

Evaluation of Corrosion Cost in Some Selected Fruit Juice-Processing Industries in South-West Nigeria.

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ABSTRACT

Juice processing, like any other product manufactured for human consumption, demands high quality processing in sanitary conditions. Because of this, juice-processing industries cannot tolerate corrosion deposits in their processing equipment. A wide range of machinery and fittings are used in juice processing. This makes it difficult to evaluate precisely the extent of corrosion and its cost implication. In this study, life-cycle costing has been used to assess corrosion management alternatives and determine the annualized value of some selected juice-processing industries in South-West Nigeria. Results showed that among the corrosion prevention methods identified, the use of greases and oils gave the least cost contribution (14.8%) to the total cost of prevention, followed closely by painting (15%), while cleaning added 70.2%. The contribution of each corrosion maintenance method to the total cost of corrosion was 16.5% for annual maintenance, 13.3% for repair, 21.1% for rehabilitation, while staff wages contributed 49.1%.

(Keywords: manufacturing, maintenance, life cycle costing, management studies, corrosion management)

INTRODUCTION

There is a current campaign for the consumption of locally-produced fruit juices in Nigeria. With government policies which prohibit importation of fruit juices, Nigerian industrialists are switching increasingly to the production of such juices in order to make optimum use of the large varieties of fruits grown in Nigeria (Enweremadu et al., 2004).

In processing fruit juice, a wide range of equipment is used with different operating environment. Quite often, such interactions impair the usefulness of the equipment as a result of deterioration due to corrosion (William, 1997). Different types of corrosive environments, the processes used in the industry, the compounds and chemicals employed, periodic use of certain equipment and machinery, and the applied methods of maintenance and corrosion prevention, make it complicated to determine where corrosion is likely to be most damaging (Gellings, 1985; Schouten and Gellings, 1987; Adebisi et al., 2003).

Corrosive chemical compounds, pesticides, salts, weak acids, and sterilizing chemical solutions for cleaning purposes can all be corrosive agents. The undesirable results of corrosion range from leakage and total fracture of the components concerned to contamination of the product being handled by the equipment. The resulting effects may become human health hazards.

It was reported that about \$279 billion is lost annually in the United States of America (NACE, 2002; Paul, 2002). While it is likely to be much less in Nigeria, this issue is still a major concern that has to be addressed.

In addition, product quality, health, and sanitation issues are major concerns in fruit-juice production; like in any food-processing industry. The industries, because of their particular functions, cannot tolerate corrosion deposits in the manufactured products. Hence, the need to properly account for corrosion and its effects in the production lines where metallic components have direct contact with the products for human consumption. This will assist in controlling

corrosion in the plant as a whole (Shawla and Gupta, 1993).

Fruit-juice production plant operating environments include contact with organic acids (citric acid, ascorbic acid) in the fruits which often lead to the corrosivity of the juice. Sometimes, other organic acids and oxidizing chlorides are used as disinfectants involving high temperatures. Often, fruit-juice manufacture occurs in wet conditions and corrosion occurs mostly in the presence of moisture. The pH value of the damp atmosphere, the velocity of flow of substances, wears and fretting, and heat transfer boiling are all initiators of corrosion in such industries.

In Nigeria, no national organization has been identified to collect information or make it available to the general public on the causes of equipment failure for each food industry. The result is that each equipment user or manufacturer is faced with solving their own corrosion problems without having a resource to help in the selection of a corrosion-control method that would be the most economical solution (Jekayinfa et al., 2003). Therefore, it has not been an easy task to evaluate precisely the extent of corrosion and its cost implication.

The fruit-juice processing plants adopt similar corrosion-prevention methods used in food industries such as the use of waxes, oil, grease, paints, and repair and rehabilitation of corrosion-induced material (Elliot et al., 1983). Due to minimum or lack of proper corrosion management, these prevention activities are often carried out without being accounted for. These activities, however, have financial implications on the economy of the industries. It is therefore necessary to investigate the cost implications of each preventive measure and its effect on the useful life of the processing machines in question. Similar investigations have been carried out for different industries by Gellings (1985), Javaherdashti (2000), and Jekayinfa et al. (2005).

In developed countries of the world, several methods have been used for estimating the national cost of corrosion. Such methods include life-cycle costing that assesses corrosion management alternatives (Garud, 1996; Balvanyos and Lave, 2002). This method determines the annualized value of each option, which is used to compare alternatives. The benefit cost analysis determines the net present value of options and the highest net benefit to the society.

