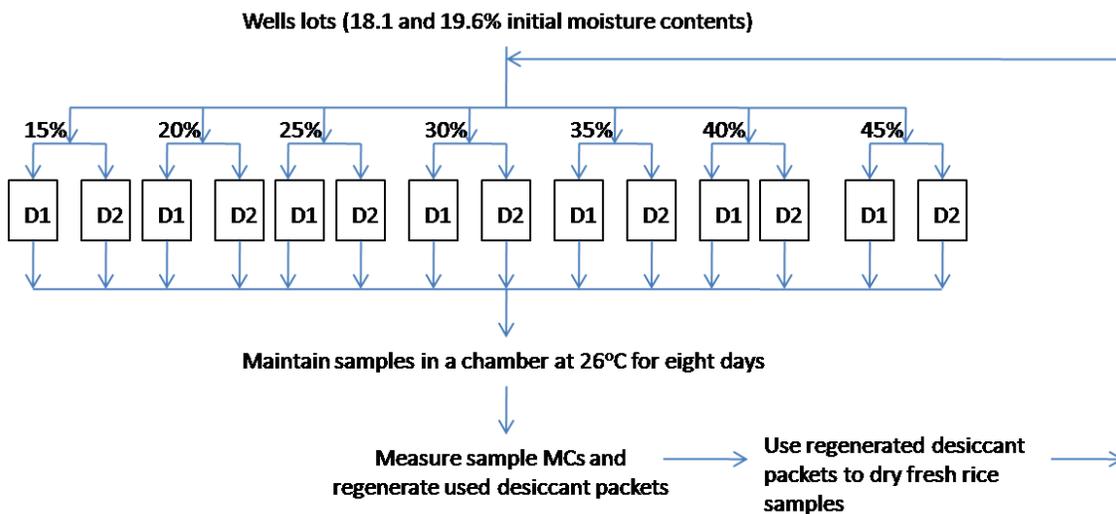


Figure 2. Schematic of experiment to determine the adsorptive capacities of new and regenerated silica gel packets intimately mixed in duplicate (D1, D2) 200-g samples of Wells rough rice at the indicated initial moisture contents (MCs), based on assumed adsorptive capacities of 15% to 45%.

