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STORAGE BEHAVIOR OF RICE AND RICE BRAN IN HERMETICALLY SEALED CONTAINER

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ABSTRACT

This paper discusses results of laboratory trials exploring benefits derived from hermetic storage of brown rice, milled rice at various milling degrees and rice bran. Thirty three glass jars containing one kilogram of rice and rice bran were used as hermetic storage vessels. Metal jar covers were modified to create a "closed circuit" for O_2 measurements. Initially, all samples were observed to have zero visible infestation since rice was freshly milled and rice bran samples were taken from the rice mills. After 3 to 6 months of storage, oxygen concentration in rice bran, brown rice, and regular milled rice dropped to 7.6%, 10.6% and 15.9%, respectively. Although these atmospheres were not sufficient to obtain complete mortality of insects, the modified atmosphere did retard insect growth and development as evidenced by weak and abnormal progenies of *Rhyzopertha dominica*. Rice quality was preserved throughout the storage period. Rice bran was observed to be insect-free and of acceptable quality after 180 days storage. The FFA content (oleic acid) of rice bran quickly increased from the initial 2.72% to 9.10% after 30 days of storage, then gradually increased to 11.85% after 180 days. According to Valdez, *et al.* (1987), after 60 days under normal warehouse storage the mean free fatty acid of rice bran is 55.37 %. The oil content of rice bran became rancid due to hydrolysis of fats through action of the enzyme lipase which catalyzes fat into free fatty acid and glycerin. Bran contains a substantial amount of rice germ, attracting storage insects, causing rapid infestation of the commodity. Based on these trials we found support to our hypothesis that rice, brown rice and rice bran may be stored under gas-tight hermetic conditions. The storage atmosphere is not only modified by insect metabolism but also through chemical oxygen depleting activity of these commodities.

INTRODUCTION

In the Philippines, cereals and its by-products are bagged and stored in warehouses at ambient conditions, which range from 29-33°C and 65-75% relative humidity. This is the conventional storage system where cereals are exposed to ambient air. Thus, paddy and its main products (brown rice or milled rice) and by-products are susceptible to insect attack and oxidation. Infestation diminishes the quality of the rice and its by-products; oxidation gives a rancid taste. When the rice and its by-products are exposed to the air for long periods, oxygen in the air oxidizes fats and oils primarily contained in the bran. The fats and oils are converted into free-fatty acids (FFA) giving the rice a rancid taste.

Hermetic storage has long been proven to be a good storage technique for cereals. In hermetic storage, oxygen concentration decreases after some time until it drops close to zero - an environment fatal to storage insects. In addition, the absence of oxygen is beneficial to rice and its by-products because oxidation of fats and oils will not take place. The decrease of oxygen concentration and formation of carbon dioxide is a result of the respiration of insects, molds and fungi, and other biological elements present in the hermetic storage.

Rice and its by-products are known to be susceptible to infestation. Moreover, the fats and oils predominantly contained in the bran are easily oxidized to form FFA. Thus, it is necessary to investigate if the concept of hermetic storage can be used to store rice at various milling degrees and its by-products.

Conventional storage has been the predominant system that the NFA employs in storing all its cereals and cereal by-products. In conventional storage, bagged grains and by-products are stacked and left exposed to ambient air, insects, rodents, and birds. After sometime in storage, grains loses weight from shrinkage due to evaporation of grain moisture to the surrounding air. Considerable grain weight is also lost due to consumption by insects, rodents, and birds. Even the judicious application of pest control measures cannot deter the growth of insect pest populations.

Hermetic storage prevents the exposure of grains to the surrounding air, insects, pests, molds and fungi, and other forms of biological elements. Hermetic storage is an air-tight sealed enclosure, preventing the entry and escape of gas. If insects and other biological elements are present, carbon dioxide is formed inside the hermetic storage due to their respiration, and the concentration of oxygen originally contained in hermetic storage lowers to near zero. There is an inverse relationship between the oxygen and carbon dioxide concentrations.

As the oxygen concentration decreases, the carbon dioxide concentration increases. The air-tight storage combined with the respiration of living elements in the storage creates an environment that is fatal to insects in the storage, preventing the growth of insect populations. Also, since oxygen is extremely low inside hermetic storage, oxidation of fats and oils in the cereals and by-products into free-fatty acids (FFA) is avoided.

The NFA has adopted hermetic storage of regularly milled rice in Volcani cubes, which has been proven to be an effective storage technique because growth of insects has been eliminated, storage loss has been minimized, and the quality of the rice including palatability has been maintained. However, the NFA has no information in its data bank about the characteristics of rice at various milling stages as well as its by-product when hermetically stored.

Rice and rice by-products are susceptible to insect attack. In conventional storage, the fats and oils which are predominantly contained in the bran are easily oxidized to form FFA. Thus, it is necessary to investigate if hermetic storage can be employed for rice and rice by-products.

Review of literature

Storage is the usual step in the normal pathway of rice from harvest to consumption. Rice is stored for different periods under diverse conditions, frequently uncontrolled and adverse. This brings about problems, the most important of which is spoilage. Of prime importance in this respect are microorganisms, insects, rodents and other pests, causing large losses of material and quality. Prevention of deterioration has received most efforts, and a major part of the investigation on storage has been directed toward developing a satisfactory and effective technology.

Storage has another important facet: it causes rice to age. Aging is a natural and spontaneous phenomenon involving changes in the physical and chemical characteristics of the rice that modify the cooking, processing, eating and nutritional qualities, and affect the commercial value of the grain. The many chemical constituents and enzymatic activities present in rice bring about a great variety of chemical and biochemical reactions. The storage situation is further complicated by the action of microorganisms, usual contaminants of rice. Depending on environmental conditions, storage time, and initial condition of the kernels, these reactions result in desirable or undesirable effects on the end product, both of which must be determined and controlled. Storage changes do not necessarily imply deterioration; they may take place well in advance of the development of off-odors, loss of flavor, or color fading. In fact, adequate storage brings about desirable changes in the properties and characteristics of rice; milled rice obtained from freshly harvested paddy is well known to be less suitable for both culinary and milling than rice which has been stored or aged prior to use.