In addition, the benefit cost analysis helps to determine the cost per unit service, which is, in fact, the highest aggregation of costs and benefits. According to the NACE "Cost of Corrosion" report (NACE, 2002), the cost of corrosion measures the cost of corrosion management to improve the function of, and to extend the life of a structure or facility.

In this study, the life-cycle cost analysis and the NACE procedural steps have been adopted in an attempt to determine the direct and indirect corrosion cost, identify the methods of corrosion control with minimum cost and evaluate the effect of corrosion cost on the economy of some selected fruit-juice processing industries in the South-West Nigeria.

METHODOLOGY

The use of questionnaires was employed to collect data from various fruit-juice processing industries. The industries from which data were collected included:

- Fumman Fruit Juice Limited, Lagos
- Lafia Canning Industries Limited, Ibadan
- Fan Milk Plc, Ibadan
- Eve Juice Industries, Ilorin

Data collected from each industry covered a period of five (5) years. In situations where data was either not in existence or not accessible, interview pro forma was used. The questionnaire was completed by maintenance personnel directly involved in corrosion prevention for each of the equipment in the selected industries. The frequency of servicing of the equipment in the selected industries were categorized as daily, weekly, monthly, quarterly, semi-annually, and annually, and data on the quantity of material used and their cost equivalents were collected with the questionnaire.

Other information obtained from the questionnaire included corrosion-prevention methods such as the use of oils and grease on metals, cleaning of corrosion-sensitive spots and parts, and painting of metal parts after a thorough pre-treatment of the surface.

Furthermore, inquiries on the frequency of repair activity and changes of parts and their costs were also requested. Apart from these, the number of staff assigned to service, repair, and overhauling

were indicated. Finally, the total capital investment and total revenue per year of each company was also collected.

- R - repair;
- RH - rehabilitation;
- SW - wages of staff.

The information gathered was evaluated to obtain the cost of corrosion-prevention methods and the cost of corrosion-maintenance methods. The following notations were adopted for each corrosion-prevention method:

- M_1 – use of oils and grease on metals;
- M_2 – cleaning and washing of corrosion-sensitive spots and parts immediately after use;
- M_3 – painting of metal parts after thorough pre-treatment of the surface.

An evaluation of these methods and their cost is presented in Table 1.

Also, the following notations were given to each corrosion-maintenance method:

- AM - annual maintenance;

The corrosion maintenance activities on the equipment available in each industry represent the total corrosion maintenance of the industry. The data for the corrosion-maintenance methods considered is summarized in Table 2.

Annual maintenance is taken to be constant throughout the life-cycle of the equipment. Thus, the present discounted annual value of annual maintenance [PDV(AM)] is calculated back to the present as:

$$PDV(AM) = \frac{AM[(1+i)^{-n}]}{i_0} \quad (1)$$

where $\frac{(1-g)}{(1+g)}$ and $i > g$

i_0 is modified interest rate
 i is interest rate
 g is constant annual growth rate

Table 1: Summary of Cost of Corrosion Prevention Methods.

Industries	Costs (N ^a)			Total
	Method C ₁	Method C ₂	Method C ₃	
Fumman Fruit Juice	94,500	552,000	103,500	750,000
Lafia Canning	108,310	632,580	118,600	859,490
Fan Milk	172,880	678,380	140,740	992,000
Eve Juice	58,800	195,450	77,500	331,750
Total	434,490 (14.8 percent ^b)	2,058,410 (70.2 percent)	440,340 (15 percent)	2,933,240 (100 percent)

^a Denomination of Nigerian currency (Naira); ^b Percent contribution of each method to total cost of corrosion prevention

Table 2: Summary of Cost of Corrosion Maintenance Methods.

Industry	Cost (N)				Total
	AM	R	RH	SW	
Fumman Fruit Juice	750,000	696,000	956,000	2,630,000	5,032,000
Lafia Canning	859,490	640,000	994,800	2,010,000	4,504,290
Fan Milk	992,000	721,746	998,200	2,761,000	5,472,946
Eve Juice	331,750	313,000	805,105	1,324,000	2,773,855
Total	2,933,240 (16.5 percent)	2,370,746 (13.3 percent)	3,754,105 (21.1 percent)	8,725,000 (49.1 percent)	17,783,091 (100 percent)

If the first payment (P_i) occurs in year one, the present value of cash flow that grows annually at a constant rate of n years is calculated by using the equation:

$$PV(P) = \frac{\left[\frac{P_i}{1+g} \right] \left[1 - (1+i_o)^{-n} \right]}{i_o} \quad (2)$$

Measurement of the current cost of corrosion was carried using the procedural steps in Balvanos and Lave (2002). The life-cycle costing analysis which determines the annualized value (AV) of each option was used to compare the alternatives so as to:

1. determine the cash flow of corrosion-related activities, describe corrosion management practices; determine the elements of corrosion cost and assign cost to all material and activities that are corrosion-related;
2. calculate the present discounted value (PDV) of the cash flow; and
3. calculate annualized value for the PDV.