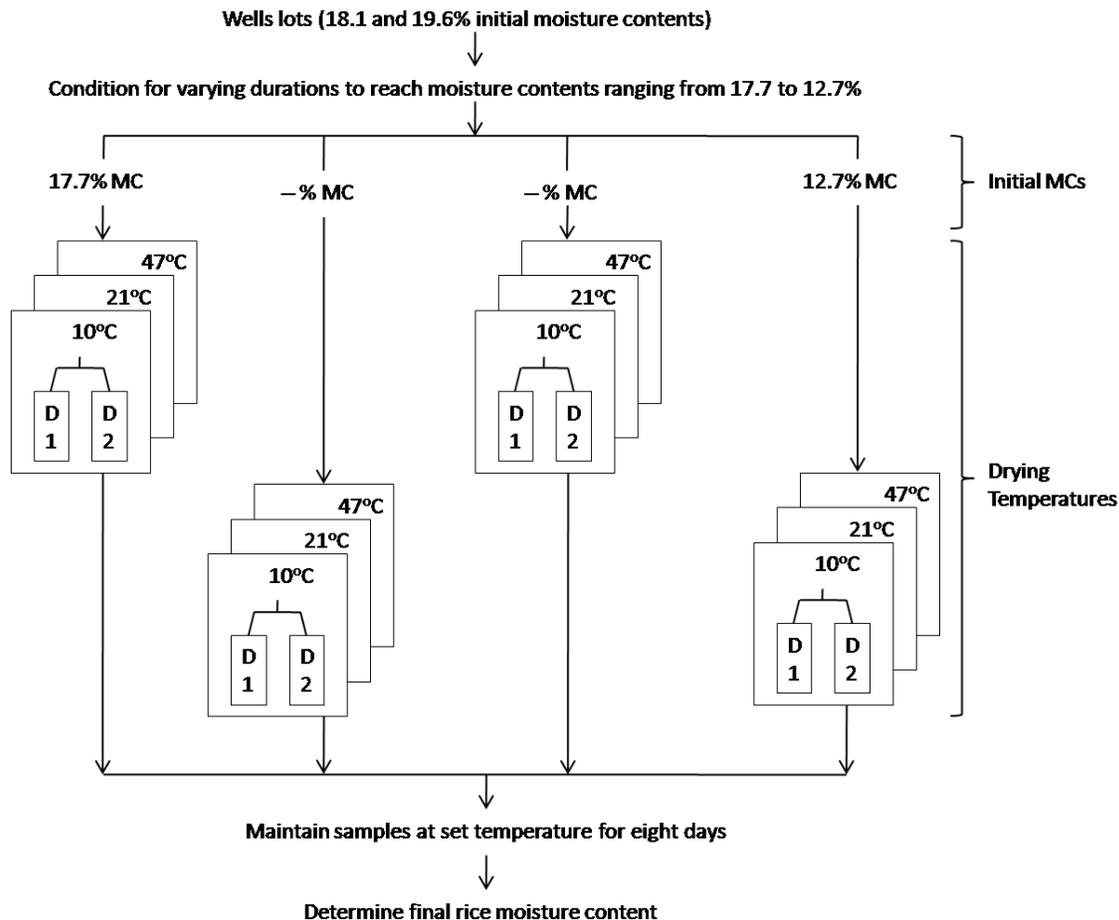


Figure 3. Schematic of experiment to determine the effect of rough rice initial moisture content (MC) and drying temperature on the final MC of duplicate (D1, D2) 200-g Wells rough rice samples at the indicated initial MCs, dried using silica gel packets.

maintained at 26°C using intimately-mixed silica gel packets, the mass of which was determined using equations 1-3. Duplicate samples of each Wells lot were obtained from the chamber at 24-h intervals for oven MC determination. Equation 4 was used to describe the drying data using nonlinear regression platform in JMP 8.0.1 (SAS Institute Inc., Cary, N.C.) and the k and n values determined through a series of iterative steps. The resulting Page equation was used to determine the drying duration required for the rough rice samples to reach 12.5% MC.

$$M_R = \frac{M - M_e}{M_o - M_e} = \exp(-kt^n) \quad (4)$$

where M_R is the moisture ratio; M is the moisture content (decimal, wet basis) at drying duration t (min); M_o is the initial moisture content; M_e is the equilibrium moisture content; k and n are drying constants.

MILLING QUALITY OF SORPTION-DRIED ROUGH RICE

Milling quality of rice is typically expressed as head rice yield (HRY). The term head rice denotes rice kernels that are at least 3/4 or more of the original kernel length after complete milling (USDA, 2005). The procedure for measuring HRY comprised passing 150-g samples of rough rice through a dehulling machine (THU, Satake Engineering Co., Tokyo, Japan) and milling the resulting brown rice for

30 s using a laboratory mill (McGill No. 2, RAPSCO, Brookshire, Tex.). Head rice was separated from broken kernels using a sizing machine (61-115-60, Grainman Machinery Co., Fla.), and HRY was expressed as the mass ratio of head rice to rough rice.

Duplicate, 200-g samples from each Wells lot were dried to approximately 12.5% MC for milling analysis in quart-size plastic bags using silica gel packets. The silica gel mass was determined using equations 1-3. Samples were placed in a chamber maintained at 26°C for eight days. Head rice yields of the dried samples were compared to HRYs of duplicate control samples dried on screened trays to 12.5% MC in a chamber maintained at 26°C and 55% RH. The MCs of desiccant dried and control samples were measured immediately prior to milling using an oven method.

RESULTS

EVALUATION OF PLASTIC BAGS AS DRYING CONTAINERS

Table 1 shows the final MCs of rice samples dried in plastic bags and glass jars using desiccants packets. The results showed no significant differences (p -value > 0.10) in final MCs of samples dried in plastic bags or glass jars. Therefore, migration of moisture into or out of the plastic bags was considered negligible, and plastic bags were deemed acceptable drying containers.

Table 1. Final moisture contents (MCs) of 200-g Wells rice samples, at the indicated initial MCs, dried at 26°C for eight days using combinations of 1- and 5-g intimately mixed silica gel packets (Aridien Inc.®).

