

THE QUALITY CHANGES OF RICE STORED UNDER VACUUM CONDITIONS**

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Abstract

The National Logistics Agency (BULOG) the Government institution responsible for maintaining reserve food stocks-encountered problems of quality deterioration of milled rice during storage, primarily due to insect infestation and microbial infection. Previous efforts to control these problems have included use of fumigants and contact pesticides, however increased concern about pesticide residues and their impact on the environment has led to the search for alternative approaches, including the application of modified atmosphere technology. In this respect, BULOG has constructed an integrated vacuum container processing plant to store rice under low oxygen conditions (less than 2%).

A study was carried out to observe the effect of low oxygen on the quality of rice during prolonged storage. Rice was stored for 16 months, either inside or outside, in 18 specially designed polyethylene plastic containers (1,000 kg capacity per container) with an oxygen level of less than 2%. Changes were recorded in: moisture content; number of insects; level of fungal and yeast infections. and quality parameters such as proportion yellow rice, aroma, colour, and cooking factors.

The results revealed that lack of oxygen had a significant impact on the mortality of insects, and inhibited the development of fungi and yeast. The quality of rice was relatively unchanged after 16 months of storage-although, as the vacuum conditions decreased the moisture content of tile rice, it absorbed more water during cooking and the rice became less sticky and fluffy. Overall, the results indicated that vacuum containers could be used to maintain the quality of rice during long-term storage. However, this technology should be supported with selection of initial good quality rice prior to storage, and accurate planning regarding the length of storage-recognising that this technology is relatively expensive.

The Indonesian Government has consistently implemented a policy to ensure the availability of basic staple food commodities, particularly rice, at a stable and affordable price as an integral part of its food security policy. To realise the policy, the Government-through the National Logistics Agency (BULOG) maintains an adequate strategic food reserve, to counter price fluctuations during the year and food shortages due to production failure caused by the impact of long droughts, floods and other natural calamities. BULOG maintains

its stock in the form of milled rice rather than rough rice (paddy), and the rice is packed in jute or polypropylene bags (1 00 or 50 kg per bag) and stored in conventional horizontal 'godowns' (warehouses) throughout the country. A standard BULOG godown has a 3,500 t capacity and normally consists of 12 stacks with a total quantity per stack of approximately 250-300 t.

The year-round, hot and humid climate Typically found in tropical areas provides favourable conditions for the development of storage pests such as insects, rodents and

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fungi. This environment, coupled with inadequate postharvest processing of grain, accelerates the degradation of the quality of rice during storage, which poses a serious threat to BULOG. Annually, significant quantitative and qualitative losses occur due to an inability to prevent rice from insect infestation and preserve rice quality throughout the storage period.

Storage losses are very counterproductive to the huge amount of energy spent increasing grain production to ensure the availability of sufficient food for the people. Thus efforts should be geared toward improving quality maintenance and minimising losses through storage management programs. Efforts to tackle storage problems have been carried out using various measures, including chemical controls such as fumigation and the implementation and application of contact insecticides, in combination with the implementation of sanitation programs. However, a greater concern of consumers about the excessive use of pesticides—owing to their impact on environment and human health—has led to renewed interest and vigour in finding new methods to combat insect infestation and fungal invasion. Such technology includes the use of modified atmosphere and controlled atmosphere storage systems. BULOG has formed a vacuum container in which the concentration of oxygen is kept below 2% throughout the storage period.

The application of low oxygen levels has been known since ancient times as 'hermetic storage', and recently the principle of this storage technique (using less than 1% O₂) in combination with a high concentration of carbon dioxide (above 35%) has been reported to provide good disinfection and prevention effects against storage insects (Banks et al. 1980, 1991). However, maintaining a very low concentration of O₂, (below 1%) for a long

period of time, although providing good control of various insect species, is expensive. Therefore, use of oxygen concentrations within the range of 1-5% is likely to be more cost-effective in large-scale applications (Annis and Dowsett 1992).

The effect of temperature on the mortality of insects under low oxygen conditions is considered to be significant. In the tropics this effect is more dramatic than in temperate zones, given that insect metabolism is much slower in cold areas than in warm climates (Navarro, et al. 1994).

This paper aims to review the results of field-testing storage of milled rice under vacuum conditions, with particular emphasis on its quality changes based on several criteria. The prospects and further application of this technology in different forms are also briefly outlined.

