Nigerian Research Journal of Engineering and Environmental Sciences
Journal homepage: www.rjees.com

Original Research Article

BENEFIT - COST ANALYSIS OF RECYCLING SOLID WASTES IN CONCRETE: A CASE STUDY OF CASSAVA PEELS IN NIGERIA

***Olonade, K.A.**

Department of Civil Engineering, Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria.
*olonade1431ah@gmail.com

ARTICLE INFORMATION

Article history:
Received 09 December 2016
Revised 30 January 2017
Accepted 01 March 2017
Available online 01 June 2017

Keywords:
Benefit-cost ratio
Cassava peel ash
Blended cement
Disamenity effect
Solid wastes

ABSTRACT

Benefit-cost analysis (BCA) of using cassava peel ash (CPA) as substitute for cement in concrete was investigated. This was with a view to determining the economic value of CPA, if used in concrete. Annual cassava peels produced in Nigeria was estimated as well as the expanse of land lost to it. Cost of disamenity effect of cassava peels disposal was determined. The cost of normal cement and blended cement as well as their benefits was also determined. Thereafter, the benefit-cost ratio of using normal cement and cement blended with CPA were determined and compared. The results showed that about 14 million tonnes of cassava peels were generated annually, which occupy about 1400 km² at a cost of ₦7.6 billion ($50 m), which is expected to increase to ₦13.5 billion ($90m) in 2020, all things being equal. The cost of disamenity effect of cassava peels was estimated to be ₦21 million ($140,000), while cost of CPA was found to be about 26.7% of the cost of an equal quantity of cement. Aggregating benefits and costs of using CPA in concrete suggested that benefit-cost ratio was greater than 1 (about 1.8). The study concluded that processing cassava peels for use as construction material could be economically viable.

1. INTRODUCTION

Cassava processing produces large quantities of cassava peels (CP) and this contributes significantly to environmental pollution (FAO, 2001). In Nigeria, cassava peels are mainly left to rot away or burnt to create space for new generation of peels, emitting obnoxious gases with strong offensive odour for no benefit in return (Calvosa and Amoriggi, 2009).

Presently, cassava peels could be used as animal feeds when thoroughly dried. But cassava peels contain phytates, high amounts of cyanogenic glycosides and have low protein content

(Iyayi and Tewe, 2009). These constraints limit the use of cassava peels as animal feed. Furthermore, lack of technology makes it difficult to use cassava peels in large scale production of enzyme and ethanol (Calvosa and Amoriggi, 2009). The consequence of underutilization of CP results in its indiscriminate disposal, which becomes a threat to the environment (Figure 1). Thus, disposing cassava peels effectively remains a big challenge. Hence, recycling CP for use in construction industry is a novel strategy that could effectively alleviate the challenge of disposing these *wastes*.

Figure 1: Heap of cassava peels in a cassava processing centre (Salau and Olonade, 2011)

Substantial works have been reported on the pozzolanic potential of cassava peel ash (CPA) in cement-based products. The most interesting part of the findings indicates that 15% of cement could be replaced with cassava peel ash to produce cement-based products of comparable quality (Salau and Olonade, 2011; Salau *et. al*. 2012). Using cassava peel ash in this form would not only improve the management of cassava peels but also add to the local construction materials pool of the country.

Nevertheless, there is dearth of information on the socio-economic and environmental benefits of using CPA as construction material. Benefit – cost analysis (BCA) measures total benefits and costs wherever they fall and compares one with another. Wellbeing-improving projects or policies are those for which the total benefits exceed the total costs (Tim *et al.* 2007). Money is used as a way of aggregating overall impacts on wellbeing. Hence, decisions to replace cement with CPA or not is based on weighing up the costs and benefits of those decisions. In this study, socio-economic and environmental benefits of recycling cassava peels as construction material is presented by performing benefit - cost analysis (BCA) of using CPA in concrete. The results of this study, if positive, would attract attention of potential investors to develop this novel approach to solid wastes management.