Initial Rice MC (%)	Final Rice MC (%) ^{[a][b]}	
	Plastic Bag	Glass Jar
19.6	13.0 ^a	13.2 ^a
18.1	12.6 ^a	12.5 ^a

[a] The final MCs are averages of four measurements, comprising duplicate oven MC measurements of duplicated drying treatments.

[b] Values with the same alphabetical letter are not significantly different (p-value > 0.10).

RICE SAMPLE/DESICCANT PACKET DRYING TREATMENTS

The final MCs of rice samples dried using the intimate mixing (IM), intimate mixing with agitation (IMA), and surface placement (SP) methods are shown in table 2. According to the results shown in table 2, the IM and IMA methods yielded final MCs that were closest to the desired 12.5% MC. No significant differences were observed in final MCs of the 250-, 500-, and 1000-g samples dried using the IM and IMA methods: the IM method was thus preferred because it was less laborious but equally effective. The final MCs of 500- and 1000-g samples dried using the SP method were significantly greater than those of the IM and IMA methods (p-value < 0.10). Greater moisture retention in samples dried using the SP method can be attributed to moisture stratification within the drying container, which slowed the rate of moisture transfer from the rice kernels into the desiccant packets. Similar findings were reported by Zhangyong et al. (2002) who found well-mixing of silica gel and grain as a prerequisite for sorption drying. Sturton et al. (1981) recommended uniform mixtures of desiccant and grain to avoid any locations being overdried, and Graham et al. (1983) observed fast drying rate when the effective contact between desiccant and grain was maximum.

ADSORPTIVE CAPACITY OF NEW AND REGENERATED SILICA GEL IN ROUGH RICE SAMPLES

A regression analysis, in which a quadratic relationship was established between final MCs and assumed adsorptive

Table 2. Final moisture contents (MCs) of 250-, 500-, and 1000-g rice samples from Wells rice lots at the indicated initial MCs dried using the indicated methods with silica gel packets (Aridien Inc.®) for eight days in a chamber maintained at 26°C.

Drying Method	Rice Mass (g)	Final Rice MC (%) ^{[a][b]}	
		18.1% Initial MC	19.6% Initial MC
Intimately mixed	250	12.9 ^a	13.0 ^a
	500	12.8 ^a	13.5 ^a
	1000	13.2 ^a	13.4 ^a
Intimately mixed and agitated	250	12.9 ^a	13.1 ^a
	500	12.8 ^a	13.3 ^a
	1000	12.6 ^a	13.5 ^a
Surface placement	250	12.9 ^a	12.7 ^a
	500	13.8 ^b	13.8 ^b
	1000	14.1 ^b	14.0 ^b

[a] Each MC value is an average of four measurements, comprising duplicate oven MC measurements of duplicated drying treatments (fig. 1).

[b] For each drying method, values with the same alphabetical letter are not significantly different (p-value > 0.10).

capacities, was used to determine the actual adsorptive capacity of the silica gel packets when used to dry rough rice. The actual, in-rice adsorptive capacity of the packets was determined as the x-axis value, or assumed adsorptive capacity, that corresponded to the desired 12.5% rice MC on the y-axis, as illustrated in figure 4. Based on the procedure, the adsorptive capacity of the new silica gel packets required to dry Wells rice samples (18.1% and 19.6% initial MC) to the desired 12.5% MC was 24.6% and 24.0%, respectively (table 3).

After these same silica gel packets were regenerated once, the adsorptive capacity from the regression analysis for both lots (18.1 and 19.6% initial MCs) increased slightly from 24.6% to 27.0% and from 24.0% to 25.7%, respectively (table 3). The new desiccant packets presumably contained previously adsorbed moisture, which prevented them from adsorbing as much moisture from the rice samples as the once-regenerated packets. The moisture present in the new packets may have been adsorbed during opening and closing of the desiccant container. All moisture was speculated to have been evaporated during the first regeneration, resulting in an increased adsorptive capacity. Sturton et al. (1981) recommended oven drying of desiccant material prior to initial use to remove inadvertently adsorbed moisture. Initial oven drying would yield a more accurate and consistent adsorptive capacity value that would facilitate better estimation of desiccant masses (eq. 3), subsequently resulting in more accurate final product MCs. Following these findings, the adsorptive capacity of silica gel in rough rice was estimated to range between 25% and 27%.

