Journal of Agricultural and Crop Research
Vol. 3(1), pp. 11-20, February 2015
ISSN: 2384-731X
Research Paper

Quality and acceptability of inert-atmosphere-metal-silo stored paddy rice as food and planting material

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Accepted 18th February, 2015

Abstract. Moisture content, mould growth, insect infestation, damage, seed and food utilizability of NERICA variety of Paddy rice from Baddegi were investigated during storage in inert-atmosphere-metal-silo at Nigerian Stored Products Research Institute, Ibadan over 24 months period. In the 24 months storage trial of paddy rice, the low moisture content (7.0 ± 0.0%), mould growth detection frequency (0%), insect infestation (0%) and damage (2%) at on-set of storage were maintained (to maximum moisture content of 8.6%, mould growth frequency of 0% and insect infestation of 0% in this study), but the high germination rate (88.2%) at on-set of storage was maintained high (≥85%) only for 3 months in storage. After 3 months' storage of paddy rice in Inert-Atmosphere-Metal-Silo, rapid decrease in germination rate down to 22% by the 12th month of storage was observed. However, the high acceptability of the stored paddy rice (8) as scored by processors or as desired on sale in markets by house wives for food were maintained in the 24 months storage. The limited mould growth, control of insect infestation and limited storability of paddy rice for seed in this silo at Ibadan have been discussed, with recommendation for caution in the use of the silo for long term storage of paddy rice for seeds in Nigeria in the present state of design, construction and accessory provisions. That, an effective cooling system would rather be required to enable prolong storage of paddy rice in Inert-Atmosphere-Metal-Silo for seeds.

Keywords: Paddy rice, inert-atmosphere-metal-silo, moisture content, mould growth, insect infestation, germination rate, acceptability for food rice.

Abbreviations: IAMS, Inert-atmosphere-metal-silo; **NSPRI,** Nigerian Stored Products Research Institute; **FAO,** Food and Agricultural Organization of the United Nations; **CBN,** Central Bank of Nigeria.

INTRODUCTION

Rice is an important staple for about 60% of world population (Kush and Chowdhury, 1981; Spore, 2005). In Nigeria, rice has become particularly very important, as a staple. It is a convenient food in every home and an important ceremonial food in urban and rural areas. Up to the early 1960s, rice was essentially a ceremonial food eaten mainly at festivals, like Christmas in Nigeria. However, rice is now used for food and non-food products (Agu and Michael-Agwuoke, 2012). Ayernor and Ocloo (2007) also reported that rice, in its relative availability compared to barley and sorghum in Ghana, are malted in brewing industries as alternative to barley and sorghum.

Paddy rice is generally processed into food rice; which exists in the markets as White and Brown food rice. Apart from being processed to food rice or malting in breweries, paddy rice is also the planting material for cultivation of rice. FAO (2000) included Nigeria in the list of 15 major countries of the world that produce rice. Nigeria's 46% rice production in West Africa is by far the largest in the region, ahead of other major producing countries like Cote d' Ivoire and Sierra Leone (FAO, 2007). Nigeria's rice production which though has been on the increase up to 6 folds in 30 years (Fashola et al., 2007), was low in yield index of 42% behind India's 68% and China's 142% yield indices (FAO, 2000), which showed possibility of increasing Nigeria's rice production. Nigeria's increased rice production was up to 3.6 mt between years 2000 and 2005 (Fashola et al., 2007), but even more production is required to enable self sufficiency of Nigeria. In the subsequent lower 2.8 mt national preproduction level of rice, CBN (2011) reported Nigeria's importation of 1.6 mt of rice to meet the shortfall of demand. This dipped into Nigeria's foreign reserve by as much as Three Billions US Dollars ($3,000,000,000).

Nigeria became the largest importer of rice; not only in the West Africa but in the whole world since 2004, when it overtook Indonesia which has now become self-sufficient. Nigeria's high importation of rice is not surprising, with the known demand of Nigerians for rice as a staple and increasing population, but this high level of importation of rice is becoming a drain on Nigeria's foreign exchange reserve. The high demand for rice in Nigeria is a justification for seeking increase in rice production, such as by improving cultivation practice and land area cultivated. Also, there is need for proper conservation of rice production, by improve storage techniques to prevent or minimize losses that may be due to or caused by mould growth and development effects and or insect infestation. These efforts have become very important for Nigeria to attain food security.