MATERIALS AND METHODS

Vacuum storage containers

Specially designed plastic containers with a capacity of 1,000 kg of rice per container were used. The plastic used was polyethylene, with anti-oxidation and anti-ultraviolet chemicals added during the moulding process to make the containers more resistant to the impact of the sun's rays. The dimensions of the containers were 1 00 x 1 00 x 120 cm, with the plastic approximately 1-3 mm thick and resistant to cold and hot temperatures (-60°C to 60°C). All of the processes involved—manufacture of the containers (from plastic granules), filling the containers with rice, applying the vacuum conditions, and sealing the containers—were carried out in an integrated manner in an automatic processing plant which was constructed in East Java, with a capacity of 1 00,000 t/year. A schematic diagram of the overall process is shown in Figure 1.

Materials

Milled rice of the 'Cisadane' variety (a mixture of International Rice Research Institute and local varieties) was procured by BULOG. The rice had met the quality standards of this organisation, which included the following criteria:

- moisture content, maximum 14.0%;
- milling degree, minimum 85%;
- percentage of broken kernels, maximum 25%; and
- chalky kernels and yellow kernels, maximum 2% and 3%, respectively.

18 containers (18,000 kg) were randomly selected for this study, and samples were drawn at 60-day intervals for a period of 16 months. Nine containers were stored inside, and the rest were stored outside.

At each time interval, samples of 5 kg were taken from one container from each storage condition and sent to the laboratory for analysis of moisture content (MC), insect counts, microorganism identification and counts, quality analysis (odour/aroma, colour, appearance / translucency) and organoleptic tests of the cooked rice.

Methods of analysis

The MC of the rice was determined by a forced-air oven method-drying 10 g rice samples at 120°C for 24 h. For insect observations, 100 g samples were analysed visually to count the number of dead and live insects. The percentage of yellow kernels was determined by hand-picking discoloured kernels from a 25 g milled rice sample.

For identification of microorganisms (fungi and yeast), 25 rice kernels were plated onto potato dextrose agar (PDA) media in petri dishes after surface-disinfecting the rice by rinsing for 5-10 seconds in 95% ethanol, shaking for 1 min

in 2% NAOCl (bleaching inside storage was 27-35°C and outside storage agent), and then rinsing in sterilised distilled water. 30 35°C). The species of fungi were identified and counted to determine the percentage of rice kernels infected by microorganisms. The average of two replicates was Number of insects used to determine the results of each analysis.

The quality of the raw rice was determined through There were three species of insects found in the rice panel tests, using 10 panelists to detect changes in odour (aroma), colour and translucency of the rice kernels. Similarly, cooked rice was subjected to organoleptic tests covering odour, colour, stickiness and mouth-feel (softness). Panelists were requested to score each parameter from 1 to 7 (the higher the score the better).

RESULTS AND DISCUSSION

Moisture content

The MC of the rice declined throughout the observation period of 16 months. The initial MC of the rice was 14.20% and after 16 months the MC was 12.87% for rice stored inside and 11.95% for rice stored outside. The results indicated the temperature had a significant effect on the MC of the rice and the difference between the final MCs of rice stored at the two locations was significant. The variations in MC between individual sampling times were not significant, however the difference between the initial and final MC of the rice after 16 months of storage was significant. Thus, it seems likely that vacuum conditions significantly altered the MC of rice, particularly rice stored outside, which showed a > 2% decrease in MC (Table 1 and 2, Figure 2).

Together with temperature, MC is considered to be one of the most important factors in determining the quality retention of stored grains, including rice (Juliano

1994), and 14.00% MC is the maximum safe level for the storage of cereals. In this study, the MC of milled rice under vacuum conditions decreased gradually with storage time, to a level of nearly 12% in open storage and slightly above 12 % for rice stored inside. At these low MCs the milled rice quality was maintained, as indicated by the low percentage of yellow kernels and quality of the cooked rice, even though the temperatures were relatively high throughout the storage period (the temperature of the inside storage was 27-35°C and outside storage was 30-35°C).

Number of insects

There were three species of insects found in the rice at the beginning of the study, namely *Sitophilus zeamais*, *Tribolium castaneum* and *Oryzaephilus surinamensis* and the numbers were relatively low (less than 5 per 100 g rice sample) with *T. castaneum* being the most common. Live insects were only found at the beginning of the study. After that, only dead insects were found throughout the 16 months of storage, indicating that the low level of oxygen had killed all species of insects (Table 1 and 2, Figure 2). This shows that lack of oxygen is an important factor in increasing the mortality of storage insect pests and is in agreement with the observations made by Bailey (1965) and Caliboso and Sabio (1999). Interestingly, *Sitophilus sp.* Had been thought to be resistant to low oxygen levels, however in this no *Sitophilus sp.* Were found alive after 2 months of storage.

