Cost–Benefit Analysis of Stock Preservation Systems. A Comparison of Controlled Atmosphere and the Use of Conventional Pesticides under Operational Conditions in Indonesia

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Abstract

In attempting to adapt the cost–benefit technique as a management tool for general application to stock preservation systems, the data derived from the three-year operational experience of Badan Urusan Logistik (Bulog) with controlled atmosphere (CA) storage in Indonesia are used.

A financial cost–benefit approach is adopted in order to derive the Break-Even Month (BEM) for CA and conventional fumigation-based preservation systems for milled rice. The sensitivity of the results to a range of assumptions is determined for those factors considered to be of primary cost significance on the basis of operational experience of the two techniques. The limited actual data on valued benefits is placed in the context of the sensitivity of the BEM to benefit assumptions. The relevance of these results to other foodgrain marketing systems in the ASEAN region and the use of the BEM concept in evaluating CA for bagged storage systems elsewhere are discussed.

Development work in Australia in 1979 and on a larger scale in Indonesia in 1980 explored the technical feasibility of using controlled atmospheres containing introduced carbon dioxide for disinfesting sheeted stacks of bagged milled rice (Annis et al. 1984).

This work showed that the presence of the plastic sheets, or the levels of CO_2 retained, or a combination of the two factors, prevented reinfestation by insect pests for up to four months when the stacks were left sealed after the initial gassing. It was further demonstrated that initial rice quality was maintained without detectable deterioration for the 4-month trial period.

Operational scale work by BULOG in 1982 evaluated the possibility of maintaining initial rice quality, in addition to disinfesting the stock and preventing reinfestation, for up to 16 months following sealing and gassing with CO_2 (Suharno et al. 1984). This initiative to explore the longer-term possibilities of the technique was stimulated by BULOG's desire to identify appropriate, longer-term, stock preservation systems. The agency was faced with a growing stock inventory, leading to slower turnover and increased risk of quality deterioration. The results of this later work indicated that the objectives could be achieved with the CO_2 technique, provided that the integrity of the sealed system was maintained throughout the storage period.

Still faced with heavy stocking pressure, BULOG placed 65,000 tonnes of milled rice under CO_2 at various locations in 1985 and maintained this stock successfully for 18–24 months. A program for 145,000 tonnes of stock under CO_2 for 1987–88 was subsequently scaled down to roughly 50,000 tonnes due to shortage of rice stock for long-term storage.

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Annis and van Graver (1987), in proposing an Integrated Commodity Management Strategy for the ASEAN region, advocated a short-term (less than 9 months) approach based on admixture of chemical protectants with commodities. For periods of more than 9 months, the use of CO_2 in sealed stacks was recommended, although it was suggested that the definition of short or long term would be reduced as familiarity with sealed storage procedure increased. In Indonesia, although there are Pesticide Committee clearances for admixture of insecticides with commodities at the BULOG level, the bag handling system does not lend itself to cost-efficient admixture, therefore this technique is not adopted by BULOG.

BULOG's 'conventional' stock preservation system is based on quarterly fumigation of stock under gasproof sheets and a regime of routine application of contact insecticides to stack surfaces and warehouse structure. This system has been described as part of BULOG's Integrated Storage Pest Management (ISPM) program by Sidik et al. (1985). Under this regime, certain types of qualitative deterioration are inevitable if storage is prolonged, and ancillary problems such as physical losses, insecticidal residues, adulteration of stock, etc. assume significance.

Comparison of Techniques

In terms of relative costs, the CO_2 technique is characterised by heavy initial expenditure followed by low maintenance costs for the remainder of the storage period. Conversely, the conventional regime requires a modest initial investment but involves higher maintenance costs reflecting the expensive pesticides required on a routine basis.