K.A. Olonade / Nigerian Research Journal of Engineering and Environmental Sciences
2(1) 2017 pp. 01-08

2. METHODOLOGY

2.1. Determination of Quantity of Cassava Peels and Processing of Cassava Peel Ash

Based on the available information from the literature, quantity of cassava peels was estimated. According to Adesanya et al. (2008), between 20 and 30% of cassava tubers are cassava peels. Using an average, 25% was adopted in estimating quantity of cassava peels generated. Thus, 25% of annual cassava tuber generated was computed. In preparing cassava peel ash (CPA), dried cassava peels were collected from the dump site in one of the processing centres in Ilaro, Ogun State. The dried cassava peels were put in a furnace for 90 minutes at 700^{o}C. Thereafter, the ash was allowed to cool before sieving through 150 μm sieve size. The sieved ash was used to replace cement in producing blended cement-CPA concrete. Salau and Olonade (2011) gave details of the processing.

2.2. Estimating Area and Cost of Land Loss to Disposing Cassava Peels

Presently, there are no designated land fill to receive cassava peels in the country; hence it was difficult to get actual land lost to disposing cassava peels. For the purpose of this study, the weight of cassava peel occupying 1 m^2 of land was estimated by selecting 10 locations each of 1 m^2 in area and the cassava processors were allowed to dump the cassava peels generated on the locations, until filled up. Average weight of the 10 points was determined and was taken as the quantity of cassava peels that occupied 1 m^2. Thereafter, area of land occupied by the annual cassava peels generated as was determined in Section 2.1 by dividing annual weight of cassava peels by the weight occupying 1 m^2 of land. Though, this approach may not be accurate but it gives sufficient idea as to the expanse of land loss to cassava peels disposal. Then average cost of a plot of land in the locality was used as basis to determine the cost of land used to receive cassava peels.

2.3. Determination of cost of CPA and Cement in Concrete

Except cement that was partially replaced with CPA, all the materials in normal concrete were the same with blended cement-CPA concrete. Salau et al. (2012) suggest that 15% of cement be replaced with CPA to produce concrete comparable to normal concrete. Thus, cost of 1 ton (20 bags) of cement was obtained from the local market. In estimating the cost of producing CPA (laboratory production), cost of energy to power the furnace was estimated using the energy rating of the furnace as given by the manufacturer. Quantity of CP to produce CPA was equally quantified and the cost of labour for burning and sieving were evaluated. The cost of transportation was not taken into consideration and was also not considered for the cement.

2.4. Estimating Costs of Greenhouse Gases, Disamenity Effect and Raw Materials Consumed

Cost of gases emitted during burning of cassava peels was ignored, taking into consideration that the usual practice in disposing them is through open burning. Thus, processing CPA would not lead to additional cost in terms of gases emitted. Cost of disamenity effect of current disposal method of CP was estimated using the approach adopted by Tim et al. (2007). The data from the Federal Ministry Mine and Solid Minerals was used to estimate the amount of natural raw materials consumed by cement, while the cost of greenhouse gas associated with cement production was also determined.

2.5. Determination of Benefit – Cost Ratio

Aggregate benefits, in monetary value, of using CPA to replace cement were determined by summing up all the potential benefits. Total cost of using it was also summed up. The benefit-cost ratio (BCR) was determined using Equation (1).

$$BCR = \frac{Benefit}{Cost} \quad (1)$$

3. RESULTS AND DISCUSSION

3.1. Quantity of CP and Cost of Processing CPA

Table 1 shows the production of cassava per geo-political region in Nigeria for the year 2002. About 28 million tonnes were produced in that year, while the International Institute of Tropical Agriculture (IITA, 2004) projected the production to reach 60 million tonnes in the year 2020.

Table 1: Production of cassava and its peels by geo-political zones in Nigeria in 2002

Region	[a]Quantity. of Cassava tubers produced (Tonnes)	[b]Quantity. of Cassava peels generated (Tonnes)
South West	5 883 805	1470951
South South	6 321 674	1580419
South East	5 846 310	1461578
North West	2 340 000	585000
North Central	7 405 640	1851410
North East	140 620	35155
Total	27938049	6984512

[a] (PCU, 2003); [b]Cassava peels are 25% by weight of Cassava tubers (Adesanya et al., 2008).