As compared with color, the odor of milled rice changes very readily during storage. Barbers *et al.* and Primo *et al.* (in Houston, 1972) reported the development of off-odors within short periods in milled rice stored in sealed bottles and held under very mild conditions. Accumulation of volatile compounds in the intergranular air could have caused off-odors to be detected earlier. Yasumatsu (in Houston, 1972) reported noticeable flavor deterioration in polished rice (cooked samples) within 2 to 4 weeks' storage at room conditions. The presence of off-flavors in milled rice is more easily detected in cooked than in raw samples. The recent paper by Mitsuda *et al*. (in Houston, 1972) on volatile components of rice bran is of interest in this connection. Total amounts of volatile carbonyl compounds and its contents increased with storage time, the changes being associated with deterioration of unsaturated fatty acids.

Primo *et al.* and Barber *et al.* (in Houston, 1972) investigated the influence of temperature, moisture content and milling degree on the development of off-odors during airtight storage of milled rice. High temperature, high moisture content, and low milling degree enhance odor deterioration. That well-milled rice keeps better than under-milled rice has long been known. However, it should be pointed out that relatively small differences in milling degree might result in noticeable differences in lipid content and hydrolytic and oxidative enzymatic activities of the surface layer and consequently, in different stabilities.

Rice bran and polish are the by-products formed from the outer layers of the brown or husked rice kernel in milling it to produce white or milled rice. The descriptive term for bran suggested by the FAO is "a by-product from the milling of rice, consisting of the outer bran layers of the kernel with part of the germ" (Houston, 1972). Bran, as milled, also contains most of the germ and portions of the aleurone layer, together with bits of hull and starchy endosperm.

Ordinary rice bran is a light tan, slightly oily, unstable meal containing a wide range of particle sizes. The oily nature makes it rather cohesive and it can serve as a binder in feed compositions. One highly important bran property is the instability of the oil in the bran. In the milling process the active oil-splitting enzyme, lipase and the oil are released from their normally separate cellular containment and are intimately mixed. The result is a very rapid splitting of the fats and formation of free fatty acids; this is a hydrolytic type of rancidification. The free acids can then be acted upon more readily than the neutral oils by oxidative agents, with a resulting oxidative rancidity and the production of unpleasant odors and flavors. Prevention of this series of reactions must be either by deactivation of the lipase or a rapid separation of oil from the lipase; the oil is quite stable by itself, as is the bran after the oil is removed.

Degree of milling is the extent to which the bran layers and germ have been removed from the rice endosperm. A majority of consumers prefer well-milled rice with little or no bran adhering to the endosperm. Ironically, in countries where rice is the principal food, the preference is generally for well-milled rice, which is decreased in nutrient value since the proteins, fats, vitamins and minerals are concentrated in the germ and outer layer of the starchy endosperm. Furthermore, in rice that is over-milled, there is a reduction in both the total and whole-kernel milling yields, with a subsequent loss in market value.

In general, there are four degrees of milling: well-milled, reasonably well-milled, lightly -milled and under-milled. These descriptions are nebulous in that there is no precise definition for them. The FAO has recommended at least three degrees of milling: fully-milled, medium-milled and under-milled. These are defined, but again the descriptions are nebulous, since relative descriptive terms such as "the greater part of the inner bran layers" are used.

Objectives

General: To explore the benefits of hermetic storage that can be derived when storing brown rice, milled rice at various milling degrees, and rice bran.

Specific: To monitor the gas concentration in the hermetically sealed storage container which contains rice and rice bran.

To establish the effect of gas concentration to the quality characteristics of the commodities.

METHODOLOGY

Materials

The following materials were needed for the study:

- Paddy - mixed IR varieties
- Rice bran - fresh output from rice mill
- Copper tubing
- Stop Cocks
- Plastic tubing
- Glass jars with cover seal; 940 ml capacity
- Epoxy all purpose and silicon sealants

Procedure

The experiment used medium size bottles that contain about a kilogram or less of rice or bran as hermetic storage. The bottle covers were modified or redesigned to fit the connection for the oxygen meter. Two small holes were made at the middle of the covers. Copper tubes permanently attached to a stop cock with plastic tubes were inserted in each hole. The set-up served as access in measuring the gas concentration inside the well-sealed bottle. All purpose epoxy and silicon sealant were used in sealing the bottles/jars (attached experimental set-up).

Paddy samples were taken from the provinces of Isabela, Bulacan and Batangas/Mindoro Occidental. Figures 1 and 2 show the schematic diagrams on how the samples were prepared for the experiment. The Satake laboratory dehuller and ricemill were used to prepare the different commodities, i.e., brown rice (BR), regular milled rice (RMR), and well milled rice (WMR). Likewise, the rice bran samples were fresh output taken from the rice mills of the said provinces.

