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FINANCIAL IMPACT ON A CEMENT PLANT IN THE CO-PROCESSING OF MEAT AND BONE MEAL

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Abstract. *Animal carcasses and byproducts do not have environmental regulation concerning their destination. Liquid emission of greenhouse gases can be drastically reduced by replacing traditional fuels with other materials, such as agriculture biomass, urban solid residues (USR), or meat and bone meal (MBM).The great amount of clandestine animal slaughter and the inappropriate destination of its byproducts are great environmental and public health problems. Deaths due to accidents, diseases and electrical charges also produce environmental liabilities since they are not properly collected and disposed. In other countries such residues have regulation and specific classification for their coprocess into alternative fuel in the cement plant, as they are burnt into meat and bone meal. This work aims at carrying out a study on the technical and economical viability of co-processing meat and bone meal at a cement plant in the Central-West Region of The State of Minas Gerais, Brazil. The numbers of mortality were calculated from the statistical data on cattle. The composition of alternative fuels co-processed at a cement plant in the region and the financial impact to introduce meat and bone meals were verified. The national and foreign technologies were verified, in order to adapt the best cost benefit, profitable and advantageous to the environment, as well as generate income to the local community, thus fulfilling their social role. The results showed that the financial impact of the introduction of meat and bone meals to the coprocess at the cement plant is positive, since it enables environmental, social and economical gains to the region.*

Keywords: *Waste co-processing; cement kiln; meat and bone meal; feasibility study; Alternative fuel.*

1. INTRODUCTION

Co-processing of waste as alternative fuels is an effective option for proper disposal and for reducing consumption of non-renewable resources. Waste derived fuels often have lower calorific value (LCV) minor than fossil fuels. It may be necessary to add a lot of thermal energy to achieve the proper operating temperatures.

Due to the characteristics of the cement kiln, which operate at high temperatures and have adequate residence time, they are one of the major waste coprocessors of non-renewable fuels. The high temperature promote the destruction of the residues and the incorporation of the ashes of the residue in the cement, not resulting in environmental liabilities at the end of the process.

Co-processing technologies in cement plants are regulated and consolidated, eliminating properly large amounts of waste at extensive production chain.

One of the large-scale co-processed wastes in Europe and the USA is Meat and Bone Meal (MBM), which comes from the animal by-products processing industry, slaughterhouses, farms and disaster mortalities.

The industry of animal by-products represents a potentially polluting activity and can cause significant environmental impacts. The major producers in the sector have waste disposal programs, but many small producers still dump large volumes of waste directly into the environment.

To co-processing MBM on the cement plant, the technical conditions for receiving, processing, transport, storage and injection should be analyzed and compared with data from other alternative fuels. In the case of industrial processes, the economic conditions should be evaluated in view of the investments to be made, considering the costs of processing and transporting the new alternative fuel.

Animal recycling industries in Brazil usually process only animal byproducts on category 3, for food and cosmetic purposes. Europe and USA has regulations and laws to processing byproducts and tailings from animal mortalities (dead carcasses) classified on category 1 and 2 for co-processing, as well as category 3.

In order to make feasible the coprocess of MBM produced from tailings rating 1 and 2 at a cement plant, the technical conditions for reception, processing, transportation, storage and injection must be analyzed and compared to data from other alternative fuels.

To make possible to eliminate the mortalities, it was necessary to carry out investment analysis in a new plant to receive this material, to process and supply the MBM with a competitive price compared to the traditional methods currently used, such as composting, incineration or burial.

In order to make feasible the destination of MBM in the cement plant it was necessary to verify the financial impact of this material in relation to the other co-processed wastes currently in the plant.

The research was carried out throughout the production chain, starting with studies on the generation and elimination of mortalities in rural properties, including visits to the processing plant of animal by-products and to the cement plant Minas Gerais - CPMG, located in the Center-West region of the State of Minas Gerais, in Brazil.

National and foreign technologies have been verified in order to adapt the best cost-benefit ratio that is profitable and advantageous to the environment and that can generate income for the local community, verifying the social function of the project.

The study presented satisfactory results, showing feasibility and possibility of being applied in different Brazilian regions.

2. BIBLIOGRAPHY AND REVIEW

The coprocess of residues as alternative fuels is an effective option for the proper disposal and consumption reduction of non-renewable source fuels. Liquid emission of greenhouse gases can be drastically reduced by replacing traditional fuels with other materials, such as agriculture biomass, urban solid residues (USR), or meat and bone meals (Uson, 2013). The main fossil fuels (“primary” fuels) in the cement industry are coal, petroleum coke, fuel oil and - in minor amount - natural gas (Karstensen, 2010).