Meanwhile, as at 2014, when this study was conducted, the annual cassava production in the country was put at 54,831,600 tons (FAO, 2016). Using 25% as cassava peels content in cassava tubers, an average of 7 million tonnes of cassava peels was generated in the year 2002, which increased by 100% in 2014 and this will increase to about 15 million tonnes come year 2020, indicating that large quantities of cassava peels are generated annually. On the cost of processing CPA, it was estimated that 1 tonne of CPA costs about ₦10, 650.00 ($71) equivalent to ₦10.65 per kg which was 26.7% of the cost of equal quantity of cement (₦ 40, 000.00) (Table 2). The low cost of producing CPA might be due to the abundant availability of cassava peels, which are available almost free. Its production is also not labour intensive and energy needed to initiate burning is not expensive. It was noted that the cost of cement is still high, despite the incentives given to local producers to bring the price of cement down.

Table 2: Cost of cassava peel ash and ordinary Portland cement per tonne

Items	Amount (₦)
Cassava Peel Ash	
[a]Material (Cassava Peels)	-
[b]Energy	650.00
Labour for 2 persons @ ₦2500 per person per day for two days	10,000.00
Total	10,650.00
Cement	
OPC at N2,000 per bag of 50 kg	40,000.00

[a]Cassava peels are available for free; [b]41.45kWh at ₦15.68 per unit energy in 2014

3.2. Benefits of using Cassava Peel Ash in Concrete

3.2.1. Savings from dumpsite costs

There are no official landfills established in Nigeria to receive cassava peels. The tradition is that cassava peels are deposited indiscriminately nearby processing centres (Figure 1). So, there is no data on the actual land area covered by cassava peels. Based on our field measurement, it was found that about 10 kg of cassava peels occupies 1 m^2. On the basis of this, cassava peels generated in 2002 occupied 698.46 km^2 of land area (Table 3). It was about 1400 km^2 in 2014, while it is expected to be 1,5000 km^2 in 2020. The cost of the land area used as dumpsite for cassava peels is an opportunity cost for using it for more beneficial purposes. A plot of land (648 m^2), where these *wastes* are deposited, costs an average of ₦ 400,000 ($2,666.7) in 2014, when this study was conducted. This is assumed for other areas given that most of the production centres are situated in semi-urban areas. In monetary value, close to ₦3.8 billion ($25m) was the estimated cost of land used to dispose cassava peels in 2002 (Table 3). This will increase to a minimum of ₦7.6 billion ($50 m) and ₦8.14 billion ($53.6 m) in 2014 and 2020, respectively. If cassava peels are not recycled, more land would be lost to disposing these *wastes*.

Table 3: Quantity of CP and cost savings in 2002

Region	[a]Area of Land Required to dispose Cassava Peels (km^2)	[b]Cost of Land Used (₦ m) ($m)[f]	[c]Disamenity Effect Cost (₦ m) ($'000)
South West	147.10	794.31 (5.30)	2.21(14.73)
South South	158.04	853.43 (5.69)	2.37 (15.80)
South East	146.16	789.25 (5.26)	2.19(14.60)
North West	58.50	315.90 (2.11)	0.88(5.87)
North Central	185.14	999.76 (6.67)	2.78(18.53)
North East	3.52	18.98 (0.13)	0.05(0.33)
Total	698.46	3771.64(25.14)	10.48(69.87)

[a]10kg of cassava peels occupy 1 m^2 of area; [b]N400,000 per plot of land (648 m^2); [c]$0.01(N1.50) per tonne (Tim et al., 2007); [f]Exchange rate: $1 = N150