The Agricultural Transformation Agenda of the Federal Government of Nigeria hoped to increase production of rice to 7 mt by this 2015. However, achievement of food security goal of the Government, strategically also include concern for storage of paddy rice for food rice and as planting material. Thus, it is important to ascertain the effectiveness of recommendable storage structures, their suitability and influencing factors, including effect of air tightness, gas composition, and temperature on quality of paddy rice and safe storage against mould growth, insect infestation and germination rate of paddy rice. This is because management requirement for quality parameters and influencing factors, including dryness of paddy rice, nature of packaging material or container and storage conditions are known and compliance of proposed recommendations need to be tested and limitation established.

IRRI (2009) reported that although the harvesting of rice at 20 to 22% moisture content is the recommended to enable drying to safe moisture content and limit field losses, paddy rice is harvested at 16 to 26% moisture contents, with consequent field losses and risk or difficulty of drying paddy rice adequately to safe moisture level. Donahaye et al. (2001) and Alam et al. (2009) noted that the critical moisture content for storage of paddy rice ranged from 12 to 14%, depending on the prevalent temperature and relative humidity. Similarly, IRRI (2009) reported that adequate drying of paddy rice to 12% was suitable for prolonged storage while 14% moisture content was recommendable only for short term storage. Further, Ren-Yong et al. (1990) reported that drying and storage were the most critical post harvest operations for rice loss prevention. Chanpagne et al. (2004) stressed the importance of timely reduction of moisture of harvested paddy rice to prevent mouldiness. Achievement of drying of harvested paddy to safe level within 24 h is indicated as the desired, but it was noted that achievement depends on the initial moisture content and the capacity of dryer.

Mettanada (2005) reported that storage condition and packaging materials are important factors in maintaining paddy seeds' viability. Joao and Lovato (1999) had also noted that 25°C and 65% relative humidity conditions as optimal for storage of many seeds. Akinnusi et al. (1984) and Donahaye et al. (2001) reported that diurnal changes in temperature between night and day influenced condition of storage depending on storage material. Heating of the top 10 cm paddy rice to 55°C in outdoor hermetic sealed bulk bag storage in 'Volcani Cubes' in Israel without consequences was noted, but it caused moisture migration effect in the more humid Sri Lanka and Philippine; and so needed accessories and space costs to correct against moisture increase and mould growth on rice.

Tapa people of Kwara and Niger States and the Egba and Ijebu people in Ogun State are some of the renowned groups involved in the cultivation and processing of rice in Nigeria. It was considered that acceptability of paddy rice for food rice could be different from the acceptability as seed for planting. Meanwhile, moisture content, mould growth, insect infestation, germination rate as well as storage conditions of temperature, relative humidity, gas composition and pesticides are parameters considered relevant for determination and interpretation of quality of stored paddy rice for uses. Also, Mettanada (2005) reported variable responses of seed types to moisture increases or high moisture in an atmosphere, but noted that storage temperature and relative humidity were important parameters determining seed viability of crops in storage. At 85% germination rate benchmark for acceptability of seeds, storability of paddy rice for only 5 months (in warehouse with Aluminum foil layer beneath the roofing sheets to reduce store temperature by 7°C) was considered poor. On the other hand, paddy rice stored in conventional warehouse with more aeration which maintained acceptable germination rate of ≥85% for up to 8 months, was considered satisfactory (Mettananda et al., 2002). These workers observed that 18 to 20°C and 50 to 60% relative humidity conditions considered ideal for storage of many seeds were lower than ambient conditions in Sri Lanka. These ideal storage conditions are also lower than can be expected generally in Ibadan, Nigeria.