MBM is one of alternative fuels and it can reach 15.7% of the replacement rate at a certain cement facility in Italy (Rahman *et al*., 2015). However, MBM is not co-processed in Brazil.

Moreover, the financial impact of the material compared to other residues co-processed at the plant must be verified. The MBM dosing and injection process is presented through the diagram in figure 1:

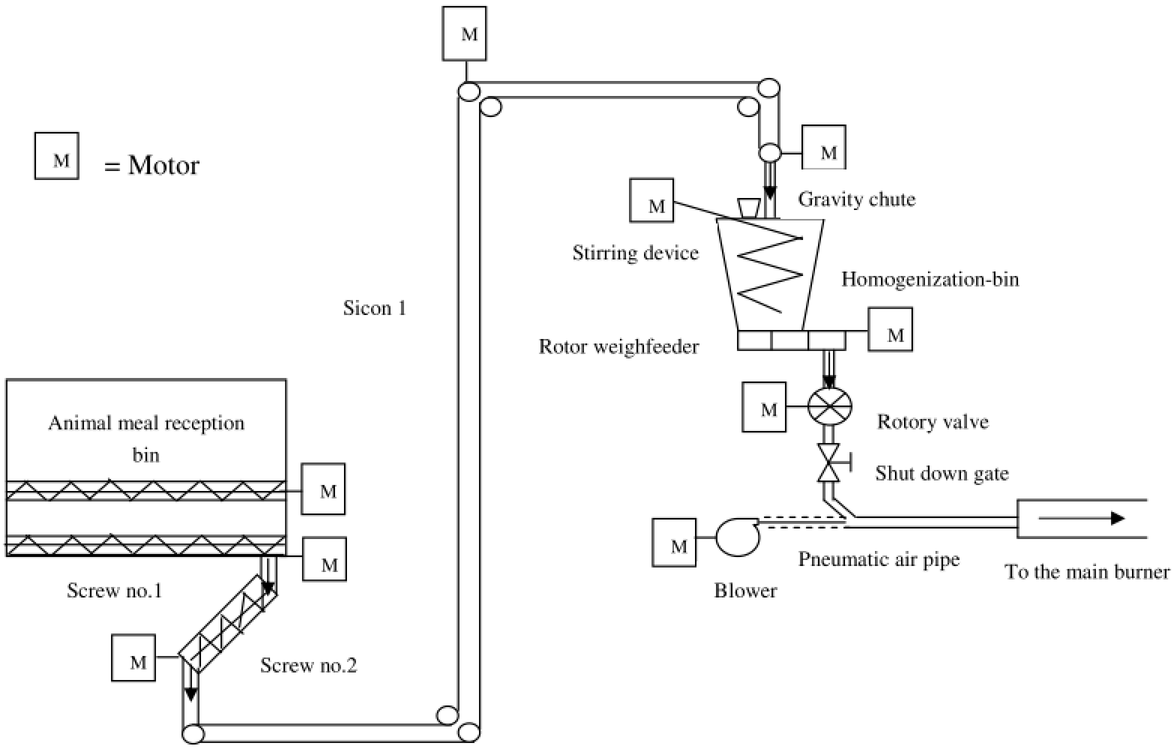

Figure 1: Injection process of alternative fuel and MBM at a cement plant diagram (Ariyaratne, 2009).

The received animal meal is stored in a reception bin. Then it is fed to a long closed conveying belt by means of push floor dischargers and then two screws. There is a special sensor is located at the end of belt to sense the malfunctions of conveying belt. The material is then directly conveyed to a pre-hopper which is also called calibration bin or homogenization-bin of the rotary weight feeder through a gravity chute. However, the size and design of supply conveyor has to be selected to ensure that the rotor weighfeeder system including homogenization bin is provided with sufficient supply of bulk material with at least 120% of the maximum feed rate (Ariyaratne, 2009).

The main fossil fuels (“primary” fuels) in the cement plant are coal, petroleum coke, fuel oil and - in minor amount - natural gas (Karstensen, 2006). Tests of coal and MBM co-combustion, verifying the CO relatively low levels, suggest that the combustion efficiency was highly elevated, especially when MBM was used (Gulyurtlu, *et al.*,2005).

Production operators usually optimize residues mix used at a cement plant based on software and spreadsheets developed for this purpose.