It was suggested in the earlier developmental work with CO_2 that costs for a one-year storage period were roughly equal to those of the conventional regime. This assumed that physical losses with the CO_2 system would be 50% of those estimated to occur with the conventional system. Later examinations of relative costs by BULOG suggested that, for storage periods in the 12–15 months range and beyond, CO_2 became economically viable. However, no assessment of the effect of benefits, if any, was made.

There is a wide range of possible benefits for the CO_2 technique. These can be categorised into three groups:

(a) Reduction in quantitative losses (actual weight losses) caused by:

- shrinkage
- spillage
- pest attack
- pilferage etc.

(b) Reduction in qualitative losses (loss of market value) due to changes in:

- colour
- head rice yield
- texture
- moisture etc.

(c) Difference in operational/environmental factors between the two systems:

- working conditions
- exposure to pesticides
- labour demand
- pesticide residues etc.

This study concentrated on those benefits for which data were available and which were of primary significance to BULOG. These were comparative figures on quantitative and qualitative losses as just listed under (a) and (b).

Although it is clear that use of the CO_2 system confers considerable positive operational and environmental benefits such as those in (c), they are not at all easy to quantify in monetary terms. This is partly because within the BULOG storage system one or more storage units at a typical complex will be used for CO_2 and other units will continue to be used for conventional storage. After a period of use for CO_2 stock, a unit will revert to conventional use. Full equipment and staff inventories are therefore maintained even if, for the period of CO_2 usage, they are not required in a particular unit or group of units.

Analysis and Results

The two categories of storage preservation system, conventional and CO_2, involve different patterns of cost (expenditure) and benefit over time. However, in the BULOG context many of the costs of grain storage such as warehousing, or the interest charges on the capital embodied in grain stocks, are common to both systems. Under these circumstances, a discounting approach based solely on those items of cost or benefit which are not common to both systems seemed appropriate. Also, from the perspective of BULOG management, a financial rather than an economic assessment was more relevant. Thus questions of shadow exchange rates and shadow wage rates are not addressed here. The methodology adopted is precisely that of financial cost–benefit analysis as described, for example, in Gittinger (1982) and numerous other texts.

Costs

The comparison of techniques is focused at the warehouse level. Overheads, management costs, etc. are assumed to be common to the two systems. Also, the costs associated with the procurement and storage of 3500 tonnes of bagged milled rice (corresponding to a standard BULOG warehouse), meeting BULOG's standard intake quality requirements, are assumed to be identical and are excluded.

Appendices 1 and 2 show examples of typical model outputs for an initial six-month storage period and illustrate cost components assembled.

As mentioned earlier, the essential difference between the two systems from a financial perspective is that the conventional approach involves relatively low initial costs, but relatively high operating costs, whereas the CO_2 system is just the reverse. Hence, for very short periods of storage the conventional approach is certain to be cheaper whereas, even if both systems were to provide equal benefits in terms of the quantity and quality of grain preserved, there will be a point of time in store beyond which the CO_2 technique will show a cost advantage. This point of time is referred to as the Break-Even Month (BEM). Figure 1 sets out the storage costs over time for the two systems under three assumptions concerning the discount rate. The costs were actually calculated for 6, 12, and 18 months of storage with intermediate values interpolated on a straight-line basis.

The three discount rate assumptions correspond to:

(1) A non-discounted solution (0%)

(2) A rate corresponding to BULOG's current financial situation (see below) (10%)

(3) A realistic commercial rate in Indonesia (24%).

The main conclusion to be drawn from Figure 1 is that for the purposes of comparing conventional and CO_2 rice preservation systems in the BULOG context the discount rate adopted is not a critical factor. Even taking the difference between the two extreme cases (i.e. 0 and 24%) the impact on the BEM is minimal, corresponding to less than two weeks of storage.