Percentage of yellow kernels

Statistical analysis showed no significant difference in the percentage of

yellow kernels over time or between locations (Table 1 and 2, Figure 2). Yellow rice kernels are assumed to be a result of a non-enzymatic browning reaction rather than due to microbial action (Phillips et al. 1988, 1989). Although the occurrence of a moderate proportion of yellow kernels has no adverse effects on rats and broiler chicks in nutritionally balanced diet tests (NRI 1991), in practice, the presence of yellow kernels above the maximum tolerable level (>3%) leads to a significant drop in price in the rice market. With a maximum of 3.05%, the proportion of yellow kernels in outside storage was slightly above this level, while inside storage the highest proportion was 2.56% which is below the maximum allowable level. Our results indicate that the yellowing process almost stopped under low oxygen conditions, even though the relatively high temperatures (up to 35°C) the study period provided otherwise suitable conditions for discoloured grain development.

Fungal infection

The rice was infected by various species of storage fungi at the beginning of the study. The percentage of fungal infection declined significantly after 2 months in the inside storage, and 6 months in the outside storage. There was no fungal infection in the rice after 10 months of storage (Tables 1 and 2, Figure 3), which showed that the low oxygen level (and low MC) was not unsuitable for fungal survival. However, there was no proof that fungal spores were completely killed, and a return to aerobic conditions may allow reinfection via these spores. Therefore, to avoid this possibility, rice should be promptly distributed after prolonged storage under vacuum conditions.

Table 1.

Changes in quality parameters of milled rice stored inside under vacuum conditions over a 16-month period.

Changes of Rice Stored
(Sidik)

Parameter	Months of observation								
	0	2	4	6	8	10	12	14	16
Moisture content (%)	14,20	14,60	13.89	13.72	13.50	13.40	13.21	13.30	12.87
Number of insects ^a (/100 g rice sample)	4	3	4	4	2	2	3	3	3
Yellow kernels (%)	2.52	2.54	2.50	2.56	2.54	2.50	2.34	2.40	2.30
Fungal infection (%)	100	80	80	40	0	0	0	0	0
Yeast infection (%)	100	100	100	80	80	80	60	60	60
Organoleptic tests ^b									
a) Raw rice									
Aroma	4.78	4.74	4.34	4.16	4.01	3.85	3.70	3.55	3.50
Colour	4.72	4.68	4.61	4.60	4.59	4.58	4.55	4.50	4.50
Appearance	5.02	5.00	4.98	4.97	4.89	4.86	4.81	4.78	4.75
b) Cooked rice									
Aroma	4.85	4.80	4.75	4.67	4.62	4.57	4.56	4.50	4.46
Colour	5.45	5.40	5.38	5.24	5.18	5.10	4.97	4.90	4.83
Smoothness	4.89	4.81	4.66	4.63	4.60	4.57	4.53	4.49	4.43
Stickiness	4.95	4.82	4.75	4.66	4.65	4.54	4.48	4.41	4.34
^a Note the after the initial measurement. All insects found were dead									
^b Organoleptic qualities were rated on scale of 1-7 (the higher the score the better)									

Table 2.
Changes in quality parameters of milled rice stored inside under vacuum conditions over a 16-month period.

Parameter	Months of observation								
	0	2	4	6	8	10	12	14	16
Moisture content (%)	14,20	14,00	13.84	13.54	13.40	12.55	12.20	12.07	11.95
Number of insects ^a (/100 g rice sample)	4	3	3	2	3	3	2	2	2
Yellow kernels (%)	2.83	2.80	2.85	2.99	2.89	3.02	3.05	3.00	2.95
Fungal infection (%)	100	100	100	80	40	0	0	0	0
Yeast infection (%)	100	100	100	100	80	80	60	60	60
Organoleptic tests ^b									
a) Raw rice									
Aroma	4.75	4.65	4.04	3.92	3.59	3.36	3.50	3.01	2.90
Colour	4.75	4.72	4.67	4.63	4.40	4.12	4.00	3.80	3.60
Appearance	4.97	4.93	4.88	4.78	4.71	4.64	4.58	4.50	4.43
b) Cooked rice									
Aroma	4.82	4.70	4.68	4.44	4.22	4.14	4.02	3.80	3.59
Colour	5.07	5.01	4.97	4.81	4.70	4.59	4.43	4.27	4.11
Smoothness	4.69	4.69	4.52	4.43	4.29	4.18	4.03	3.90	3.70
Stickiness	4.80	4.77	4.64	4.55	4.46	4.37	4.28	4.20	4.20
^a Note the after the initial measurement. All insects found were dead									
^b Organoleptic qualities were rated on scale of 1-7 (the higher the score the better)									