Ibadan is classified as a warm moderately humid area in Nigeria. The prevalence of diurnal changes in temperature between night and day has been recognized as characteristic of most parts of Nigeria. Akinnusi et al. (1984) observed high differential between stored maize temperatures during the day and night in Inert-Atmosphere-Metal-Silos (IAMS) without shed as contrasted to under a shed. The hot afternoon in Nigeria was the reason for painting the metal silo at NSPRI Ibadan white to limit heat absorption. Also, palm fronds, grass thatch and mats have been considered for insulating metal silos from heat of sun rays at the top of metal silo. However, these insulation measures have not been of lasting effect in the associated poor durability of the materials under Nigeria's weather breaking down effect.

However, Inert-atmosphere-metal-silo (IAMS) has been used for storage of Maize (Oyeniran et al., 1983; Akinnusi et al., 1984) for 4 years, 1981 to 1984 and Cowpeas for 2 years, 2006 to 2008 at NSPRI Ibadan. Reports were that IAMS was effective for storage of maize and cowpeas meant for food as well as for seeds. The "non-chemical pesticide" nature of mechanism of pest control in IAMS technology remained uniquely attractive for safe insect infestation control for bulked stored grains, against misuse and abuse of chemical pesticides. Hence, it was the desire of the institute to investigate the appropriateness of extending the use of IAMS technology to storage of paddy rice for seed and for food rice in Nigeria. Since storage of paddy rice to limit losses of planting material and for ensuring availability of food rice remains strategic for Nigeria's rice production interest and necessary conservation of production in the food security agenda, possible role or suitability of the use of IAMS for bulk storage of paddy rice for food rice and as seeds was investigated over 24 months.

MATERIALS AND METHODS

Procurement of paddy rice and improved warehouse used for temporary holding

Four hundred and fifty (450) 100Kg bags of paddy rice were procured from Baddegi in Niger state and transported in a trailer were received by manual off loading temporarily (within one month of receipt until loaded into IAMS for this storage trial) into Improved Warehouse at NSPRI Ibadan. The improved warehouse used for temporary holding of procured paddy rice was designed and constructed to be flood and leak proof with tight closing access door. The floor of improved warehouse is well cemented and provided with wooden pallets to prevent risk of moisture migration from the ground. The bags of paddy rice were stacked on the wooden pallets in the warehouse. Figure 1 shows receipt of bagged paddy rice transported by trailer from Baddegi to NSPRI Ibadan.

45 tones inert-atmosphere-metal-silo, the loading with paddy rice and subsequent purging off of air with nitrogen

A 45 tones capacity IAMS at NSPRI Ibadan was used for storage of paddy rice trial over 24 months. The metal silo painted white was designed and constructed to be air tight, and provided with tight fitting lidded top and bottom spouts for loading and discharge of grains respectively. The metal silo used was one of a pair of silos installed in batteries, but provided with piping with separating valves for target use as may be required for purging the air atmosphere with Nitrogen gas in a particular silo in use. The silo is also provided with a generator powered augur for mechanized loading with grains.

Figure 2 shows the mechanical loading of the received paddy rice by augur into the 45 tones capacity IAMS. Bagged paddy rice were carried manually from the temporary holding improved warehouse and discharged into the augur bin from where paddy rice was mechanically moved up the augur into the IAMS, under dry weather condition within 8 h. Next, the air in the interstitial spaces of paddy rice in the metal silo was purged off with Nitrogen from Gas Cylinder by piping under pressure for 1 h 30 min before closure of the valves. Complete purging to remove Oxygen from the storage container was at detection of bubbling in transparent water tank beside the silo into which the outlet pipe was led.

Sampling of Paddy rice from bags and metal silos for analysis

Initial sample of paddy rice was drawn at reception using sampling probe randomly on 30 of 450 bags stacked on pallets in improved warehouse. The 30 subsamples (each of about 1 kg) were bulked and quartered for duplicate sampling 100 g each for assessment and analysis of the initial quality parameters of paddy rice used for this investigation. Also, IAMS' top tight lid was opened to sample the stored paddy rice at intervals of storage, from the top, middle and bottom levels of the 45 ton metal silo by means of the silo's special sampling dip tool. The drawn subsamples (twice each of about 500 g) of stored paddy rice from top, middle and bottom of IAMS were bulked and quartered for duplicate sampling 100 g each for assessment and analysis of quality parameters of paddy rice.