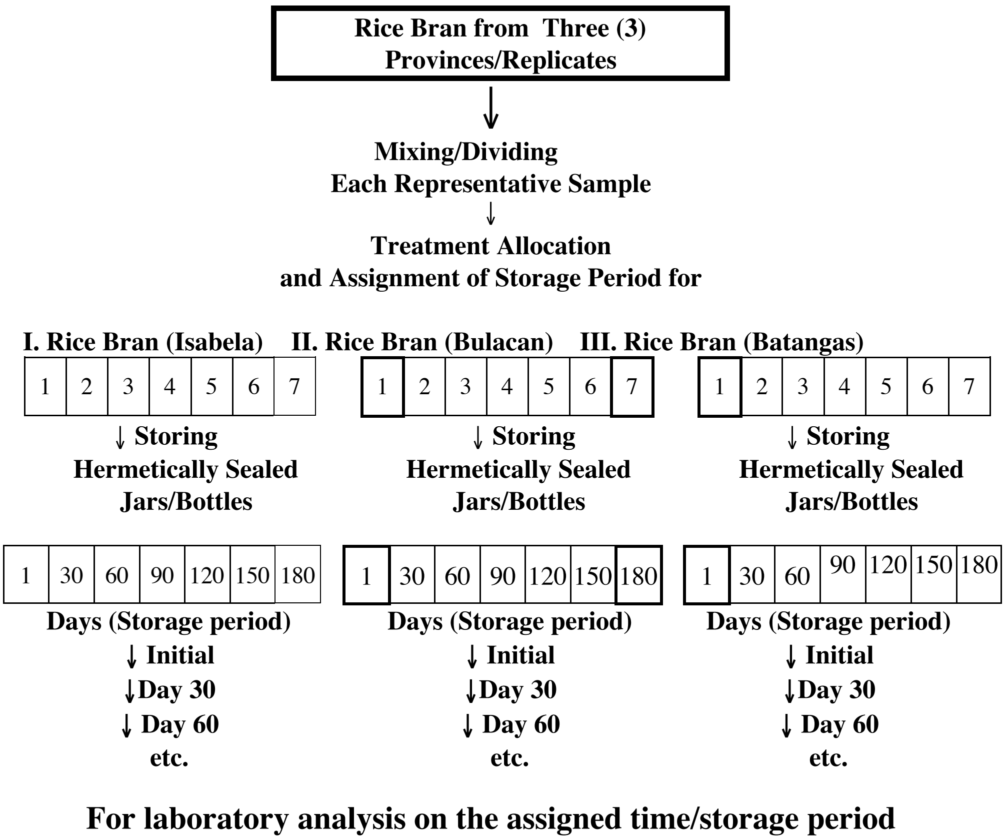

Figure 1. Preparation of bran samples

Rice Bran

Figure I shows the schematic diagram in the preparation of rice bran samples taken from the provinces of Isabela, Bulacan and Batangas. After thorough mixing and dividing each representative sample, treatment allocation is done, i.e., as Rice Bran I, II, III. Storage period was then assigned to the samples. The samples were immediately stored in the hermetically sealed jars/bottles, properly labeled with the assigned storage period.

The samples intended for 'day one' were immediately analyzed for moisture and free fatty acid contents as well as insect count/analysis to determine their initial quality/condition.

The remaining samples were then analyzed for the above parameters when their corresponding storage periods were reached.

The oxygen gas concentration of all the replicates were measured using the Oxy Chek 2 Analyzer initially and during the corresponding sampling period.

Regression and correlation analysis was also used to determine the relationship between FFA and storage period and between gas concentration and storage period.

Rice

The factors involved were milling degree and storage period. The milling degree includes brown rice (BR), regular milled rice (RMR) and well milled rice (WMR) . The storage periods were 7: days 1, 30, 60, 90, 120, 150 & 180. All the factors were replicated three times.

As shown in Figure 2, paddy samples taken from each province were mixed well and divided into 16 parts. The 16 samples were further divided for the milling degree treatment: 8 for brown rice, 4 for regular milled rice and the remaining 4 for well milled rice. Storage periods were then assigned to the samples after which all of them were dehulled to produce brown rice.

The 8 samples assigned for BR treatment were immediately stored in the hermetically sealed jars/bottles properly labeled with the assigned storage period. The remaining two sets of brown rice samples were further milled to produce RMR and WMR after which they were also stored in the hermetically sealed jars/bottles properly sealed with the assigned storage period.