From BULOG's financial perspective the inter-

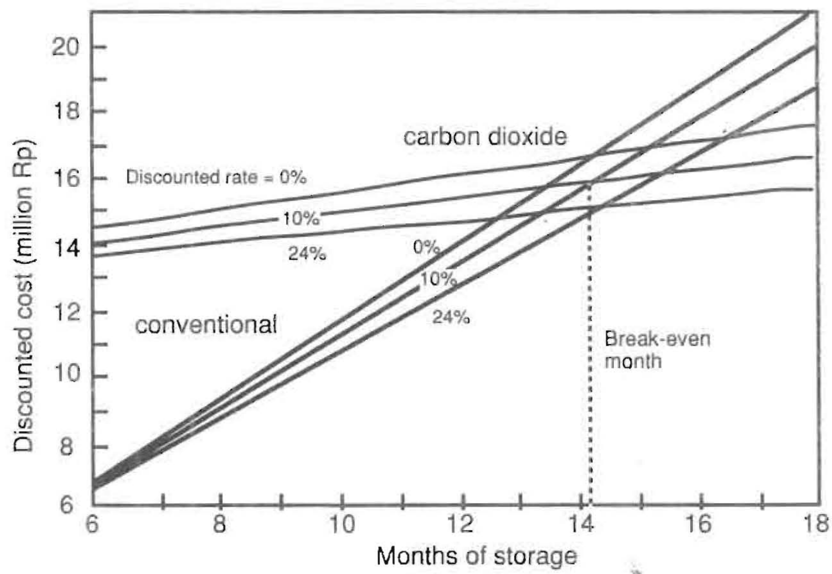

Fig. 1. Comparative costs of BULOG stock preservation systems. Assumes 3500 tonnes in one warehouse, 50% RV for CO_2 plastic cover and base, and 5% probability of CO_2 failure.

est charged on government loans, specifically for rice, is 6%. Allowing for non-interest discounting of the future by BULOG management, 10% would seem a reasonable rate to use for internal management purposes and is adopted for the remainder of this paper.

Figure 1 could be interpreted as implying that, given the cost assumptions made, and in the absence of benefits, the CO_2 system would be appropriate only for rice for which the expected period in store exceeds 14 months. However, of the necessary assumptions, two were deemed both controversial and (probably) important enough to seriously affect the BEM. These were:

(1) The residual value (RV) ascribed to the plastic cover and base (which will be termed the 'plastic enclosure') needed for CO_2 storage.

(2) The probability that a given application of CO_2 would fail to maintain the necessary concentration of gas (e.g. due to leaks) and have to be repeated.

The Residual Value of CO_2 Enclosure

The term residual value (RV) is used here to represent not the likely sale value of the CO_2 enclosure, but rather the reuse value to BULOG itself. Hence, an RV of 50% implies that, on average, all plastic enclosures would be used twice, 25% that, again on average, only half would be used twice, and zero percent that none would be reused or sold. In practice, the scrap value was assessed at 10%, and 67% taken as the upper limit for RV (corresponding to use three times). Figure 2 indicates that the impact of the RV assumption on the BEM in the absence of CO_2 failure is substantial. For example, an assumption that only half the sheets could be used twice (RV = 25%) as against the assumption that, on average, all sheets would be used twice (RV = 50%) increases the BEM by 3.75 months.

This result demonstrates the high proportion of costs embodied in the purchase of the plastic enclosure.

Operational experience indicates that a figure of 50% RV is a reasonable working assumption and this has been adopted for the remainder of this paper.

The CO_2 Failure Rate

The term 'failure' is used to describe the situation where some time after the introduction of CO_2, monitoring procedures reveal an inadequate concentration of gas. It is assumed that a complete resealing and regassing will be required together with their associated costs.