Upon second and third regeneration, the adsorptive capacity of desiccant packets reduced significantly (p-value < 0.05). Examination of the twice- and thrice-regenerated packets showed that the integrity of the packet fabric was severely compromised to the extent that most packets became fragile and prone to tearing during handling. This may have compromised moisture permeability through the packet, resulting in the decrease in adsorptive capacity indicated in table 3.

EFFECT OF ROUGH RICE INITIAL MOISTURE CONTENT AND TEMPERATURE ON FINAL RICE MOISTURE CONTENT

The effects of initial rough rice MC and ambient temperature on the final MC of rice samples are shown in figure 5. As the initial MC of samples dried at a particular temperature increased, a consistent increasing or decreasing trend in final MCs was not apparent (fig. 5). Initial MC, therefore, did not have an effect on the final MC of rice samples dried using the silica gel packets. The average final MC of rice samples dried at 47°C (12.2%) was significantly less (p-value < 0.05) than that of samples dried at 10°C (12.7%) and 21°C (12.6%); there were no significant final MC differences between samples dried at 10°C and 21°C. The final MC difference between the 47°C samples and the 10°C and 21°C samples can be explained through grain desorption isotherm trends in that as air temperature increases for constant RHs, the grain equilibrium moisture content associated with the air decreases, causing rice at greater drying temperatures to reach lower final MCs. While the difference in final MC was nominal, this finding does prompt the need to control the surrounding temperature to some degree for research-scale drying.

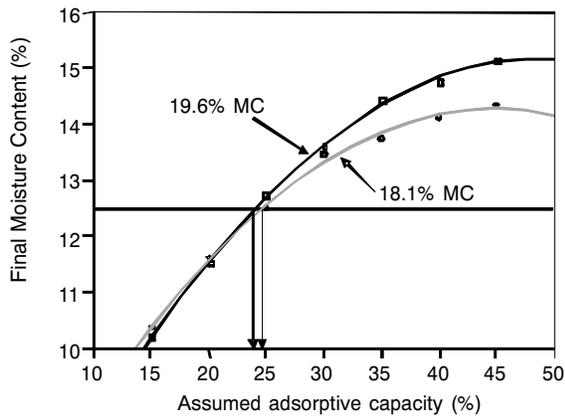


Figure 4. Illustration of technique for estimating the silica gel (Aridien Inc.[®]) adsorptive capacity to attain a 12.5% rice moisture content (MC). Final MCs were achieved by drying Wells rough rice samples at the indicated initial MCs using new silica gel packets, the mass of which was determined using a range of assumed adsorptive capacities. The final MCs are averages of four measurements, comprising duplicate oven MC measurements of duplicated drying treatments.

DRYING DURATION REQUIRED TO ATTAIN 12.5% MOISTURE CONTENT

Figure 6 shows the drying curves attained when drying Wells samples, initially at 18.1% and 19.6% MC, with intimately mixed silica gel packets and allowing to dry in plastic bags at 26°C. The EMCs of 12.6% and 13.2%, associated with the 18.1% and 19.6% initial-MC lots,

Table 3. Adsorptive capacities (%) of new, once-, twice-, and thrice-regenerated desiccant packets (Aridien Inc.[®]) used to dry 200-g Wells rough rice samples at the indicated initial moisture contents (MCs) to a final MC of 12.5%.

Initial MC ^[a]	New Desiccant Packets ^{[b][c]}	Once-regenerated Desiccant Packets	Twice-regenerated Desiccant Packets	Thrice-regenerated Desiccant Packets
18.1% MC	24.6 ^b	27.0 ^a	21.4 ^c	22.7 ^c
19.6% MC	24.0 ^b	25.7 ^a	22.1 ^c	20.9 ^c

[a] Adsorptive capacities were calculated from a regression of final rice MC against assumed adsorptive capacities (fig. 4).

[b] Desiccant packets were intimately mixed with rice samples, which were dried for eight days in a chamber maintained at 26°C.