It must be considered that the “burning services” or “waste disposal services” solve the generating companies’ problem, since fines and foreclosures are avoided by the fulfillment of the law. Such services provide financial gains to the cement factories; however, there are internal expenses that must be counted, such as: chemical analysis, reception, storage, mixtures, transportation and fuel injection within the process.

Gulyurtlu et al. (2005) conducted co-combustion tests of coal and MBM, concluding the relatively low CO levels suggest combustion efficiency, particularly when MBM was used. The authors used online analyzers, correcting concentrations to 11% O_2, in accordance with waste incineration legislation. The same O_2 concentration references were used for the charcoal-only and co-combustion tests with MBM to allow comparison of the tests. The results are shown in Tab. 1.

Ariyaratne et al. (2010) performed tests with MBM injection in a clinker kiln for 12 hours, varying the feed rate at specific time intervals. In these tests, MBM was fed through to rotary feeder in the production of portland cement. In the experiment, the authors maintained the crude feed rate at 220 t/h. However, the feed rate had to be reduced by 10 t/h in the final stage of the experiment to maintain clinker quality within the desired specification. The results of the tests were presented in Tab. 1.

Table 1. Properties of coal and MBM. (Ariyaratne *et al*., 2010)

Property	Coal	MBM
Moisture (wt.%)	1.0	4.0
Volatiles (wt.%)	31.6	60.8
Fixed Carbon (wt.%)	56.3	6.0
Ash (wt.%)	11.1	27.2
P_2O_5 (wt.%)	0.007	13.0
CaO (wt.%)	0.02	13.3
Lower Calorific Value (kcal/kg)	6,689.0	4,423.0
Freely settled density (kg/m^3)	640.0	720.0

Table 2 shows the experimental schedule and thermal energy replacement by MBM in the main burner, gradually increased by reducing coal supply in order to keep the thermal energy consumption of the kiln at almost constant level.

Table 2. Experimental schedule and thermal energy. (Ariyaratne et al., 2010)

Time interval	MBM feeding rate (t/hr)	Coal feeding rate (t/hr)	Energy substitution at main burner (%)
9.00-11.00	0	7.8	0
11.00-13.00	2	2	16.9
13.00-15.00	4	4	33.5
15.00-17.00	6	5	42.4
17.00-19.00	8	6	50.4
19.00-21.00	10	7	59.1

Ariyaratne et al. (2010) concluded that there is a possibility of significant substitution of coal in the main rotary kiln burner without adversely affecting the product quality, production rate and overall emissions of the operation.

The authors did not observed significant impacts on the emissions or the operation of the furnace system, regardless of the feed rate of MBM.

According to Pecchio (2013), recent examples of destruction of carcasses from contaminated animals in clinker kilns result in phosphate (P_2O_5) inputs, since the bones are composed of hydrated calcium phosphate, which is incorporated into the inorganic fraction of clinker raw materials, replacing limestone in part. However, the author explains that there is no consensus regarding the maximum levels of phosphate that can be incorporated into the clinker without compromising its final quality.

3. EXPERIMENTAL PROCEDURE

3.1 Estimation of the MBM quantity obtained from mortalities in the region

The herds of pigs, cattle and poultry were verified in official government statistic data. It was multiplied by the mortality rates, excluding the unusable parts.

The amount of MBM that can be produced in the region using as raw material proteins improper for human and animal consumption (animals injured, hit or struck by lightning) has been verified. The calculated amount of mortalities in the region is 11.7 t/d.

3.2 Co-processed wastes in the cement plant CPMG

The simulation of residues is carried out daily in the cement plant to verify the best mixture of residues as a function of the fuel stock, emission limits of this mixture and the economic gain due to the substitution of conventional fuels.

Figure 2 shows a typical composition of co-processed wastes in the cement plant CPMG. The proportions of each residue vary according to market availability, calibration of calorific value and chemical analysis performed upon receipt, among other parameters to choose the composition of each mixture.

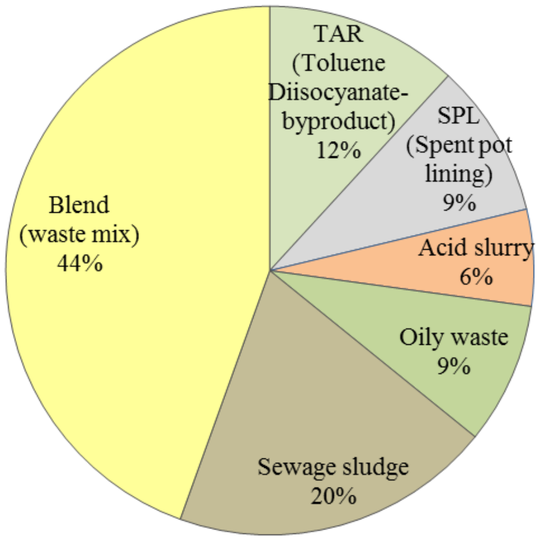

Figure 2. Typical composition of co-processed wastes in the cement plant CPMG.

