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Economic efficiency of two baling systems for sugarcane straw

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ABSTRACT

In recent years, harvesting process of sugarcane is changing itself, passing through semi-mechanized for mechanized system, who, currently predominate in Sao Paulo state, Brazil. Mechanized harvesting consists in a sequence of operations which includes cutting the pointer and chopping the stalk. The straw is a harvesting residue, and it stays in the ground, piling up above soil, with a possible prejudice for crop yield. An economic way to retract this straw is using mechanized processing for bailing it, involving hay balers, which are imported to Brazil and their use require regularly field conditions of work. Those balers could produce square or round bales, which can be sold to energy generation. This study aims to estimate economic efficiency indicators of round and square systems for sugarcane straw, establishing a relationship between baling costs and the incoming generated from those bales. Based on data set, round baling system was 26% more efficient than square baling system, and that round baler has a lower purchase price and a higher compress ratio of biomass, allowing a greater potential for power generation, turning it a more advantageous in a possible marketing for bales produced.

1. Introduction

In Brazil, the forecast for sugarcane area, that will be harvested and intended in 2012/2013 season, is estimated in 8.5 millions of hectares and its productivity is estimated in 69,846 kg ha^{-1} (Conab, 2012).

The concern in energy production from biomass has increased in recent years, overdue to fossil energy supplies and climate change (Sokhansanj et al., 2006).

Sugarcane is the most promising culture inside the crops that produce renewable bioenergy and the ethanol is the best and viable way to replace petroleum derivative, like gas and diesel, with a great importance in Brazilian agriculture scenario, and has a promising future in global scenario (Megda et al., 2012).

In the beginning of 2000, sugarcane market scenario was changed due to global concern about the price of oil. So, the incentive to use alternative fuels was initiated and, among them, was ethanol.

Ethanol production is in the commercial expansion phase for it is a renewable product, and a worldwide alternative energy source. The increasing trend of its production in Brazil is due to increase of flex-fuel cars fleet to domestic demand; and with Kyoto Protocol and the increase in oil prices, according to foreign demand.

Burning residues is a common practice of sugarcane production in Brazil, to facilitate more efficient manual harvest and transport. However, burning plant residues leads to emissions of greenhouse gases (e.g., CO_2, CH_4 and N_2O) particles into the atmosphere (Galdos et al., 2010).

However, according to legal, environmental and economic reasons, the use of fire is prohibited in most sugarcane areas, leaving harvest mechanization as the only practice to be followed. Reinforcing this process, several programs and state laws were established and agreed upon, such as the Environmental Protocol of Sao Paulo state (Sao Paulo, 2012).

Sao Paulo state is the largest producer of sugarcane, with an area of 4419.46 thousand hectares (Conab, 2012), and hence the state needs alternatives instead burning for sugarcane harvesting.

In 2002 was formed the State Law no. 11124, which provides gradual elimination of sugarcane straw burning. Signed in 2007, the Environmental Protocol anticipates Sao Paulo state legal deadlines for burning practice elimination, from 2021 to 2014 in areas where it is possible to harvest, and from 2031 to 2017 in areas where there are adequate technologies for mechanization (Novaes et al., 2011).

According to a study with greenhouse gases emissions, in pre-mechanization period, GHGs emissions were 1.1 kg CO_2 equiv. L^{-1}. Currently, this number felt for 0.6 kg CO_2 equiv. L^{-1}, and about 10 years, this result will be to 0.4, showing a clear trend for decreased emissions, which is related to the phase out of burning and to the

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increase in sugarcane and ethanol production efficiency per hectare of land (Galdos et al., 2013).

An estimate asserts that in a production of 301.6 million tons of sugarcane, there is a collecting potential of 42.2 million tons dry residues potential (Hassuani et al., 2005).

Worldwide supply of lignocellulosic waste represents approximately 2.9×10^3 million tons produced in cereal crops, 3×10^3 million in seed production and 5.4×10^2 millions of other types of crops. About 50% of this biomass would be available for ethanol production (Gomes et al., 2012).

Straw burning elimination in the fields is expected to bring benefits, particularly in terms of air quality and health, which is straw burning a major source of local air pollution and releases carcinogens. Eliminating it, may allow for more residues to remain on the field, which benefit soil fertility. Alternatively, the straw may be used for electricity production and even second-generation (cellulosic) ethanol production (Duarte et al., 2013).

Therefore, in a short time there will be a wide availability of straw from sugarcane and the waste could be recycled as raw material in renewable energy generation processes (Gomez et al., 2010).