Although the expected number of 'failures' might be assumed to decline as staff become more familiar with the sealing and gassing techniques, a proportion of failures is still possible, due to damage to the plastic enclosure either at time of gas application or during the storage period. Figure 3 sets out the effect of failure rate assumptions between 0 and 40%. Since the latter corresponds to two out of five sealing and gassing attempts resulting in failure, an even higher level would imply serious and

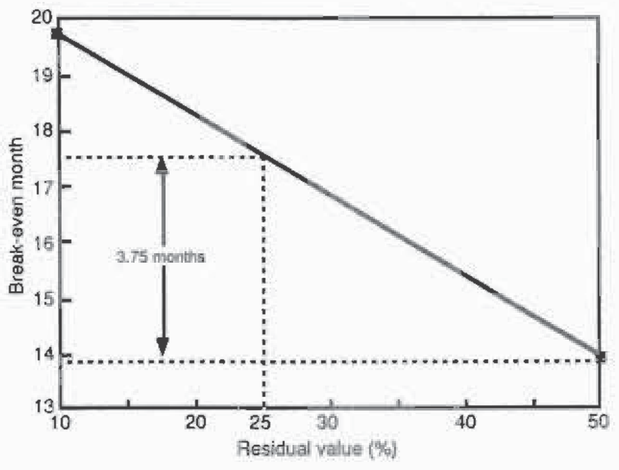

Fig. 2. Break-even month and CO_2 cover and base residual value. (Assumes 0% probability of CO_2 failure.)

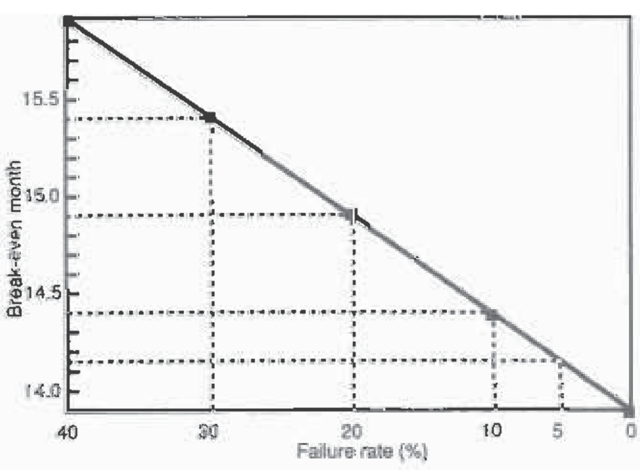

Fig. 3. Break-even month and CO_2 failure rate at 50% RV of CO_2 cover and base.

unacceptable management or technical deficiencies with the CO_2 technique.

From Figure 3 it can be seen that even this very wide range of failure rates corresponds to a variation in the BEM of just two months. Experience in BULOG operations would indicate that failure rates of 5–10% are realistic. This narrower range corresponds to less than 0.5 months differences in BEM. Hence, in situations where a fairly high level of technical and managerial control is achievable, the precise level of CO_2 failures is unlikely to critically affect the choice of preservation technique.

Benefits

In approaching the benefits issue attempts were made to quantify, in monetary terms, differences in quantitative and qualitative losses. Other benefits, or indeed disadvantages, of CO_2 as against conventional systems could well be included in a full social cost–benefit analysis but that was beyond the scope of the work presented here.

As a first stage in assessing the impact of benefits certain assumptions were made to simplify the analytical procedure. These were that:

(1) rice stored for periods of four months or less would be treated as 'fresh' by consumers and both weight and quality losses would be identical under the two systems; and

2) after four months, benefits (of one system over the other) would accrue equally for each additional month of storage.

Both these assumptions are arbitrary, but operational experience and the data collected to date do not provide evidence pointing to alternatives. On a priori grounds one might expect qualitative and quantitative losses to accelerate under conventional storage if fumigations were not 100% successful. Hence, interpreting losses recorded after substantial periods of storage as if they had occurred evenly over the period, probably exaggerates early period losses and understates those in the later period.

It may also be noted that while conventional storage might, in theory, demonstrate benefits over CO_2, in fact, none has been observed to date. Hence, the term 'benefits' is used to refer to qualitative or quantitative advantages of CO_2 over conventional storage expressed in monetary terms.

With these assumptions, the benefits of CO_2 storage can be expressed as a revenue stream, zero for months 1–4 and constant thereafter. The curve in Figure 4 describes the BEM for a range of benefit values expressed in rupiah per kilogram of rice stored per month.