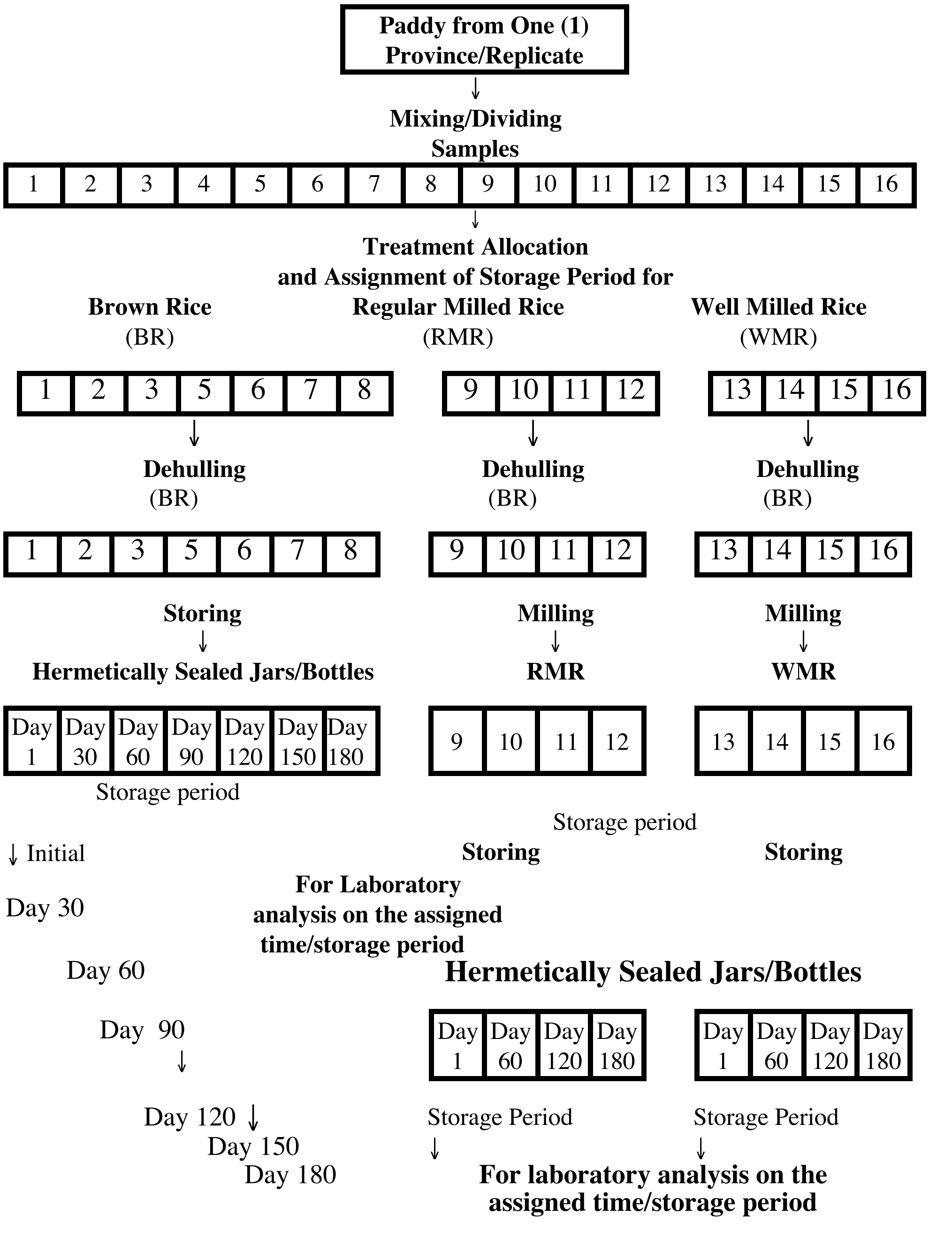

Figure 2. Preparation of rice samples

Note: The above diagram is followed for all the three (3) provinces. Drawn lots is used in treatment allocation and assignment of storage period.

The samples intended for day one were immediately analyzed for the following parameters to determine their initial quality/condition:

- % Free-fatty acids
- % Moisture Content
- % Discolored and Damaged grains
- Insect count
- Sensory evaluation of raw and cooked milled rice

The remaining samples were analyzed for the above mentioned parameters when their corresponding storage periods were reached; monthly for rice bran and brown rice and every other month or every 60 days for milled rice

The oxygen gas concentration of all the replicates was measured using the Oxy Chek 2 Analyzer (attached experimental set-up) during the corresponding sampling period.

Regression and correlation analysis was used to determine the degree of relationship, if any, between quality changes of rice and storage period and between gas concentration of the four commodities and storage period.

RESULTS AND DISCUSSION

The experiment was performed in the laboratory within a period of six months using rice bran and rice at various milling degrees. The results of the experiment are shown in Figures 3-9 and Tables 1-7.

Oxygen concentration

Figure 3 and Tables 1a and 1b (Annex A) show the behavior of oxygen trapped in a hermetic storage that is filled with milled rice or rice bran. Initially, the bottles used as hermetic storage for the four commodities recorded an oxygen concentration of 21%. The air is composed primarily of two components: 79% nitrogen and 21% oxygen. Thus, the bottles that were used as hermetic storage initially exhibited an "internal" environment similar to its outside world - an environment that was practically suitable for living beings to survive.

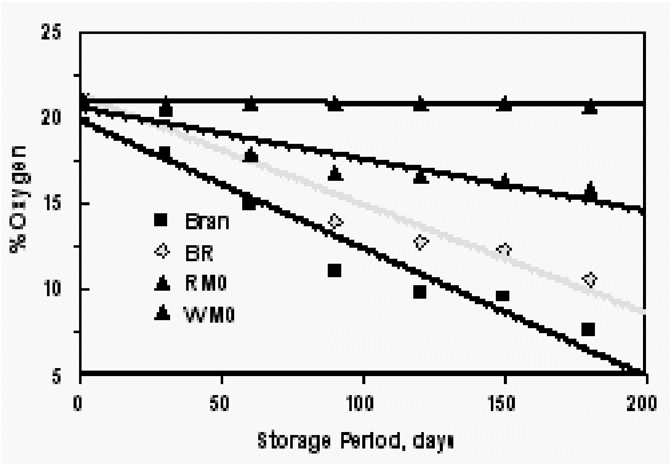

Figure 3. Changes in oxygen concentration during storage

From an initial concentration of 21%, the oxygen tended to decrease at prolonged storage and this was true for all the four stored commodities. Hence, the oxygen in hermetic storage has an inverse relationship with time. The regression coefficients shown in Table 1b were subjected to F-test to test their homogeneity. The same table shows that the regression coefficients are highly significantly different. Of the four commodities that were separately stored in tightly sealed containers, the oxygen in the bottle containing the rice bran was fastest to decrease as given by its regression coefficient of 0.0743, followed by the bottle containing brown rice with a regression coefficient of 0.0631, then the bottle with RMR at 0.0298. The oxygen found in the bottle containing WMR was slowest to decrease at a rate of 0.0014. The negative signs before the regression coefficients indicated that the oxygen concentration was decreasing within the bottles converted as hermetic storage.

The decreasing trend of oxygen concentration inside the bottles used as hermetic storage was primarily due to the presence of insects which were initially found in the sample. This means that there were some insects already present in the bran when initially placed inside the jars/bottles but were not detected by the naked eye. Insects are living beings that need oxygen in order to live. They helped consume the limited oxygen found inside the bottles until such time that the bottles were depleted of oxygen.