The Species of fungi found in this study were mostly storage fungi rather than field fungi, and the species were *Aspergillus*

glaucus, *A. flavus*, *A. niger*, *A. verA*, *.andidus*, and *Penicillium* spp. Only two species of field fungi were present, namely

Fusarium spp. and Eurotium spp. These findings are in agreement with the studies of Sidik and Cahyana (1992) and Dharmaputra et al. (1992). Dharmaputra et al. (1992) observed various species of both field and storage fungi in maize stored for a short period after fumigation with phosphine. Trigo-Stockli and Pedersen (1994) found similar species in their study on the effects of storage conditions on the quality of milled rice using rough rice stored for a maximum of 30 days. Most of the fungi found were associated with heat accumulation, particularly in rough rice with high MC (26%).

Yeast counts

Yeast was found in almost all samples drawn both storage locations, but the percentage declined through the first 12 months of storage, after which time its level stabilised (Tables 1 and 2, Figure 3). The persistence of some yeast throughout the 16-month storage period indicates that this microorganism is resistant to low oxygen conditions.

Organoleptic tests

Organoleptic tests of raw rice, as indicated by the scores given by 10 panelists, showed that the rice remained of good quality under the vacuum conditions, even after 16 months of storage (Tables 1 and 2, Figure 4). The quality of the rice tended to decline towards the end of the study, as shown by the decline in scores based on aroma, colour and translucency, but the degradation of quality was not significantly different over time or between locations. Even the lower scores given by the panelists at the end of the 16 months were within the acceptable range, showing that the rice retained its quality even after storage for a relatively long period of time. It should be pointed out, however, that the rice started to lose its aroma after 8 months

of storage (outside), when panelists gave it only half of the maximum score possible (Tables 1 and 2, Figure 4). As Juliano (1994) stated, one of the characteristics of rice is its aroma and people in rice-eating countries prefer to consume rice immediately after harvest, when the aroma level is still high. The longer the rice is stored, the greater chance it has to lose its aroma.

Organoleptic tests of the cooked rice gave similar results, with the quality of the cooked rice at the beginning of the study not significantly different to that stored for 16 months, in terms of the aroma and colour of the rice. Although the colour of the aged rice after cooking was slightly creamy rather than white, it did not cause any rejection by the tests. The panelists, however, gave lower score for the stickiness and smoothness of the cooked rice, and the difference seemed to more significant towards the end the storage time (Table 1 and 2, Figure 5).

The stickiness of the rice declined more rapidly in rice stored outside compared to inside, indicating that temperature and solar radiation had a significant impact on the changes in stickiness were still at an acceptable level (more than 4 out of 7). Similar findings were made by the panelists on the cooked rice (Table 1 and 2, Figure 5). The score tended to decline towards the end of the 16-months' storage, but were still within the acceptable range (above 4 for inside storage and above 3 for outside storage).

The aged milled rice absorbed more water during cooking compared to freshly harvested rice, resulting in more expansion and less sticky or more flaky cooked rice. Rice stored under low oxygen conditions seemed to make longer to age, although it tended to absorb more water during cooking and the cooked rice was considered a little bit tasteless, as compared to newly

harvested rice. This was reinforced by the panelists who gave relatively low score for smoothness and stickiness of the rice stored for 16 months, probably because the panelists had a preference for sticky rice over the non-sticky and flaky one. As Julianto (1994) stated, the stickiness of rice is very much influenced by the amylose content of the rice and in this study-after prolonged storage under low oxygen-it is likely that the amylose content increased to a level that brought the lack of stickiness after cooking.