Maintenance of nitrogen purged condition of inert-atmosphere-metal-silo

After each sampling of IAMS stored paddy rice, there was

Figure 1. Showing receipt of bagged paddy rice by manual carriage from trailer for temporary storage in improved warehouse, stacking on pallets at NSPRI Ibadan after transportation from Baddegi where it was procured by NSPRI in collaboration with NCRI Badegi in March 2010. [a]NSPRI = Nigerian Stored Products Research Institute; [b]NCRI = National Cereal Research Institute

re-purging with nitrogen gas again, to sustain exclusion of oxygen from the storage atmosphere following sampling at intervals for analysis (in a way that would be expected for continuous storage without sampling) in 30 min when the gas bubbling tank was observed.

Analyses of paddy rice samples

Paddy rice or processed rice samples were respectively assessed for acceptability on hedonic scale of 1 to 9 and analyzed for damage (%), moisture content (%), germination rate (%), insect infestation (%) and mould growth (%) as follow:

Acceptability scoring of paddy rice for purposes

Acceptability of paddy rice samples were assessed for by a panel of 5 processors in their experience by observation of appearance and scoring of quality for purpose (processing into food rice and food rice products) on the hedonic scale of 1 to 9 as described by Ihekoronye and Ngoddy (1985) and Munoz and King (2007) during storage. Respective scores by processors panel members for a sample were computed, average determined and rounded up to the nearer score as the Acceptability Score. Also, about 10Kg lots of 0, 12 and 24 months IAMS stored paddy rice were drawn and pro-

Figure 2. Mechanical loading of paddy rice into a 45 Tones capacity Inert-Atmosphere-Metal-Silo at NSPRI Ibadan in April 2010. [a]NSPRI = Nigerian Stored Products Research Institute.

cessed into food rice by hired processors, soaking in water overnight, parboiled to partially cooked, drained and sundried on NSPRI Solar Tent in 3 days, threshed and winnowed manually. The winnowed samples of proceed stored paddy rice, as bulked quartered stock were drawn in 1Kg sizes for panel of 5 house wives in their experiences by observation of appearance, to assess for acceptability of food rice quality on the hedonic scale of 1 to 9 scores, as described by Ihekoronye and Ngoddy (1985) and Munoz and King (2007). Respective scores of acceptability of food rice by panel members were computed for determination of average score, which was rounded up to the nearer hedonic score for sample.

Assessment of damage of paddy rice

Damage of paddy rice was evaluated by weight difference of damaged portion as sorted in duplicate weighed samples. Results of damage portions was expressed as percentages of the weighted samples and computed for mean of duplicate samples (IRRI, 2009).

Moisture content of paddy rice sample

Moisture contents of samples of paddy rice were determined by the oven method as reported by Zareiforoush et al. (2010). Duplicate 10 g samples, (being analytical samples from bulked, quartered sample at intervals of analysis) in drying cans were oven dried to constant weights at 103°C in 48 h. Moisture content of sample was computed from weight loss expressed as percentage of weighted sample dried and mean for duplicate samples was computed.

Determination of mould growth on paddy rice sample

Mould growth on paddy rice in 10 sub-lots in petri dishes from of bulked and quartered sample were examined visually and by means of Stereomicroscope for detection of visible mould growths on the scale of 0 to 4 in which 0 = No visible mould growth, 1 = 1 to 10%, 2 = 11 to 25%, 3 = 26 to 50%, and 4 = more than 50% of paddy, as according to ICRISAT (1985) and Forbes et al. (1992). Frequency of detection from in 10 sub-lots per sample

Table 1. Quality parameters and acceptability of paddy rice used for storage trial in 45 ton IAMS at Ibadan.