Another cause of the depletion of oxygen was the activation of the lipase enzyme which catalyzed or triggered the oil in the bran into free fatty acid and glycerin, and reacted with the oxygen. The bran component of the rice kernel contains the highest percentage of oil. This further explains why the oxygen concentration in the bottle containing the bran had the fastest rate of decrease among the four commodities while WMR, which has the least bran, had the slowest rate of decrease of oxygen concentration.

Effect of oxygen concentration on the quality of bran and milled rice

As has been discussed earlier, the oxygen concentration inside the sealed bottles decreased as the milled rice and bran were stored longer. This indicated that the oxygen was used up by or reacted with the commodities as well as other biological elements present inside the gas-tight bottles.

Chemical analysis

The four commodities were subjected to chemical analysis. Only two specific chemical analyses were done. These were the free-fatty acids and moisture contents.

Free Fatty Acid: Most of the fats found in a grain of rice is found in its bran layers. When the bran layers that are intact on the grain are scratched, its fats react with the oxygen in the air thereby causing fat degradation which ultimately turns the fats into free fatty acids. The process is called oxidation. When the bran layers are removed from the endosperm through milling, the oxidation process becomes faster and lot easier.

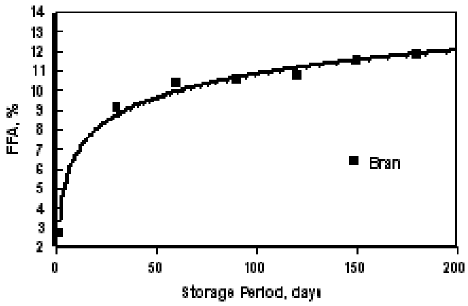

Figure 4a. Free fatty acids of bran

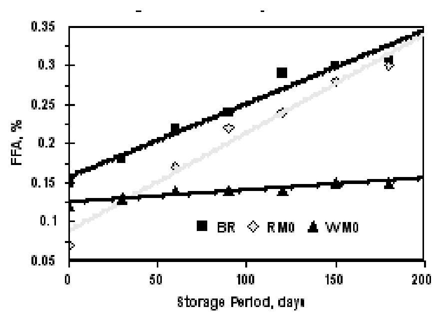

Figure 4b. Free fatty acids of rice

Figures 4a and 4b as well as Tables 2a and 2b (Annex A) display the behavior of free fatty acids found in milled rice and bran under hermetic storage. Figure 4a shows that the bran has a logarithmic pattern of its FFA. The logarithmic pattern is attributed to the rapid increase of FFA through the first 30 days of storage, after which the increase gradually slowed during the rest of the storage period. The FFA found in rice bran kept in hermetic storage has a rate of increase of 1.73. This is a very slow rate as compared to the rate of 8.38 of bran in conventional storage, (Valdez *et al.*, 1987; Tampoc *et al.*, 1990) also found in Table 2b. Thus, the enzymatic degradation of fats into FFA occurs at a very slow pace when the bran is stored in hermetic storage. This happens because the oxygen inside the hermetic storage keeps diminishing (Figure 3) compared to the oxygen inside a conventional warehouse which remains constant at about 21%.

On the other hand, BR, RMR, and WMR in Figure 4b show a direct linear trend. Their rates of increase as given by their respective slopes or regression coefficients are not significantly different based from the F-test done in verifying their homogeneity. However, the rates of increase of FFA in bran and rice under hermetic storage are slower compared to those in conventional storage as proven by their lower regression coefficients. (Table 2b).

Moisture Content: Figure 5 and Table 3 show the moisture content behavior of the four commodities. All have moisture contents lower than the maximum limit of 14%. Furthermore, all the commodities exhibit a decreasing moisture trend as storage increases, meaning they were losing some of their moisture content.

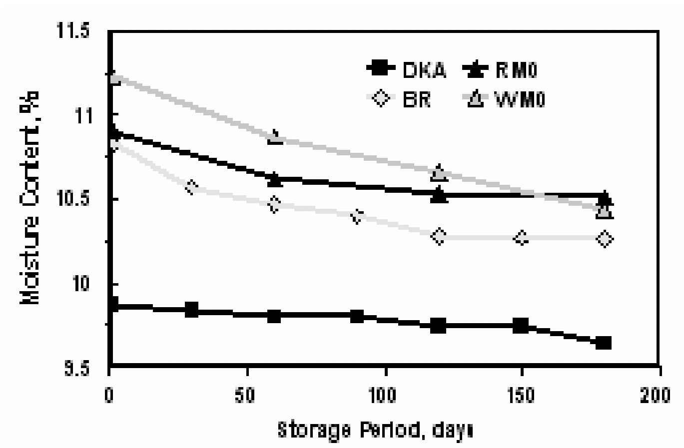

Figure 5. Mean moisture content during storage

Physical analysis

Physical quality of rice stored in hermetic storage was also determined to find out the rate of change. Specific physical qualities that were measured were discolored and damaged grains.

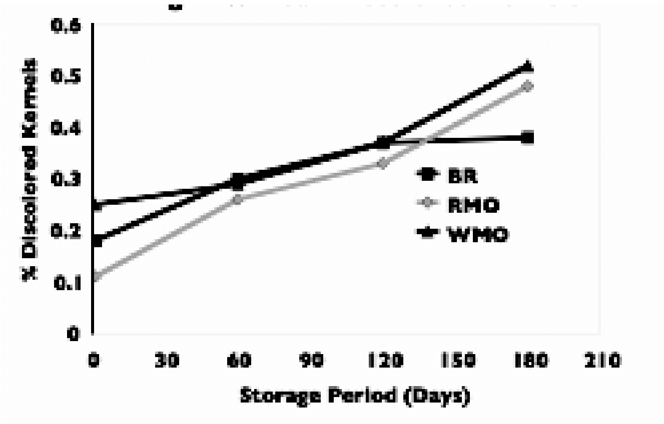

Figure 6. Percentage mean discolored kernels

Discolored Kernels: Table 4 in Annex A shows the values obtained for % discolored kernels for the three milling conditions of rice. It was observed that there was minimal increase in discolored kernels as the storage period progressed (Figure 6). Moreover, the values obtained were considerably lower than the maximum limit of 3.5% discolored and damaged kernels for good quality grains. The 3.5% maximum limit is the standard specification required by the country for good quality rice.