[c] Values with the same alphabetical letter are not significantly different (p-value > 0.10).

respectively, were determined as asymptotic values of the Page equation (eq. 4). Results show significant moisture reductions within the first 24 h due to the low relative humidity created by the silica gel. Similar observations were reported by Zhangyong et al. (2002) and Sturton et al. (1981) who used silica gel and bentonite, respectively, to dry cereal grains. The moisture reduction rate gradually reduced as the silica gel approached saturation. From a practical standpoint, most drying had occurred within four to five days (fig. 6), as the MC of each lot was reduced to a level safe for storage (<13%) within this drying duration. Therefore, it is possible for silica gel-dried rough rice samples to reach a MC

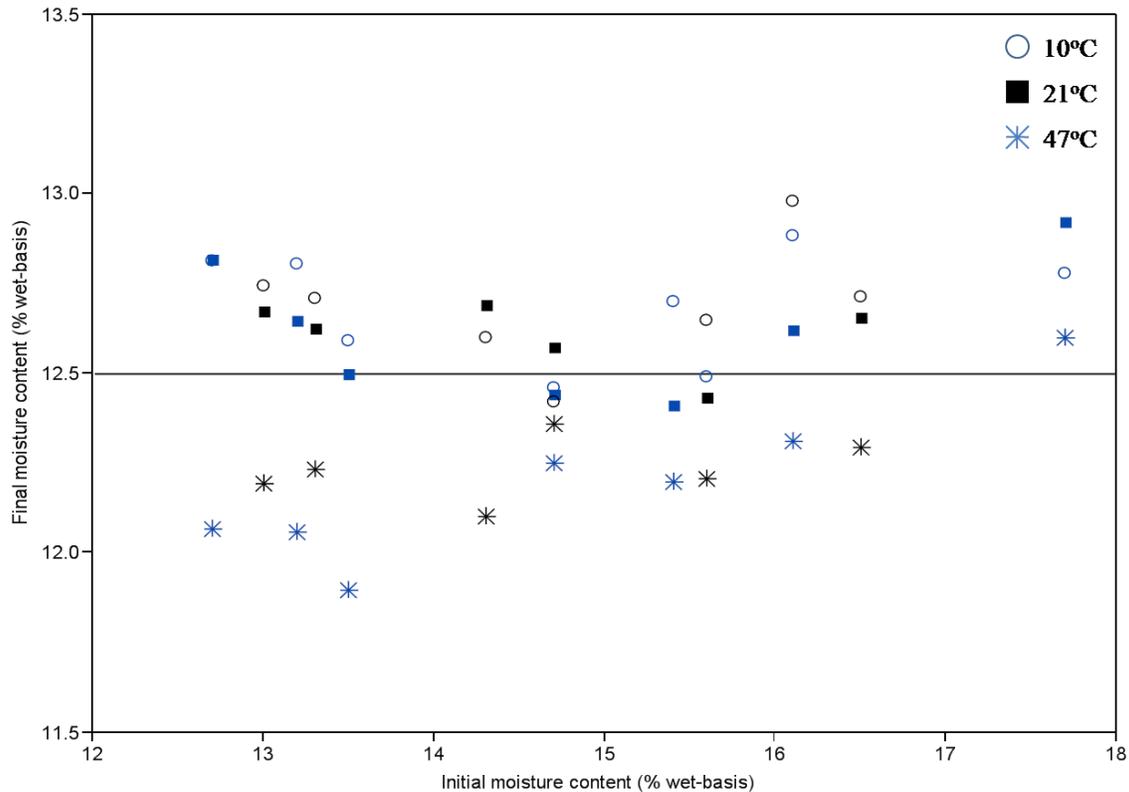


Figure 5. Effect of initial rough rice moisture content (MC) and drying temperature on the final MC of Wells lots when drying using an intimately mixed combination of 1- and 5-g silica gel packets (Aridien Inc.[®]) with an assumed adsorptive capacity of 26.6% for eight days. The final MCs are averages of four measurements, comprising duplicate oven MC measurements of duplicated drying treatments.

practically close to EMC within a reasonably short drying duration.

A greater final MC was observed for samples that were initially at 19.6% MC relative to those initially at 18.1% MC (fig. 6). The trend was not apparent in samples whose initial MCs were less than 17% (fig. 5). Mooney (1951) conducted adsorption studies using desiccants and found the adsorption curves to be dependent on the initial MC at which the adsorption was commenced. It is therefore possible that progressively greater amounts of silica gel are required to dry high MC (>18%) rice samples compared to that required to dry samples at a relatively lower MCs.