3.2.2. Savings from disamenity effects costs

Cassava peels when rotten produce offensive odour, indicating that their disamenity effect is high. Though, some of the disamenity effects of disposing cassava peels will apply equally to recycling activity, including those associated with materials recovery facilities but the net effect would likely be minimal. There is no reported work on the cost of disamenity effect due to disposal of cassava peels in Nigeria. But European Commission and others suggest that if a landfill is located more than five kilometres from residential areas, the costs of disamenity effects are likely to be \$0.01 per tonne of waste, but if located in a built-up area and poorly managed, the loss of amenity can impose external costs up to \$3.70 per tonne (Tim et al., 2007). Since the dumpsites for cassava peels are not quite far away from populated area, a minimum cost of \$0.01 (₦1.50) per tonne of waste was assumed and used to compute disamenity effect cost of cassava peels. Hence, in 2002, a sum of ₦10.48 million (\$70,000) was estimated to have been lost to disamenity effect of disposing cassava peels while this was doubled in 2014 and about ₦22.46 million (\$149,714.29) could be saved in 2020, if cassava peels are used for more beneficial purposes like using it as pozzolan in concrete (Table 3).

3.2.3. Savings from depletion of natural raw materials

The raw materials used in cement manufacturing are extracted in large quarries, typically with outputs of up to, or over, 2.5 million tonnes per year. A tonne of Portland cement actually requires about 1.6 tonnes of raw material, because of mass lost due to emissions and other factors. Substituting 15% of cement by weight with CPA could save up to 0.24 tonnes of raw materials, mainly limestone. According to a circular released by the Federal Ministry of Mines and Solid Minerals in 2010, a tonne of limestone costs a sum of ₦450 (\$3).

3.3. Cost and Benefit of Using Cassava Peel Ash as Substitute for Cement

In 1 tonne of the blended concrete, 150 kg of CPA was required which could be produced by burning about 5.7 tonnes (5725 kg) of CP. Hence, the cost of producing 150 kg of CPA and the savings made due to its usage were estimated. The results are summarized in Table 4.

Table 4: Benefit and cost of normal cement and cement blended with CPA

Item	Cement /tonne (₦)(\$)		Cement with 15% CPA/tonne (₦)(\$)	
	Benefit	Cost	Benefit	Cost
Cost of Production	-	40,000(267)	-	35,597.50(237)
Cost of Land Use by CP that produce 15% CPA	0	-	[a]63,446.67(423)	-
Disamenity Effect Cost	0	-	[b]8.59 (0.06)	-
GHG Emission	0	-	[c]613.86 (4.1)	-
Cost of limestone saved	0	-	[d]108.00 (0.72)	-

[a]Cost of land covered by 5725 kg of cassava peels which 572.5 m^2; [b]Cost of disamenity effect for 5.725 tonnes at N 1.50 per tonne; [c]15% of the cost of GHG emission per tonne; [d]15% of cost of limestone per tonne

It is observed that a tonne of cement costs ₦40,000 (\$267) but when 15% CPA replaces cement, the cost reduces to ₦35,597.50 (\$237), showing a reduction of about 11%. Furthermore, a sum of ₦63,446.67 (\$423) is saved due to the cost of land that could have been used to receive the volume of CP needed to produce the quantity of CPA in 1 tonne of blended cement (5.7 tonnes). Also, ₦8.59 (\$0.06), ₦108 (\$0.72) and ₦613.86 (\$4.1) are saved due to disamenity effect of cassava peels deposition, greenhouse gasses (GHG) emitted and raw materials used to produce cement that is replaced with CPA, respectively. Though, the production of CPA is expected to emit some quantity of GHGs, being an agricultural by-product, it does not emit heavy metals. However, its emission is not taken into consideration as an additional cost in the production of CPA because cassava peels are usually burnt to create space for new wastes generated.

The comparison of the economic value of using normal cement (0% CPA) and cement blended with 15% CPA is presented in Table 5. It is shown that the net benefit of using CPA is ₦28,579.67 ($190.5) while normal cement has negative economic benefit of N 40,000 ($267). The benefit-cost ratio (BCR) for normal cement was zero and that of blended cement was 1.80. The implication of this result is that, since BCR is greater than 1 (1.80) and the net benefit is positive, suggesting that the use of CPA as substitute for cement up to 15% replacement level is an economically viable project that is worthy of pursuing.