Paddy rice	Damage (%)	Insect infestation (%)	Mould growth (%)	[c]Moisture content (%)	[d]Germination rate (%)	[e]Acceptability score (1- 9)	
						Seed	Food
[a] At receipt	2 ± 0.0	0	0	7. 0 ± 0.0	88.0 ± 1.14	8	8
[b] At loading	2 ± 0.0	0	0	7.6 ± 0.14	88.5 ± 0.71	8	8

[a]Sample of paddy rice at receipt in March 2010 for temporary storage in Improved Warehouse, prior to loading into Inert-Atmosphere-Metal-Silo within one month.
[b]Sample of paddy rice at loading into Inert-Atmosphere-Metal-Silo from bags held stacked on pallets in Improved Warehouse within one month.
[c]Moisture contents of paddy rice were much below the 12% safe moisture content.
[d]High germination rate maintained was comparable to 85% level, considered as acceptable seed viability level for use as planting material.
[e]Mean of Acceptability scores on the hedonic scale of 1 to 9 by a panel of 5 as rounded up to the nearer score.
[f]Damage, insect infestation and mould growth showed to be satisfactorily low and paddy rice was considered good for use for this investigation.

was expressed as percent = (x/10) × 100%.

Germination rate of paddy rice sample

Germination rate of paddy rice was determined according to ISTA (1996) and IRRI (2009), by plating 100 paddy rice ‘grains’, 10/plate in 10 plates on moist cotton wool in petri-dishes and incubated for 5 days at ambient in the laboratory cupboard. Duplicate sets of 10 plates each for plated paddy rice were visually examined on day 5 of incubation for detection of emergence of radicle and pulmle visually and by means of a stereomicroscope for germination. Germinated paddy seeds in a set of 10 plates were counted and germination rate, expressed in percentage of 100 plated paddy rice by summation in a set and mean ± SD for duplicate sets was computed.

Determination of Insect infestation of paddy rice

Insect infestation of paddy rice was determined by examining duplicate paddy rice samples visually and by means of a stereomicroscope to detect and count any living, dead insects or infestation sign on paddy rice in 10 sub-lots to indicate frequency of detection of insect infestation and expressed same as percentage for sample.

RESULTS AND DISCUSSION

Paddy rice received and loaded into the metal silo

Table 1 shows quality parameters of paddy rice as evaluated at receipt of procurement and following loading into IAMS. At receipt of the paddy rice, insect infestation and mould growth were both nil (0%). That is, insect infestation and moulds growth were not detected by visual observation, even with the aid of a stereomicroscope. The low damage level of the received paddy rice (2%) meant grade II in the specification of paddy under Agricultural Produce Grading and Marketing Act 1937. The moisture content of paddy rice at receipt was also very low (7.47%), since the safe moisture content for prolonged storage has been put at 12%. The germination rate (88.2%) of the procured paddy rice was also high, with benchmark for acceptability as seed put at 85%. Further, the high acceptability scores of 8 for paddy rice and 8 for food rice obtained from processing are indicative of high quality of procured paddy rice used for this investigation.

Limited drudgery of operation in augur loading of paddy rice into IAMS contrasts observation in earlier attempt at manual loading of IAMS with maize. The retained high quality of paddy rice from IAMS after temporary storage (within 1 month of receipt) showed suitability of holding measure prior to commencement of storage trial, for determination of effectiveness of IAMS for use in maintaining quality and acceptability of the stored paddy rice for uses (Table 1). The stock of NERICA variety of paddy rice used was described as being procured from the new season’s rice. This description explained the good quality suggested and confirmed in this study. The periods of preparation of paddy rice for this study coincided with dry season in Nigeria, which helped in enabling successful planning and implementation of procurement, transportation and loading into IAMS in good quality was worthy of note for related venture concerns.

Quality parameters and acceptability of IAMS stored paddy rice over 24 months

The satisfactorily good quality of paddy rice procured (March 2010) for this study was maintained over the temporary storage period until loaded into IAMS (in April 2010) for storage. Table 2 shows changes in quality parameters and acceptability of IAMS stored paddy rice over 24 months under climatic conditions in Ibadan.

Damage of IAMS stored paddy rice

Low damage rate (breakage level of 2%) of the paddy rice in IAMS was considered maintained (in the range of

Table 2. Changes in quality parameters and acceptability of paddy rice during storage in 45 ton IAMS at Ibadan.