As would be expected from algebraic considerations, benefits reduce the BEM but at a diminishing rate as the level of benefit rises[1]. As can be seen, even at very low levels of benefit, e.g. 0.2 Rph/kg/month, the impact on the BEM is considerable. This represents approximately 0.044% of the value of the rice per month or 0.53% per year, yet results in a reduction in the BEM of almost 4 months.

Figures were obtained on actual weights of intake and outturn, on an individual stack basis, in three storage complexes in East Java where stocks were held for comparable periods under both preservation systems. The results were used to derive a 95% confidence interval for the reduction in actual weight losses accruing to the CO_2 system.

Recorded losses under both concentration regimes were extremely low. The mean weight loss per month in store was only 0.0125% for 33 stacks under the conventional system and 0.0038% for 37 stacks under CO_2. Although the means were significantly different at the 95% confidence level, the size of that difference (0.0088% of weight loss per month) is very small. At prevailing Indonesian prices of around Rph450/kg, this difference corresponds to a benefit of 0.039 Rph/kg/month.

A test-marketing was carried out at a major Jakarta wholesale market utilising stock from

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[1] Consider the simple case where the discount rate is zero, and for conventional and CO_2 storage respectively, 'A' and 'B' are the initial costs and 'x' and 'y' the operational costs per month. Then if 'n' is the Break-Even Month, and 'a' the number of months after which CO_2 storage yields (equal monthly) benefits of value 'z'

$A + nx = B + ny-(n-a) z$

$n (x-y=z) = B- A + az$

if $k_1 = B-A$, $k_2 = x - y$ and $k_1, k_2 \geq 0$

then $n = (k_1 + az)/(k_2+z)$

and $dn/dz = (ak_2-k_1) / (k_2+z)^2$

hence assuming $k_1 \geq ak^2$ (i.e. benefits start before the BEM) then $dn/dz \geq 0$ and as $z — \infty$, $dn/dz — 0$ and $n — a$.

both preservation systems, originating from an identical consignment and stored for 18 months in Jakarta storage complexes. In the test-marketing used for this study, it was considered that the two factors which contributed most to the higher retained value of the CO_2 stock were (a) whiteness and (b) hardness/texture of the milled rice. In some rice marketing systems, the quality factors conferring enhanced value will differ but a similar approach to their quantification may be adopted. The results indicate that benefits could be as high as 1.0 Rph/kg/month, i.e. approximately 0.22 per cent of the value of the rice, per month.

Figure 4 places these rather sparse data in the context of the potential impact of benefits on the BEM.

From these results it would appear that the cost-effective use of the CO_2 technique as an alternative to conventional storage depends heavily on the value ascribed to benefits.

Discussion

It should be reemphasised that the results presented here are based on assumptions which were held to be valid for the public sector storage system in Indonesia. The results reflect the costs and benefits of the two preservation strategies compared under the prevailing cost structure and storage management practices within that system.

Management practices, as well as costs and benefits, may differ markedly in other countries. These results must therefore be regarded as specific to Indonesia.

The results show that, without quantified benefits, the point at which costs for both CO_2 and conventional preservation systems are broadly equal (BEM) is at 14 months of storage, assuming a 50% RV and 5% CO_2 failure rate.

The BEM is shown to be very sensitive to the residual value placed upon the plastic cover and base used to form the gastight enclosure for the CO_2 technique. Therefore, the likelihood of damage to, or degradation of, this plastic enclosure is a critical factor in an assessment of the financial viability of the technique.

The opposite is true regarding the requirement to reseal and regas enclosures following failure to maintain a gas-tight seal. However, the minimal impact of this factor on the BEM reflects the wide availability and relatively low price of CO_2 in Indonesia.