Due to lack of sufficient data in the country, savings from pollution effect of cassava peels could not be captured in the benefit-cost analysis. Thus, there is need for further study to quantify the pollution level of cassava peels dumpsite sites as well as pollution from different cement plants.

Table 5: Comparison between economic value of normal cement and cement blended with CPA

Material	Cost (₦)($)	Benefit (₦)($)	Net Benefit (₦)($)	*BCR
Normal Cement (0% CPA)	40,000.00(267)	0(0)	-40,000.00(267)	0
Blended Cement (15% CPA)	35,597.50(237)	64,177.12(428)	28,579.67(190.5)	1.80

*Benefit-Cost Ratio

4. CONCLUSION

The benefit – cost analysis of recycling cassava peels in concrete was carried out. The study concludes as follow:

i. Cassava peels constitute environmental nuisance that is too much a cost for the environment to bear.
ii. Effective disposal of cassava peels is still a mirage as large expanse of land is lost to accommodate cassava peels.
iii. Recycling of cassava peels in form of CPA in concrete portends an effective strategy to manage cassava peels.
iv. The use of CPA in concrete brings about environmental and socio-economic benefits as shown by its benefit-cost ratio of 1.80 (greater than 1).

5. ACKONWLEDGEMENT

The author appreciates the support of the Department of Civil and Environmental Engineering of the University of Lagos for permitting the use of their industrial furnace for burning the cassava peels. Appreciation also go to Mr. Luqman for assisting in collecting the cassava peels.

6. CONFLICT OF INTEREST

There is no conflict of interest associated with this work.

REFERENCES

Adesanya, O.A, Oluyemi, K.A., Josiah, S.J., Adesanya, R.A., Shittu, L. A. J., Ofusori, D.A., Bankole, M.A. and Babalola, G.B. (2008). Ethanol Production by *Saccharomyces cereviasiae* from cassava peel hydrolysate, *The Internet Journal of Microbiology,* 5(1), pp. 25-35.

Calvosa, C. and Amoriggi, G. (2009). The feasibility study to put in place an animal feed plant in Ogun State (Abeokuta), making use of cassava peel. Sponsored by International Fund for Agricultural Develpoment (IFAD), Rome.

FAO (Food and Agriculture Organization), (2001). An assessment of the impact of cassava production and processing on the environment and biodiversity. *Proceedings of the validation forum on the global cassava development strategy*. 5, pp. 214 – 221.

FAO (Food and Agriculture Organization), (2016). In Fact Fish: Cassava, production quantity (tons) – for all countries. Accessed: http://www.factfish.com/statistic/cassava,%20 production %20quantity. Retrieved: 20th January, 2017.

IITA (International Institute for Tropical Agriculture) 2004. Nigerian's Cassava Industry: Statistical Handbook for the Year 2004, Publication of International Institute for Tropical Agriculture, Ibadan.

Iyayi, E.A. and Tewe, O.O. (2009). Effect of protein deficiency on utilization cassava peel by growing pigs. In: FAO Corporate Document Repository. Accessed through: http://www.fao.org/wairdocs/ilri/x5458e/x5458e08.htm. Retrieved: 12th November, 2010.

PCU (Projects Coordinating Unit). (2003). Crop Area Yield Survey. Abuja, Nigeria: Federal Ministry of Agriculture and Rural Development: Project Coordinating Unit.

Salau, M.A. and Olonade, K.A. (2011). Pozzolanic Potentials of Cassava Peel Ash. *Journal of Engineering Research*, 16(1), pp. 10 – 21.

Salau M.A., Ikponmwosa, E.E. and Olonade, K.A. (2012). Structural Strength Characteristics of Cement-Cassava Peel Ash Blended Concrete. *Civil and Environmental Research*, 2(2), pp. 68-77.

Tim D., Reuben I., Nikhil, A. and Mark, R. (2007). Recycling: Cost - Benefit Analysis, Covec. Ltd. pp. 1-74.