Storage duration (months)	Damage (%)	Insect infestation (%)	Mould growth (%)	Moisture content (%)	Germination rate (%)	Acceptability score (1 - 9)	
						Paddy rice	Food rice
0 – April ’10	2.00 ± 0.00	0	0	7.60 ± 0.07	88.5 ± 2.1	8	8
1 – MAY’10	2.00 ± 0.00	0	0	7.90 ± 0.14	90.5 ± 2.1	8	
2 – JUNE’10		0	0	7.56 ± 0.07	87.0 ± 2.8	8	
3 – JULY’10	2.25 ± 0.35	0	0	7.90 ± 0.60	85.5 ± 0.7	8	
4 – AUG’10	2.25 ± 0.35						
5– SEPT’10	3.25 ± 0.35	0	0	8.08 ± 0.33	79.5 ± 2.1	8	
6 – OCT’10							
7 – NOV’10							
8 – DEC’10	3.25 ± 1.06	0	0	8.35 ± 0.20	58.5 ± 2.1	8	
9 – JAN ’11	3.00 ± 0.00	0	0	8.00± 0.10	56.5 ± 3.5	8	
10 – FEB ‘11	2.75 ± 0.35	0	0	8.00 ± 0.14	55.5 ± 2.1	8	
11 – MAR ’11	3.38 ± 0.18	0	0	8.40 ± 0.16	27.5 ± 4.2	8	
12 – APRIL ‘11	3.56 ± 0.30	0	0	8.50 ± 0.12	22.0 ± 2.8	8	8
24 – APRIL ‘12	3.50 ± 0.45	0	0	8.60 ± 0.08	ND	8	8

[a]Storage of paddy rice in IAMS reported was from April 2010 to April, 2012 in satisfactorily good condition for food rice, but not as long (only 3 months) for seed
[b]Samples were not drawn for determination of quality parameters in August 2010 due to industrial strike of technical assistants
[c]Samples were not drawn for determination of quality parameters in October and November 2010 due to prevalence of rain and high humidity, to prevent of wetting of the stored paddy rice.
[d]ND = Not determined further as per termination of analysis for germination rate which has long been established.
[e]The stored paddy rice remained satisfactorily acceptable for food rice over 24 months storage in IAMS and has in fact just discharged 2014 for processing into food rice.

2 to 4% level) during the 24 months’ storage as indicated in Table 2 and illustrated in Figure 1, but grading of paddy rice at damage level of 4% is grade III. The slight variation from initial may be related to the slight damage during the mechanical loading by augur, required to limit drudgery of loading the silo manually.

Moisture content of IAMS stored paddy rice

The moisture content of the IAMS stored paddy rice remained low in the range of 7.6 to 8.6% over the 24 months storage period (Table 2). These moisture levels are much lower than the 12% level recommended for prolong storage of paddy rice to prevent mould growth. In this respect, it should be mentioned that USAID (2009) advised that paddy rice intended as seed for planting should not be over dried, as may have been the case for stock used in this study. The retention of low moisture is not surprising in the air tightness that is associated with such closed structure filled with adequately dried paddy rice. Thus, the stored paddy rice should be safe from mouldiness. However, such low level of moisture would translate to quantity advantage for food rice buyers and processors.

Mould growth on paddy rice stored in IAMS

No mould growth was observed on the IAMS stored paddy rice throughout the 24 months storage in this study. This finding is consistent with expectation from the observation that moisture content of the stored paddy rice was maintained very low, much below the safe level (12%) prior to and during the 24 months storage in IAMS. The stored paddy rice maintained visual wholesomeness as shown in Figure 3 at 24 months of storage. It would be surprising and will represent a major loss of production effort, if such visibly wholesome paddy rice lost acceptability for use as food rice.