The values of cash flow of the corrosion-related activities shown in Table 2 represent the value of corrosion cost in each industry.

In calculating the PDV and the annualized value of each cash flow, the following values were assumed as a constant number for all the

industries. Interest rate (i) = 20% = 0.2, number of years (n) = 5 years.

Since the first payment for repair activities does not usually occur in year one but in year t (service life), then Equation (2) calculates the value at year $(t-1)$ discounted back to zero of the life-cycle to determine the PDV of the repair. Therefore:

$$PDV(P) = PV(P) \left[(1+i)^{-(t-1)} \right] \quad (3)$$

The PDV of one time costs, such as one time repair (R), rehabilitation (RH) is given as:

$$PDV(R) = R(1+i)^{-tR} \quad (4)$$

$$PDV(RH) = RH(1+t)^{-tRH} \quad (5)$$

The present value (PV) of alternatives is calculated as the sum of the PV of its each added to the initial investment (I):

$$PDV = I + PDV[AM, P, R, RH] \quad (6)$$

The annualized value (AV) is calculated from PDV using the formula:

$$AV = \frac{PDV \times i}{\left[1 - (1+i)^{-n} \right]} \quad (7)$$

The value of AV is added to the initial capital cost for the subsequent number of years. These values of present discounted value (PV), annualized value (AV), and total cost (TC) are presented in Table 3 for the selected industries.

Table 3: The Effect of Corrosion Cost on Total Investment and Total Revenue per Year in Each Company.

Industry	Total Investment TI(N)	Total Revenue TR(N)	Corrosion cost CC(N)	Ratio to TI (percent)	Ratio to TR (percent)
Fumman Fruit Juice	49,600,000	73,624,000	5,032,000	10.15	6.83
Lafia Canning	31,000,000	125,800,000	4,504,290	14.53	3.58
Fan Milk	33,000,000	120,198,000	5,472,946	16.58	4.55
Eve Juice	44,000,000	121,000,000	2,773,855	6.30	2.29

A typical calculation of cost for each corrosion prevention method for each industry is illustrated for the industry Fumman Fruit Juice Limited.

- Method M_1 : 25 tins of oil/grease at N315/tin gives N7875 monthly or N94,500 per annum.
- Method M_2 : Five (5) workers at N460/worker/day. This is equivalent to N2,300 daily; N46,000 monthly for 20 working days; N552,000 per annum.
- Method M_3 : Five (5) tins of paint at N20,700. This is equivalent to 103,500 per annum.

Results for this and other industries are summarized in Table 1.

The calculation of the cost of each corrosion maintenance method for each industry is calculated for the industry Fumman Fruit Juice Limited and the results for this and other industries are summarized in Table 2.

E denotes equipment available: for pumps – E_1 ; compressor – E_2 ; boiler – E_3 ; washing machine – E_4 ; packing machine – E_5 ; mixer – E_6 ; heat exchanger – E_7 ; pressing machine – E_8 ; sterilizer – E_9 ; filling machine – E_{10} ; sealing machine – E_{11} ; conveying machine – E_{12} .

For Fumman Fruit Juice Limited:

Annual Maintenance (AM);
 - Methods ($M_1 + M_2 + M_3$)=
 $N(94,500+552,000+103,500) = N750,000$

Repair(R)= $E_1+E_2+E_3+E_4+E_5+E_6+E_7+E_8+E_9+E_{10}+E_{11}+E_{12}=(15,000 \times 12) + (27,000 \times 1) + (25,000 \times 4) + (15,000 \times 1) + (15,000 \times 4) + (2,500 \times 12) + (10,000 \times 4) + (12,000 \times 12) + (10,000 \times 2) + (25,000 \times 2) + (15,000 \times 2) + (10,000 \times 2) = N696,000$

Rehabilitation (RH) = N956,000

Staff wages (SW) = N2,630,000

RESULTS AND DISCUSSION

Table 1 shows the values of costs of corrosion prevention methods and their contributions to the total cost of corrosion prevention in each industry while Table 2 presents the costs of corrosion maintenance methods. From Table 1, it is evident

that method M_1 (greasing) has the least cost contribution to the total cost of corrosion prevention, followed by method M_3 (painting), and method M_2 (cleaning).