CONCLUSIONS

From this study, we conclude that the quality of milled rice stored under low oxygen conditions (less than 5%) for 16 months was not significantly different from its original state, as indicated by changes in MC, yellow kernels, fungal infection, insect infestation and organoleptic tests. Slight changes in stickiness, aroma and mouth-feeling of the cooked rice may, however, have an effect on consumer preference, particularly for rice caters who prefer sticky rice over flaky rice.

The study revealed that lack of oxygen gave almost complete control of insect pests and fungal invasion that are associated with quality deterioration during storage. Near-vacuum containers, as used by BULOG, give good control over quality degradation which commonly occur during a long storage period (more than 6 months). It should be pointed out, however, that this type of modified atmosphere storage should be supported with good initial quality of rice prior to storage, otherwise the advantage of this technology would not be economically feasible, since vacuum container technology is indeed a capital-intensive venture. Therefore the length of storage time, quality and value of the product should be considered to justify the implementation of this technology.

REFERENCES

- Annis, P.C. and Dowsett, H.A. 1992. *Low oxygen disinfestation of grain: exposure period needed for high mortality*. In: Navarro, S. and Donahaye, E. ed., Proceedings of the international conference on controlled atmosphere and fumigation in grain storages, Winnipeg, Canada, 1 I- 1 3 June 1992, 70-82.
- Bailey, S.W. 1965. *Air-tight storage of grains: its effect on insects Rhyzoperta dominica (F) and some other Coleoptera that infest stored grains*. Journal of Stored Products Research, 1, 25.
- Banks, H.J., Annis, P.C., Henning, R.C. and Wilson, A.D. 1980. *Experimental and commercial modified atmosphere treatment of stored grains in Australia*. In: Shejbal, J. ed., Controlled atmosphere storage of grains. 207-224.
- Banks, H.J., Annis, P.C. and Rigby, G.R. 1991. *Controlled atmosphere storage of grains: the known and the future*. In: Fleurat-Lessart, F. and Ducom, P. ed., Proceedings of the International Working Conference on Stored Products Protection, Bordeaux, September 1990, 695-707.
- Caliboso, F.M. and Sabio, G.C. 1999. *Hermetic storage of grains in the tropics*. In: Nawa, Y., Takagi, H., Noguchi, A. and Tsubota, K. ed., Postharvest technology in Asia. Proceedings of the 5th JIRCAS (Japan International Research Centre for Agricultural Sciences) Symposium, Tsukuba, Japan, 9-10 September 1998, 59-72.

- Dharmaputra, O.S., Tjitrosomo, H.S.S, Sidik, M. and Halid, H.1992. *The effects of phosphine on storage fungi of maize*. In: Sidik, M. et al., ed., Proceedings of the Symposium on Pests of Stored Products, SEAMEOBIOTROP, Bogor, Indonesia, 29-31 January 1991, 107-118.
- Juliano, B. 1994. *Concerns for quality maintenance during storage of cereals and cereals products*. In: Highley E., Wright, E.J., Banks, H.J. and Champ, B.R., ed., Proceedings of the 6th International Working Conference on Stored-product Protection, 17-23 April 1994, Canberra, Australia, Volume 1. Wallingford, CAB International, 17-24.
- Navarro, S., Donahaye, E. and Fishman, S. 1994. *The future of hermetic storage of dry grains in tropical and subtropical climates*. In: Highley, E., Wright, E.J., Banks, H.J. and Champ, B.R., ed., Proceedings of the 6th International Working Conference on Stored-Product Protection, Canberra, Australia, 17-23 April 1994. Wallingford, CAB International, 130-138.
- NRI (Natural Resources Institute) 1991. *Postharvest discoloration of cereal grains*. In: Report on operational programmes 1989-1991. Chatham Maritime, NRI, 256-258.
- Phillips, S., Widjaja, S., Wallbridge, A. and Cooke, R. 1988. *Rice yellowing during post-harvest drying by aeration and during storage*. Journal of Stored Products Research, 24,173-181.
- Phillips, S., Mitfa, R. and Wallbridge, A. 1989. *Rice yellowing during drying-delays*. Journal of Stored Products Research, 25, 155-164.
- Sidik, M. and Cahyana, Y. 1992. *Storage pest problems and their management in Indonesia*. In: Sidik, M. et al., ed., Proceedings of the Symposium on Pests of Stored Products, SEAMEO-BIOTROP, Bogor, Indonesia, 19-31 January 1991,75-87.
- Trigo-Stockli, D.M. and Pedersen, J.R. 1994. *Effect of rice storage conditions on the quality of milled rice*. In: Highley E., Wright, E.J., Banks, H.J. and Champ, BR., ed., Proceedings of the 6th International Working Conference on Stored-product Protection, 17-23 April 1994, Canberra, Australia, Volume 1. Wallingford, CAB International, 706-711.