Insect infestation of IAMS stored paddy rice

Insect infestation was controlled on paddy rice stored in IAMS in 24 months storage. No life, dead or emergent insect was found on samples of paddy rice during this study (Table 1). Insect infestation of the IAMS stored paddy rice remained at 0% over the 24 months storage period. The insect infestation control in this study confirmed the insect infestation controlling effect of oxygen exclusion that resulted from the purging off of air

Figure 3. Appearance of the paddy rice throughout 24 month storage in IAMS, considered wholesome and scored 8 on the hedonic scale of acceptability on the scale of 1 to 9.

from IAMS atmosphere with nitrogen. The use of nitrogen, an ”inert gas” option, instead of the use of chemical pesticides to control insect infestation in the stored paddy is a solution to the problem of risks, misuse and abuse of chemical pesticides. Further, IAMS is structurally an effective barrier against activities rodents and insects following closure for air tightness. Just as insect infestation was effectively controlled in the IAMS, rodents also as aerobes would not also survive and in any case should not have access into IAMS as a solid structural barrier. Dryness of crop against mouldiness does not mean prevention of insect pest activity on crops, especially when the needed oxygen for respiration is available. The IAMS ensured control of insect infestation of adequately dried paddy rice, which also did not show mould growth.

Germination rate of paddy rice during storage in IAMS at Ibadan

Germinability of the stored paddy rice was maintained satisfactorily (≥85%) for 3 months in IAMS at Ibadan; with germination rate of 87% in July 2010. However, germination rate of the stored paddy rice subsequently decreased rapidly after 3 months to 68% in 6 months storage and further down to 22% by the 12th month of storage (Figure 4). This is an indication of limited tolerance of the stored NERICA paddy rice for maintenance of germination rate during storage in IAMS under warm climate prevalent in Ibadan. Day time temperature during this study in Ibadan must have generated high temperature in the IAMS, higher than the moderate temperatures 18 to 22°C or 25°C respectively reported by Mettananda (2005) and Joao and Lovato (1999) as recommendable for optimizing the storability of paddy rice at low relative humidity of 65%. Storage of paddy rice in warehouse with Aluminum foil layer beneath the roofing sheets in Sri Lanka, which similarly resulted in with rapid loss of germination rate (within 5 months) was considered poor, though with 7°C temperature reduction was achieved (Mettanada, 2005). In addition to the high moisture factor identified in the poor storage of paddy rice in Sri Lanka, the present study emphasized the adverse impact of high temperature on germination rate of paddy rice in IAMS in Ibadan**.** However, the very low moisture content at on-set of storage may have also impacted adversely on retention of germination rate. Rapid loss of germination rate of paddy rice observed in this study is different from report of prolonged maintenance of germination rate at high level (≥ 85%) in the same IAMS for Maize (Oyeniran et al., 1983; Akinnusi 1984). The present finding suggests that IAMS may only be recommendable for short term storage of paddy rice