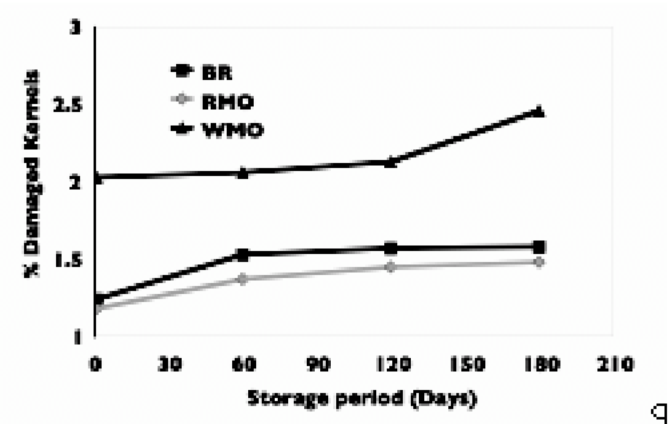

Figure 7. Percentage mean damaged kernels

Damaged Kernels: Figure 7 shows the trend of the % mean damaged kernels of all the rice commodities. Table 5 in Annex A shows the values obtained from day 1 to day 180. It was observed from the data taken that there was a minimal increase in the % damaged kernels as the storage period increased. The total of discolored and damaged grains at a given time of storage was still within the maximum limit of 3.5%. It could be noted that all the rice was still in good quality condition after 180 days in hermetic storage.

Insect count /analysis

It was observed that during the initial sampling and analysis of samples for presence of insects/infestation, all the rice bran and rice samples (BR, RMR, WMR) were insect-free and of acceptable quality. The presence of insects was visually determined.

Insect infestation, one of the major problems in storage, is effectively controlled inside the hermetically sealed container. During the monthly sampling, particularly for rice bran, few dead insects were seen inside the hermetic storage jars. This means that there were some insects present in the bran when initially placed inside the jars/bottles but was not detected by the naked eye. These insects were eventually killed by the low oxygen level under hermetic conditions inside the container.

All rice samples (BR, RMR, WMR), however, were observed to be insect-free during every designated sampling period.

Sensory evaluation of milled rice

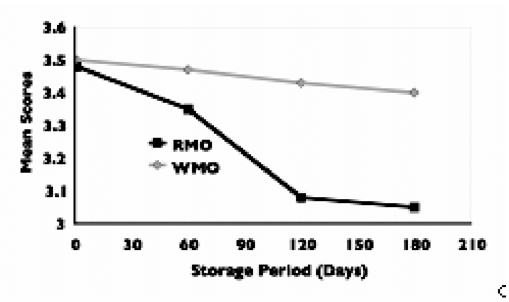

Figure 8a. Sensory evaluation of raw rice/whiteness

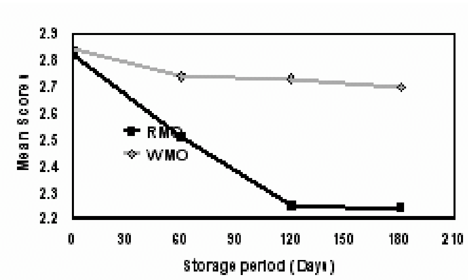

Figure 8b. Sensory evaluation of raw rice/glossines

Raw Rice: Tables 6 (Annex A) and Figures 8a to 8c respectively present the mean sensory scores and trend for appearance, glossiness and odor for raw or uncooked regular (RMR) and well milled (WMR) rices. Scores for both types of milled rice fell within the GOOD rating for whiteness and were maintained up to the 180th day of storage. However, RMR tended to have a faster rate of decrease in its score for appearance compared to WMR. This was caused by the presence of more bran streaks on the RMR. Contrarily, the glossiness of both rice milling stages were rated FAIR but was likewise maintained throughout the 180 days storage period. The trend was similar to their whiteness - RMR had a faster rate of decrease in its sensory score for whiteness than the WMR because RMR had more bran streaks than WMR.

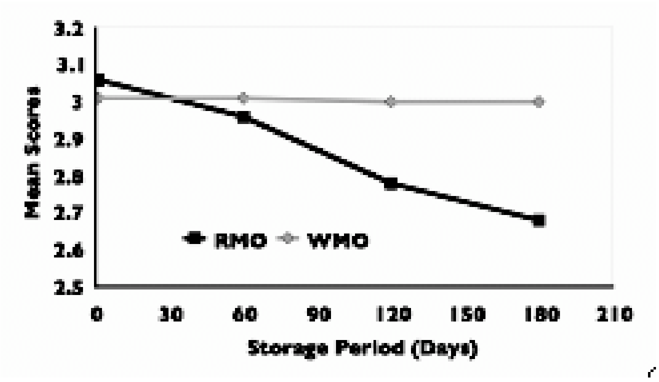

Figure 8c. Sensory evaluation of raw rice/odor

On the other hand, both rice types initially exhibited the same GOOD odor. But after several days in storage, RMR scores fell to FAIR ratings while WMR still retained GOOD ratings. This could be due to the formation of FFA which caused rancidity that affected the odor of RMR which contained more bran streaks than the WMR. Although the regression coefficients of RMR and WMR are not significantly different as shown in Table 2b, still it is clear in Figure 4b that the rate of increase of FFA for RMR is faster than that of WMR.