Ascribing even relatively small monetary values to the benefits of the CO_2 system has a considerable impact on the BEM and hence on the choice of storage technique. The evidence currently available seems to indicate that if the value of benefits could be realised the BEM would be reduced dramatically, perhaps to around six months. This being the case, the quantification of benefits, especially in relation to rice quality, is critical if the organisation involved is in a position to realise such benefits in monetary terms. Where this is not the case, as for example in Indonesia where that portion of the national rice stock distributed to civil servants is sold to the government at a fixed

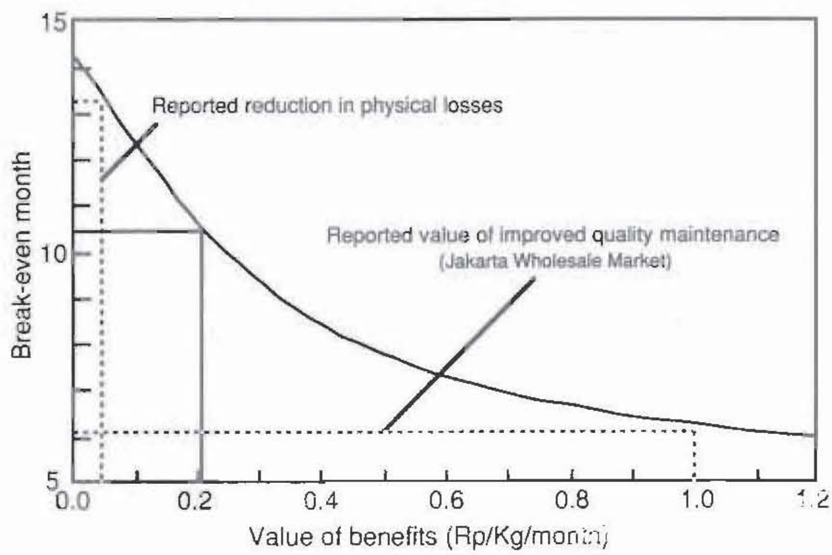

Fig. 4. Break-even month and the value of benefits.

price, the quality issue relates more to the potential benefit to consumers than to finance.

The physical losses incurred in both systems were very low and so therefore was the effect on BEM. Again, there will be many bagged storage systems where physical losses assume a much greater significance than in the BULOG system and where the combined effects of efficient pest elimination with the CO_2 coupled with a physical barrier, could produce substantial loss reductions.

The methodological framework developed here would seem to have wide applicability to public grain storage systems where a choice of preservation technique is available. The adoption of the cost–benefit framework helps to identify data requirements and indicates the relative importance of difference costs and benefits. This in turn points to the areas where further research is most needed from the management perspective.

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Appendix 1. Costs—CA System. Example of typical model output for a six month storage period.

Assumptions

1	Tonnage treated	3500
2	Storage period (months)	6
3	Discount rate/year	10%

Costs (Rph)

Item		
4	Cost of labour (Rph/day)	1,000
5	Skilled labour (Rph/day)	5,000
6	Cost of supervisor (Rph/day)	2,000
7	Electricity tariff (Rph/KWH)	750
8	Interest rate/annum	6.00%
9	Bank admin. charge(InitialLoan)	0.50%

Item			Residual Value
10	Plastic cover	10,319,400	50%
11	Plastic base	4,620,000	50%
12	Sealing material	250,000	15%
13	Vacuum cleaner	750,000	90%
14	Rodent proofing	250,000	90%
15	CO_2 meter	800,000	90%
16	Sundry cleaning	10,000	
17	Rodenticides	2,000	
18	CO_2 gas Rph/Kg	569	

No.	Description	Initial cost (Rph)
1	Plastic cover	10,319,400
2	Plastic base	4,620,000
3	Sealing material	250,000
4	Vacuum cleaner	750,000
5	Rodent proofing	250,000
6	CO_2 meter	800,000
7	Sundry cleaning	10,000
8	Cleaning godown	70,000
9	Sheeting stacks	200,000
10	Sealing & pressure testing	7,000