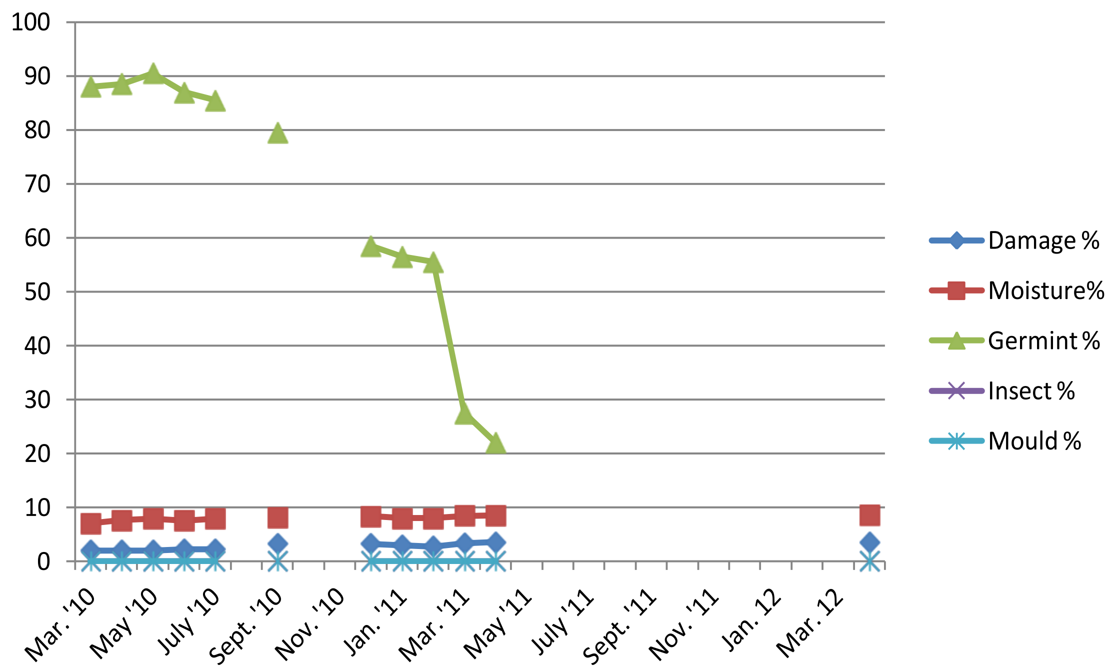

Figure 4. Quality parameters of paddy rice received and during storage in 45 Tons IAMS at NSPRI Ibadan.

(in the limit of 3 months) under warm tropical condition. However, the benefit of storage of paddy rice in IAMS for seed may increase if adequate modification is made to the design, fabrication of IAMS or accessories for temperature control in IAMS can be accommodated to maintain low temperature level within recommendations of 18 to 22°C or 25°C for optimizing storage of dried paddy rice in hermetic structure, such as IAMS that limit ingress of moisture into the storage atmosphere and limits release of moisture from content of silo out to the outside atmosphere of silo.

Germination showed obvious decreases after 3 months storage of paddy rice in IAMS until termination of the determination at 12 months storage. On the other hand, damage, moisture content, insect infestation and mould growth levels were maintained over 24 months storage.

Acceptability of IAMS stored paddy rice and of food rice processed from it

The acceptability of paddy rice stored in IAMS for up to 24 months (8) and that of food rice processed from it (8) were retained high. Given the general good appearance of the 24 months stored paddy rice and other associated quality parameters, especially the absence of mould growth (0%) and the low moisture content, much below the safe level of 12% it was pleasing that the IAMS stored paddy rice was suitable for use in processing into food rice, even when it was no longer useful as seed for planting. The IAMS has shown to be suitable for prolonged storage of well dried paddy rice for food rice, as were observed by earlier workers in NSPRI for maize (Oyeniran et al., 1983; Akinnusi, 1984).

CONCLUSION

No insect was detected on paddy rice stored for 24 months in IAMS at Ibadan, which showed the effectiveness of purging and re-purging to maintain exclusion of oxygen for controlling insect infestation. Mould growth was not detected, even with the aid of a stereomicroscope, on the IAMS stored paddy rice over 24 months storage because the moisture content was maintained low, much below the safe moisture content of 12% recommended for prolonged storage of paddy rice in the tropics. The control of mould growth is consistent with expectation for well dried paddy rice with moisture content maintained adequately low in the hermetic structure. The maintained visual wholesomeness of appearance of paddy rice throughout 24 months' storage in IAMS may be explained in terms of the maintained low moisture, no mould growth and no insect infestation, but the highly reduced germination rate after 3 months of storage called for caution, if such stored paddy rice was intended as seed for planting. However, provision or accessories that could enable low temperature within IAMS to 18 to 25°C could enable the maintenance of the germination rate of paddy rice in prolonged storage. This will increase the benefit of use of IAMS for storage of paddy rice not only for food rice but also for seeds beyond 3 months; possibly to extend shelf life to time of planting for rain fed rice cultivation.

ACKNOWLEDGEMENTS

We acknowledge the Management of Nigerian Stored Products Research Institute for procurement and delivery paddy rice to NSPRI Ibadan for this study. We appreciate the support of Ms. Ego. U Okonkwo, the Grains and Legumes Programme Leader for liaison function with Management and Engineers from the NSPRI Headquarters (Engr. Oyewole Shuaib and Engr. Omodara S.O) for professional function in installing and operating the augur used for loading paddy rice into IAMS, which limited drudgery. We also appreciate the technical services and assistance of technologists and technicians in the Institute for collection and analysis of samples and the maintenance of IAMS for this study.

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