Changes of Rice Stored
(Sidik)

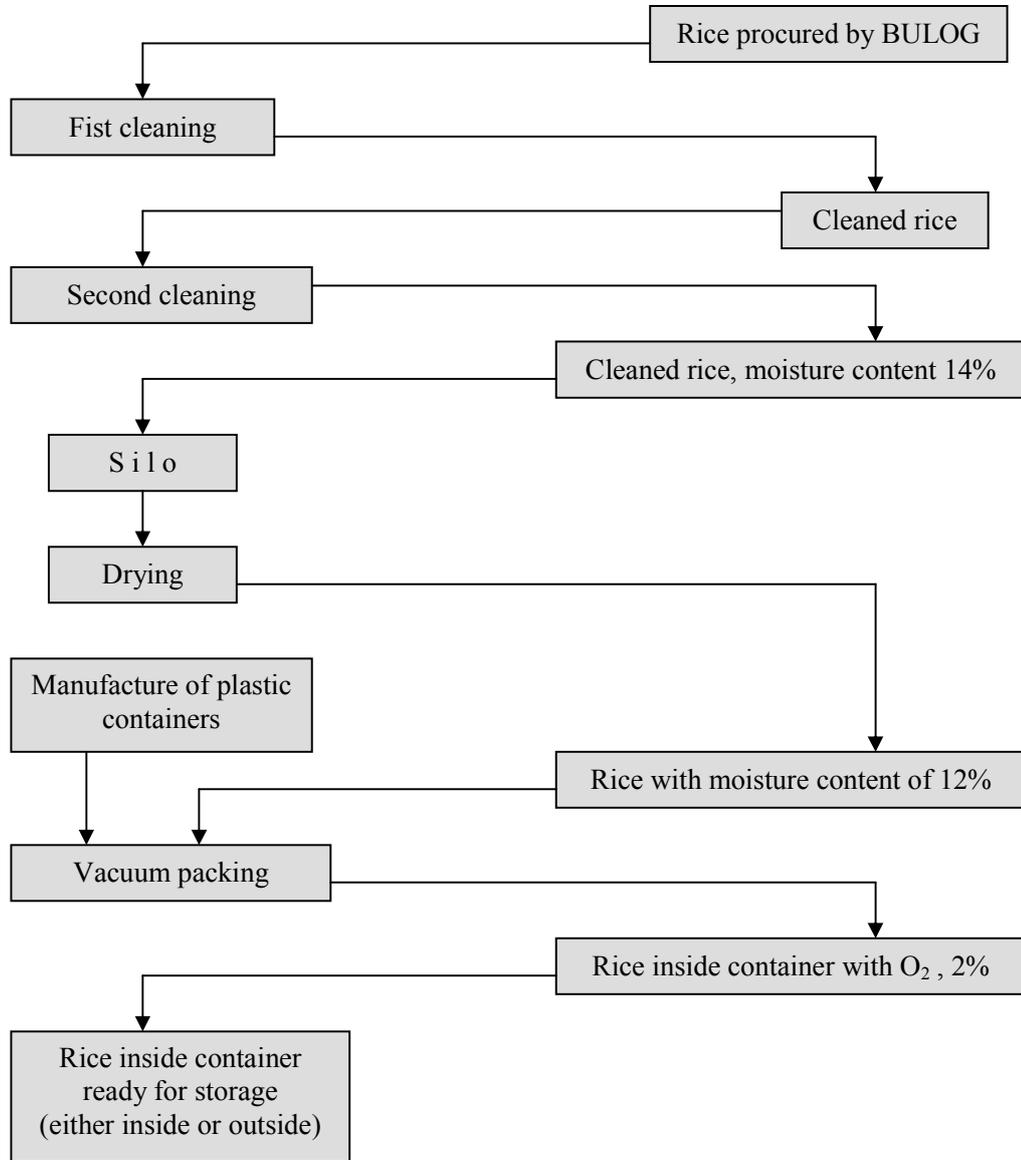


Figure 1. Schematic diagram of the vacuum process used for the modified atmosphere storage of milled rice