Operational cost and residual value (Rph)		Jan 88	Feb 88	Mar 88	Apr 88	May 8	Jun 88
1 Application CO_2	0	4,183,988	0	0	0	0	0
2 Checking concentration and damage	0	50,000	5,000	5,000	5,000	5,000	5,000
3 Resealing	0	0	12,500	0	0	0	0
4 Regassing	0	0	209,199	0	0	0	0
5 Electricity	0	36,000	0	0	0	0	0
6 Rodenticides	0	98,250	0	98,250	0	0	0
7 Training	0	30,000	0	0	0	0	0
8 Removal plastic cover & base	0	0	0	0	0	0	50,000
9 RV Plastic cover	0	0	0	0	0	0	(5,159,700)
10 RV Plastic base	0	0	0	0	0	0	(2,310,000)
11 RV Sealing material	0	0	0	0	0	0	(37,500)
12 RV Vacuum cleaner	0	0	0	0	0	0	(675,000)
13 RV Rodent proofing	0	0	0	0	0	0	(225,000)
14 RV CO_2 meter	0	0	0	0	0	0	(720,000)
15 Interest on initial loan	0	86,814	86,814	86,814	86,814	86,814	86,814
16 Bank admin. charge on initial loan	86,382	0	0	0	0	0	0
17 Interest on working capital	0	21,991	1,133	516	25	25	275
Total outflow	17,362,782	4,507,043	314,647	190,580	91,839	91,839	(8,985,111)
Present value of cost		13,940,213					
Benefit (Rph/kg/month) 0.1	0	0	0	0	0	350,000	350,000
Net Outflow	17,362,782	4,507,043	314,647	190,580	91,839	(258,161)	(9,335,111)
Net present cost		13,270,128					

Appendix 2. Costs—Conventional System. Example of typical model output for a six month storage period.

Assumptions Conventional by contractor & BULOG

1	Tonnage treated	3500
2	Storage period (months)	6
3	Discount rate/year	10%

Costs

Item			Item		Rph
4	Cost of labour (Rph/day)	1,000	10	Fumigation Eq./Set	912,400*
5	Skilled labour (Rph/day)	5,000	11	Power Sprayer	1,500,000
6	Cost of supervisor (Rph/day)	10,000	12	Fumigant/kg.	77,850
7	Electricity tariff (Rph/KWH)	750	13	Insecticide/litre	79,860
8	Interest rate/annum	6.00%	14	Fumigation fee Contractor/Ton	399
9	Bank admin. charge(Initial loan)	0.50%	15	Spraying fee Contractor/m^2	25
			16	Spraying fee Dolog/m^2	2

No	Description	Initial cost (Rph)	Jan 88	Feb 88	Mar 88	Apr 88	May 88	Jun 88
1	Fumigation equipment	0	91,200	0	0	91,200	0	0
2	Sprayer	1,500,000	0	0	0	0	0	0
	Operational cost and residual value (Rph)							
1	Fumigation cost by contractor	0	1396500	0	0	1396500	0	0
2	Spraying by contractor	0	208250	0	0	208250	0	0
3	Spraying–Damfin by Dolog	0	452359	452359	452359	452359	452359	452359
4	Spraying Fee by Dolog	0	11107	11107	11107	11107	11107	11107
5	Cleaning godown	0	20000	20000	20000	20000	20000	20000
6	Incidentals	0	10000	10000	10000	10000	10000	10000
7	RV Sprayer (95%)	0	0	0	0	0	0	(1425000)
8	Interest on initial loan	0	7500	7500	7500	7500	7500	7500
9	Interest on working capital	0	10947	2467	2467	10947	2467	2467
10	Bank admin. charge	7500	0	0	0	0	0	0
	Total outflow	1507500	2207863	503433	503433	2207863	503433	(921567)
	Sum of nominal cost	6511957						
	Present value of cost (Discounted Cost)	6428948						

* Including plastic sheet, sand-snakes and protective equipment.