Different costs were assigned to different corrosion prevention methods from the outcome of the administered questionnaire as shown Table 1. The effect of corrosion cost on initial investment and total revenue in each industry is presented in Table 3. Comparison in terms of the frequency of use of the corrosion prevention methods shows that method M_2 (cleaning) is the most useful method because it is applied on a daily basis. This means that method M_2 also has the highest contribution. Method M_1 (greasing), is always applied monthly, hence its low contribution. M_3 (painting) is applied annually; hence it has the lowest contribution. Therefore, method M_2 (cleaning) is more beneficial (in terms of cost) than method M_3 (painting) which is always applied annually with higher cost than that of method M_1 (greasing).

Table 2 shows the contribution of corrosion maintenance methods cost to the total cost in each firm. From the table, it could be deduced that repair (R) gives the least cost contribution in each of the industry to the total corrosion cost. Annual maintenance (AM) has the highest frequency of use with relatively low cost and this is likely to be the most cost-beneficial method. However, each method contributes to the running and efficient performance of the equipment in the industries. The total contribution of the maintenance methods is explained with repair cost (R) having 13.3%, annual maintenance (AM), 16.5%; rehabilitation (RH), 21.1% and staff wages, 49.1%.

The effects of corrosion costs on the total investment and total revenue and their ratios are summarized in Table 3. Insight into this table shows that the ratio of corrosion costs to the total investment of the equipment is higher than that of corrosion cost to total revenue. These results are in good agreement with similar studies carried out by Tuben and Brongers (2000), Bello (2001), and Jekayinfa et al. (2005).

The annualized value concept relates the corrosion cost to the length of service life of the equipment. An interest rate of 20 percent was used as a constant for all the industries. Careful study of Table 4 shows an increase in the present discounted value (PDV) and a total cost incurred with the increase in the number of the year of the

Table 4: Summary of Life-Cycle Cost Parameters for Each Selected Industry.

Years	PDV (N)	AV (N)	Total cost incurred (N)
(a) Fumman Fruit Juice			
0			I = 49,6000,000
1	1,416,66.67	1,666,666.67	51,266,666.67
2	1,776,239.20	1,140,624.20	52,407,290.87
3	2,583,333.33	944,829.78	53,352,120.65
4	2,016,163.95	856,203.43	54,208,324.08
5	2,174,945.66	786,850.95	54,995,175.03
(b) Lafia Canning			
0			I = 31,000,000
1	1,623,481.11	1,909,977.76	32,909,977.76
2	1,492,001.53	1,134,400.32	34,044,378.08
3	1,431,186.80	863,029.98	34,907,408.06
4	1,432,205.82	747,298.58	35,654,706.64
5	1,433,265.65	647,086.37	36,301,793.01
(c) Fan Milk			
0			I = 33,000,000
1	1,873, 777.78	2,204,444.45	35,204,444.45
2	2,349,373.23	1,508,665.61	36,713,110.06
3	2,666,713.81	1,249,694.04	37,962,804.10
4	2,876,729.16	1,132,471.36	39,095,275.46
5	2,878,777.22	980,608.20	40,075,883.66
(d) Eve Juice			
0			I = 44,000,000
1	626,638.89	737,222.22	44,737,222.22
2	575,881.14	437,836.28	45,175,058.50
3	552,270.01	332,755.57	45,507,814.07
4	552,656.60	288,133.05	45,795,947.12
5	529,626.93	249,494.41	46,045,441.53

equipment. The present total cost incurred was obtained by adding the annualized value (V) to the previous value. In addition, the annualized values were observed to decrease with an increase in the number of years.

CONCLUSIONS

The results show that method M_1 (greasing) added the least cost contribution (14.8%) to the total cost of corrosion prevention in all the industries studied. However, this method is not as frequently used as method M_2 (cleaning) and could not be regarded as the most cost-effective.

Although method M_2 (cleaning) gave the highest cost contribution of 45.6%, it is frequently used on a daily basis and therefore could be said to be the most beneficial of the three methods examined for the fruit-juice processing equipment.

The cost of repair activities gave the least contribution of the total maintenance costs (13.3%) while the annual maintenance cost contributed 16.5% with frequency of operation higher than other maintenance methods. Hence corrosion prevention is preferred to corrosion maintenance in the fruit juice processing industries.

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