Figure 3 presents the percentages of the composition of a typical mixture with the main residues co-processed at plant. Consider tons, daily consumption (t/d).

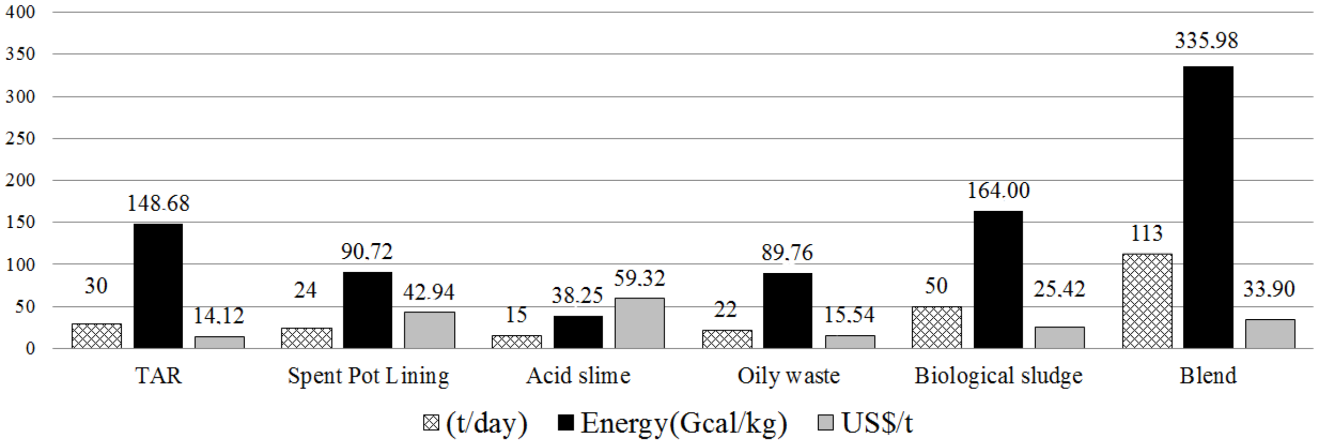

Figure 3. Fuel typical blend: daily production (t/d); energy (Ggal/kg) and price for disposal at plant (US$/t).

3.3 Total Financial Impact (TFI)

The financial viability will be verified concerning the replacement of one residue by MBM, keeping the operational balance of the productive process. Therefore the assessment based on total financial impact (TFI) of the introduction of new alternative fuel was chosen, combine with a typical blend used at the cement plant CPMG, with and without adding MBM.

TFI is the balance resulted from the introduction of fuel, considering the economy gained by the reduction on purchasing fossil fuels as well as by the benefit of the calorific power of the alternative fuels, based on Lower Calorific Value (LCV). It was considered five steps: Calculate Fuel Energy Release (FER), Thermal Input of the Fuel (TIF), Contribution of the Waste Disposal (CWD), benefit and Total Financial Impact (TFI).

Clinker production and fuel consumption are represented in t/d. The benefit, given in US$/ Kcal, is defined in 4.86 and refers to the cost saved by Gcal for not purchasing fossil fuel, in this case the pet coke, which is a commodity. The petcoke benefit value will be 4.86, considering the international price of the fuel under 39.36 US$/ t. (LCV of 8,100 Kcal/kg). The equations are shown below.