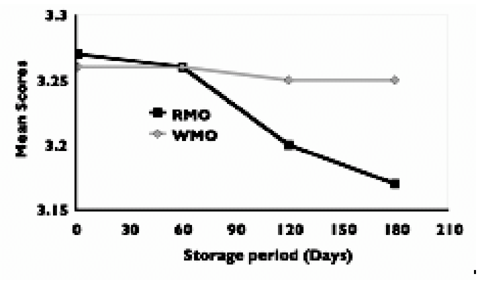

Figure 9a. Sensory evaluation of cooked rice/odor

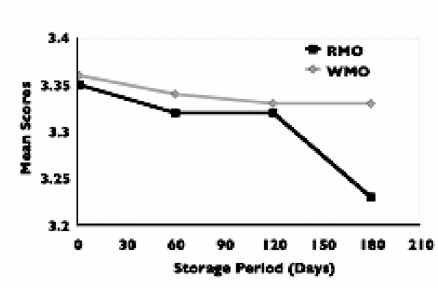

Figure 9b. Sensory evaluation of cooked rice/taste

Cooked Rice: Table 7 (Annex A) and Figures 9a to 9e respectively show the mean sensory scores and trend for odor, taste, tenderness, cohesiveness, and appearance of cooked RMR and WMR. The odor of both rice milling types remained GOOD throughout the 180 days storage period when cooked. While the odor of raw and cooked WMR remained GOOD through 180 days, the odor of uncooked RMR declined from GOOD to FAIR ratings, but after cooking it retained GOOD scores. The maintained GOOD score for cooked RMR could be attributed to the process of cooking which needed pre-washing of the rice before cooking. This process removed most of the bran found on the surface of the grain thereby cleaning the grain before cooking. Thus, the rancid smell from the FFA in the bran was removed.

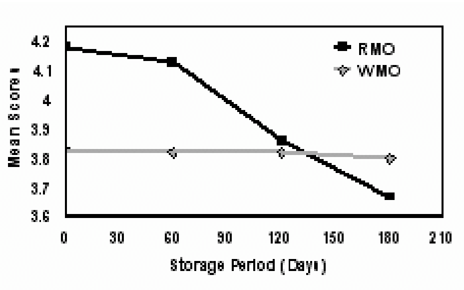

Figure 9c. Sensory evaluation of cooked rice/tenderness

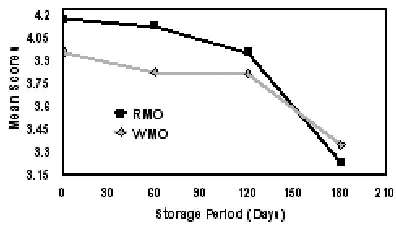

Figure 9d. Sensory evaluation of cooked rice/cohesiveness

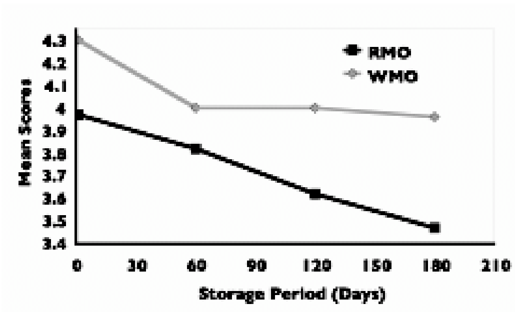

Figure 9e. Sensory evaluation of cooked rice/appearance

The taste of both milled levels of cooked rice remained GOOD and did not change as storage period was prolonged.

Tenderness measures the softness or hardness of rice, while *cohesiveness* is the degree to which the grains deform or break when separated with fork or chewed.

WMR initially obtained GOOD ratings for both tenderness and cohesiveness compared to VERY GOOD ratings of RMR. The 'very good' ratings of RMR could be related to its water absorption. RMR has more capacity to absorb water because of larger grain surface area which is retained after milling compared to WMR.

When it comes to appearance, WMR received VERY GOOD ratings while RMR showed GOOD ratings. Again, the primary factor for a very good rating of WMR was its lesser or minimal bran streaks found on its surface. But the rating values obtained in tenderness and cohesiveness were very close to the limits between GOOD and VERY GOOD ratings.

CONCLUSIONS

Conventional storage is the most common storage system practiced by the NFA in storing grains or cereals. It employs piling of bagged grains inside warehouse structures with typical ambient conditions of 29-33°C and 65-75% relative humidity. These conditions are well suited for storage insects to proliferate. Even careful application of chemical pest control measures could not deter the propagation of insects.

Hermetic storage proves to be a better storage system for cereals based on the results of this study. Because of the respiration of insects as well as the activation of the lipase enzyme which also needs the limited oxygen gas inside the hermetic storage, the oxygen therefore tends to be depleted providing an environment which is fatal to insects. Since more oil and insects were present in the rice bran, the gas-tight jar containing the bran had the fastest rate of oxygen depletion a rate of 0.0743% per hour, next was the container filled with brown rice at 0.0631%, followed by the container with regular milled rice at 0.0298% and the least was the container with well milled rice at 0.0014% per hour. Brown rice was second to rice bran because its bran layers were still intact which could hardly be penetrated by the limited oxygen present in the gas-tight container.

The activation of the lipase enzyme through the aid of oxygen triggers the oil in the bran into free fatty acid. Among the four commodities tested, the rice bran has the fastest rate of increase of free fatty acids at a rate of 1.73%. However, this is a very slow rate compared to that stored in conventional storage with a rate of 8.38% (Valdez *et al.*, 1987; Tampoc *et al.*, 1990). Thus, the enzymatic degradation of fats into free fatty acids is at a slow pace when the bran is stored in hermetic containers.