Biomass end-users may require feedstock supply in various forms. At present, for example, biomass feedstock in pellet, briquette or bale form is mainly used for co-firing with coal or combustion for domestic heating and electric power generation (Miao et al., 2011).

The inclusion of new technology in a practical context with increasing scale and broad diffusion is a major challenge for most renewable energy technologies. This technologies cause minimal disruption in routine of interested players, including consumers and producers, having a higher chance of success (Freitas and Kaneko, 2012).

The appeal to the search for new ways to avail straw is strong, and the economic factor has a greater impact to analyze the straw processing and utilization. Straw economic use will depend on further research the cost effectiveness of collecting, loading and transportation technologies, and also, the cost to use this material, turning it into a higher commercial value product (Braunbeck et al., 2005).

This study aims to estimate the economic efficiency of round and square systems of sugarcane straw baling, establishing a relationship between baling cost and the generated income based in produced bales.

2. Materials and methods

2.1. Trial information

The study was conducted in recently harvested sugarcane area, without burns, near the county of Lencois Paulista, in Sao Paulo state, between the coordinates of 22°30′ S and 48°48′ W. Data was collected in the winter season, with tropical and dry weather, and temperature in the period around 30 °C.

The area has a soil classification of dark red latosol (Embrapa, 1999), where were no problems with rocks. With respect to mineral impurities or dirt in the soil, in trial area the numbers were between 5 and 6% of mineral impurities, which are an acceptable average for straw collection in Brazil.

Straw is dried naturally in the field after sugarcane harvesting, and after 5 days, the straw in the field is already dry, allowing windrow and bale operations on the same day.

For straw collection, there is no cutting height, because straw is distributed over the stalks and pointer of sugarcane. Sugarcane harvester collects only the stalks of sugarcane, leaving straw and leaves spread out on the ground.

In relation of workers, were required one operator for windrow, one operator for each baler (there were two balers, cylindrical and prismatic baling), one operator for loader and one driver for each truck. Those operations require one supervisor, also.

Table 1
Balers cost worksheet.

Description	Round	Square
Purchase price (US$)	80,585.00	146,341.00
Expected economic life (years)	5	5
Productive machine hours	6000	6000
Productive machine hours per year	1200	1200
Salvage value (US$)[a]	0.00	0.00
Interest annual rate (%)	7%	7%

[a] Salvage value is zero for no resale concern.

In Brazil, the dimensioning of machines for straw collection starts with windrow. With one windrow working, 3 balers can collect straw, 2 bale loaders to pick them up, and 3 trucks. Adding two supervisors, this type of operation, requires 11–12 persons on the field. Making a greater scope of this work, if were adopted in agricultural production, it will be possible to work with 2 shifts of 8 h each, seven days per week.

The trial was conducted with two balers, one square and other round. For this two balers was used a unique 142 kW 4 × 4 tractor and working speed of 7 km h^{-1} at 2000 rpm.

It was performed time and motion studies, as well as determining the fuel consumption, according to the methodology described by Fiorese et al. (2012), adopted by Agroforestry Machinery and Tyres Test Center (NEMPA), who belongs to College of Agricultural Sciences (FCA/UNESP) in Sao Paulo state.

2.2. Costs calculation

Data used for cost analysis are shown in Tables 1 and 2. Purchase price, expected economic life, productive machine hours per year and operator wage was informed by equipment manufacturers, besides interest rate was set according to the rates used in the market, since appointed capital in production must assign an interest rate. Machinery costs was determined through methodology described by ASABE (2011), which included depreciation, interest on investment, fees, fuel, oil and lubrificants, maintenance and repair, and operator cost.

2.3. Economic efficiency

The costs of renewable energy technologies are initially high, as they have not undergone improvements through market experience. With increasing cumulative installation and market experience, the costs of new technologies are expected to fall (Shum and Watanabe, 2009).

Whereas in this study the prices of machinery, raw materials and labor, it felt the need to measure the performance of both systems, and thus, it was use the methodology proposed by Sink and

Table 2
Tractor cost worksheet.

Description	Tractor
Purchase price (US$)	72,000.00
Expected economic life (years)	8.33
Productive machine hours	10,000
Productive machine hours per year	1200
Salvage value (US$)[a]	0.00
Fuel cost (US$ L^{-1})[b]	0.97
Basic wage (US$ h^{-1})	7.31
Interest annual rate (%)	7%

[a] Salvage value is zero for no resale concern.
[b] Fuel cost is an average of market prices, which may vary from US$ 0.90 to 1.05 L^{-1}.