Step 01: Calculation of the Fuel Energy Release (FER) by the equation:

$$FER\ (Kcal) = \frac{LCV\ x\ \ residue\ consumption\ \ x\ \ (1 - humidity)}{1000} \tag{1}$$

Step 02: calculation of the Thermal Input of the Fuel (TIF) by the equation:

$$TIF\ (\frac{US\$}{t} clínquer) = \frac{EFC\ x\ benefício\ x\ custo\ por\ kcal}{production} \tag{2}$$

Clinker production and fuel consumption are represented in t/d. The benefit, given in US$/ Kcal, is defined in 4.86 and refers to the cost saved by Gcal for not purchasing fossil fuel, in this case the petcoke, which is a commodity. The benefit is calculated by the equation:

$$Benefit\ (\frac{US\$}{Kcal}) = \frac{Fuel\ Price}{LCV} \tag{3}$$

Step 04: Calculation of the Contribution of the Waste Disposal (CWD) by the equation:

$$CWD\ (\frac{US\$}{t}) = \frac{Waste\ comsumption\ x\ disposal\ price}{clinker\ daily\ production} \tag{4}$$

Step 05: Calculation of Total Financial Impact (TFI) by the equation:

$$TFI\ (\frac{US\$}{t} clínquer) = ATC\ (\frac{US\$}{t} clínquer) + ADR\ (\frac{US\$}{t} clínquer) \tag{5}$$

Residue mixture simulation software is frequently used in the cement plant. This software considers a thermal substitution around 25%. This is the percentage of total thermal energy consumed in the clinker manufacturing process being generated by the use of alternative fuel.

4. RESULTS AND DISCUSSION

Two simulations of TFI from residues mixing were carried in Total Financial Impact (TFI) at CPMG. The first objective is introduce MBM obtained from waste that is currently released in the Brazilian environment, but could be classified and regulated to be co-processed in Brazilian cement plants. The second objective is to reduce consumption of residue “oily waste”, which has irregular availability.

Usually are injected 254 t/d of alternative fuels into the precalciner (secondary fuel) and in the main burner of the clinker kiln (primary fuel).

Applying the equations shown, we can verify in each ton of clinker produced with alternative fuels, the total value of US $ 5.28 is earned in the current conditions, considering the main co-processed wastes in the plant. The results are shown on Tab. 3.

Table 3.Total financial impact (TFI), considering 22 t/d of oily waste and without addition of MBM.

Alternative fuel	Consumption (t/d)	TIF (US$/t clinker)	CWD (US$/t clinker)	TFI (US$/t clinker)
TAR	30	0.32	0.19	0.50
SPL	24	0.19	0.45	0.65
Acid Slurry	15	0.08	0.39	0.47
Oily waste	22	0.19	0.15	0.34
Biological sludge	50	0.35	0.56	0.91
Blend	113	0.72	1.68	2.40
Total:	254			5.28

The TFI of the composition which includes reduces 11.7 t/d of oily waste and increase 11.7 t/d of MBM results TFI U$$ 5.37/t, as shown in the Tab. 4.

Table 4. Total financial Impact (TFI) reducing 11.7 t/d of oily waste and introducing 11.7 t/d of MBM.

Alternative fuel	Consumption (t/day)	TIF (US$/t clinker)	CWD (US$/t clinker)	TFI (US$/t clinker)
Tar	30	0.32	0.19	0.50
SPL	24	0.19	0.45	0.65
Acid Slurry	15	0.08	0.56	0.64
MBM	11.7	0.11	0	0.11
Oily waste	10.3	0.09	0.07	0.16
Biological sludge	50	0.35	0.56	0.91
Blend	113	0.72	1.68	1.40
Total:	254			5.37

When 11.7 t/d of MBM are added to a composition of co-processed residues at plant, the TFI can increase US$ 0.09 US$/t clinker. Multiplying to production of 2,274.00 t/d clinker, the annual income would be US$ 74,700.09.

5. CONCLUSIONS

In the co-processing of residues on the CPMG the reduction of 11.7 t/d of oily waste and introduce MBM is advantageous from the financial perspective, according to the TFI calculation.

The MBM introduced will replace the oily waste and contaminated soil, whose availability varies on the market, making supplies irregular. The production of such residues and soil occur when there are accidental oil spills or cleaning of contaminated area, which are sporadic and unwanted situations to the environment.

There are reports about cement plants that invested in co-processing oil residues and ended up having their facilities disabled, without the financial feedback expected.

The national and foreign technologies were verified, in order to adapt the best cost benefit, profitable and advantageous to the environment, as well as generate income to the local community, in the business possibilities of handling and processing MBM category 1 and 2.

"Burning services" or "appropriate waste disposal services" should be considered as solving the problem of generating companies, by avoiding interdictions and penalties for noncompliance to environmental laws. These services generate financial gains for cement plants, but there are internal costs that must be accounted for: chemical analysis, reception, storage, mixing, transportation and fuel injection in the process.

The study presented satisfactory results, showing the viability and possibility of implementation in different regions of Brazil.

6. ACKNOWLEDGEMENTS

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