The quality of the regular milled rice as well as the well milled rice was kept below the maximum limit of 3.5% discolored and damaged grains.

Although insects were not visually found in the four commodities at the start of the experiment, a few dead insects were found during the monthly sampling and analysis of the rice bran. This indicated that insect eggs could have been initially present, hatched, but could not withstand the very low composition of oxygen inside the gas-tight container. Contrarily, the paddy rice samples were observed to be insect-free all throughout the 180 days of storage.

The sensory evaluation of the regular milled and well milled rice, in its raw or cooked form, were generally maintained within the 180 days storage period. Thus, the quality of the brown rice, regular milled rice, and well milled rice was preserved in a gas tight storage while the rate of deterioration of the bran was delayed.

RECOMMENDATION

It has been proven that the rice at various degrees of milling as well as its bran by-product can be more safely stored in gas-tight containers. The rate of deterioration of all stages of rice was at a slow rate. Thus, it is recommended that the NFA should conduct pilot storage tests in hermetic storage containers to save the grain losses and related costs. It is expected that insect-free grain stored in hermetic containers minimizes the application of pest control measures resulting to savings on chemicals. Moreover, insects could not proliferate in a gas-tight storage, hence there would be no grain losses incurred from the consumption by insects.

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ANNEX A

TABLE 1a

Percentage oxygen concentration

Storage Period, days	Rice Bran	BR - Brown Rice	RMR Regular Milled Rice	WMR Well-milled Rice
1	21.00	21.00	21.00	21.00
30	18.00	20.60	20.50	20.90
60	15.00	17.80	17.90	20.90
90	11.00	14.00	16.83	20.90
120	9.80	12.80	16.60	20.83
150	9.60	12.30	16.30	20.80
180	7.60	10.60	15.90	20.70

TABLE 1b

Regression equations for oxygen concentration

Commodity	Regression Equations	r^2	Homogeneity of Regression Coefficients F-value	Homogeneity of Regression Coefficients F-critical
Bran	Y = 19.8 - 0.0743 X	0.93	18.45 **	3.1 @ 5% level of significance 4.94 @ 1%
BR	Y = 21.3 - 0.0631 X	0.95		
RMR	Y = 20.6 - 0.0298 X	0.87		
WMR	Y = 21.0 - 0.0014 X	0.90		

Y = % Oxygen Concentration; ** - highly significant; X = Storage Period, days; r^2 - coefficient of determination

TABLE 2a

Free fatty acid content

Storage Period, days	Rice Bran	BR	RMR	WMR
1	2.72	0.15	0.07	0.12
30	9.10	0.18	0.13	0.13
60	10.37	0.22	0.17	0.14
90	10.55	0.24	0.22	0.14
120	10.77	0.29	0.24	0.14
150	11.53	0.30	0.28	0.15
180	11.85	0.31	0.30	0.15

TABLE 2b
Regression equations for free fatty acids

	Regression Equation	r^2	F-value (homogeneity of regression coeff.)	Regression Equation	r^2
Bran	Y = 2.78 + 1.75 (ln X)	0.99		Y = 1.92 + 8.38 (ln X) [a]	0.85
BR	Y = 0.159 + 0.000921 X	0.96		Y = 9.37 + 0.0793 X [b]	0.87
RMR	Y = 0.0802 + 0.00127 X	0.98	**3.14** [ns]		
WMR	Y = 0.124 + 0.000151 X	0.85		Y = 15.4 + 0.397 X [b]	0.91

a - Regression Equation was computed based on change in FFA (Source: Compiled results of NFA studies) b - Source: Tan et al. (1990) ns - not significant

TABLE 3
Percentage moisture content

Storage Period	Rice Bran	BR	RMR	WMR
Day 1	9.87	10.83	10.90	11.22
Day 30	9.84	10.57	-	
Day 60	9.80	10.47	10.62	10.87
Day 90	9.80	10.40	-	
Day 120	9.74	10.28	10.53	10.66
Day 150	9.74	10.27	-	-
Day 180	9.64	10.26	10.51	10.44

TABLE 4
Percentage discolored kernels

Storage Period	BR	RMR	WMR
Day 1	0.18	0.11	0.25
Day 60	0.30	0.26	0.29
Day 120	0.37	0.33	0.37
Day 180	0.38	0.48	0.52

TABLE 5
Percentage damaged kernels

Storage Period	BR	RMR	WMR
Day 1	1.24	1.18	2.03
Day 60	1.53	1.37	2.06
Day 120	1.57	1.45	2.30
Day 180	1.58	1.48	2.46

TABLE 6
Mean sensory scores of raw rice

Storage	Whiteness		Glossiness		Odor	
Period	RMR	WMR	RMR	WMR	RMR	WMR
Day 1	3.48	3.50	2.82	2.84	3.06	3.01
Day 60	3.35	3.47	2.51	2.74	2.96	3.01
Day 120	3.08	3.43	2.25	2.73	2.78	3.00
Day 180	3.05	3.40	2.24	2.70	2.68	3.00

TABLE 7
Mean sensory scores of cooked rice

Storage	Odor		Taste		Tenderness		Cohesiveness		Appearance	
Period	RMR	WMR	RMR	WMR	RMR	WMR	RMR	WMR	RMR	WMR
Day 1	3.27	3.26	3.35	3.36	4.18	3.83	4.18	3.96	3.97	4.30
Day 60	3.26	3.26	3.32	3.34	4.13	3.82	4.13	3.83	3.82	4.00
Day 120	3.20	3.25	3.32	3.33	3.86	3.82	3.96	3.82	3.62	4.00
Day 180	3.17	3.25	3.23	3.33	3.67	3.80	3.23	3.35	3.47	3.96