EFFECT OF SORPTION DRYING ON MILLING QUALITY OF ROUGH RICE

Milling quality results showed no significant differences (p -value >0.05) in HRYs between rice samples dried using silica gel packets and the air-dried controls (table 4). Sorption drying was conducted at 26°C, which minimized the possibility of milling quality deterioration (Sugunya et al., 2004).

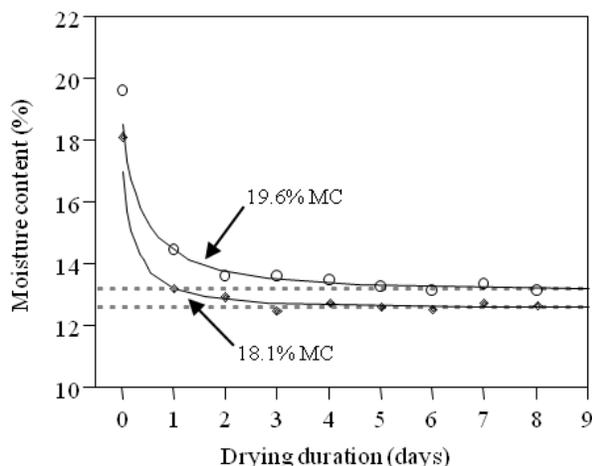


Figure 6. Moisture contents (MCs) of 200-g Wells rough rice samples initially at the indicated MCs during drying in plastic bags by silica gel packets (Aridien Inc.®) with an assumed adsorptive capacity of 26.6% and maintained in a chamber at 26°C. The final MCs are averages of four measurements, comprising duplicate oven MC measurements of duplicated drying treatments. The drying data is described by the Page equation using the nonlinear platform in JMP statistical software.

Table 4. Head rice yields of 200-g Wells rough rice samples, initially at the indicated initial moisture contents (MCs), dried for eight days using silica gel packets (Aridien Inc.®) in a chamber maintained at 26°C.^[a]

Drying Treatment	Head Rice Yield (%) ^[b]	
	18.1% MC	19.6% MC
Desiccant-dried	66.3 ^a	63.2 ^b
Control	65.5 ^a	63.4 ^b

^[a] Duplicate samples, gently dried at 26°C and 55% RH to 12.5% MC, were used as controls.

^[b] The HRYs are averages of four measurements, comprising duplicate HRY measurements of duplicated drying treatments. Values with the same alphabetical letter are not significantly different (p -value > 0.10).

SUMMARY

The investigation of using intimately-mixed 1- and 5-g silica gel packets for drying small samples of rough rice revealed the following:

- There were no significant differences in the final moisture content (MC) of samples dried in glass jars and plastic bags. Plastic bags are therefore deemed acceptable as drying containers.
- The intimately mixed (IM) and intimately mixed and agitated (IMA) desiccant placement methods were equally effective in drying samples to a consistent final MC, regardless of sample mass, up to 1 kg. The IM method is recommended as the optimum drying method for research samples because it is less laborious, requiring manual input at the beginning and end of drying.
- The adsorptive capacity of silica gel packets in closed samples of rough rice was established to range from 25% to 27%.
- The final MCs of samples dried at 47°C were significantly less (p -value < 0.05) than those of samples dried at 10°C and 21°C, which can be explained through grain desorption isotherm trends in that as air temperature increases for constant RHs, the grain equilibrium moisture content associated with the air decreases, causing rice at greater drying temperatures to reach lower final MCs. This finding does prompt the need to control the surrounding temperature to some degree for research-scale drying.
- Drying curves of Wells lots, initially at 19.6% and 18.1% MC, showed that MC can be reduced to safe storage levels within four to five days.
- Milling quality, measured as head rice yield (HRY), was not adversely affected by drying samples using the silica gel packets.

CONCLUSIONS

Drying small rice samples with silica gel packets would be convenient from the standpoint that drying could be carried out in relatively short durations at ambient conditions. Using the measured silica gel adsorptive capacities, the amount of desiccant to be added to samples to account for varying harvest MCs can be readily calculated to allow drying to desired storage MCs. As such, this drying method is deemed suitable for scientists who annually harvest and process numerous rice samples.

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