Characterisation of Fruits and Vegetables Wastes in the City of Johannesburg

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Abstract— **Municipal solid waste (MSW) composition study is very important as a baseline to utilizing fresh fruit and vegetables (FFVs) wastes in waste to energy (WtE) project. The aim of this paper is to determine the composition of various waste components at the Johannesburg FFVs market. The study was conducted during the summer in 2015 to evaluate the various components of fruit and vegetable wastes (FVWs) generated at the market. This was done in order to evaluate the amount of FVWs that are generated daily at the market as a starting point for waste to energy (WtE) proposition for the City of Johannesburg (CoJ). Two international standards: ASTM D5231-92 - 2008 (American Standard Test Method) and UNEP/IETC -2009 (United Nations Environment Programme/International Environmental Technology Centre) were used as yardsticks for the procedure used. Samples were classified based on their colours; green (vegetables and fruits), blue/purple (vegetables and fruits), tan/brown (vegetables and fruits), yellow/orange (vegetables and fruits), red (vegetables and fruits) and other wastes which include corrugated boxes, metals, woods, plastic crates and other composite wastes. Samples were further classified into 135 classes in which some were not available due to seasonal variation and the samples were manually sorted by hands. From the results of the analysis, fruits constituted 55%, vegetables 38%, corrugated boxes and cartons 3%, metals, plastics, woods and other wastes all constituted 1% each.**

***Index Terms*—Fruits, Johannesburg market, vegetables, waste to energy**

I. INTRODUCTION

Municipal Solid Wastes (MSWs) are generated annually and much closed to about 150 million tons are disposed to the landfill sites (LSs) per annum in some parts of the world. Most of these wastes are organic wastes which include fruit and vegetable wastes ((FVWs). These wastes have high potential for methane generation through anaerobic digestion (AD) but they are often landfilled [1, 2]. Since large quantities of fresh fruit and vegetables (FFVs) are produced annually, a lot of this products become rotten during harvesting, sorting, packing and storage since they are all perishable goods with limited shelf life. Some of these materials go bad easily since some might have had spots unnoticed from the farm and some might have experienced delay in shipment to the final consumer [3-7]. The high cost of managing organic wastes has made the need to divert it completely from going to the landfill sites (LSs) a prime concern in many municipalities around the world. These wastes can be treated through biological process referred to as AD which produces biogas [8-10]. Biogas is produced when organic fraction of MSW which include FVWs are fermented in an anaerobic digestion. The main products are usually methane (CH_4) and carbon dioxide (CO_2) and some traces of hydrogen sulphide (H_2S) and water vapour (H_2O). FFVs are produced in large quantities all over the world and their management is very challenging due to the fact that they are readily biodegradable. They easily decayed as soon as they are infected with microorganism. This poses greater threat to the health of the general public and the environment when they are disposed of, at the landfill [11-15]. Studies have shown that climatic changes like bad weather; diseases and pests attack, damages during harvesting and low demand for products by the consumers contribute greatly to FVWs. Post-harvest life of farm produce is largely affected by factors such as temperature, relative humidity, gaseous composition within storage and packaging and many more [16, 17]. Recent research has shown that recycling program around the world only focuses on other MSW components but not on FVWs [18]. FVWs are produced on a large scale by food industries and farmers globally. They have high moisture contents and biochemical processes which makes AD to be the best option to treat them. Hence, it becomes very important to carry out a composition study to determine the various compositions of FVWs that are available over a different season [19, 20].

The foundation of a WM program that will be a success is the accessibility of valid data on the quantity and types of MSWs that are generated per season. This information can only be obtained through waste composition study. Waste composition study becomes very crucial in order to evaluate the potential for material recovery, to determine the origin of different waste streams, to put up plans to acquire equipment that will process the waste streams, to evaluate the physical, chemical and thermal properties of waste components and to ensure that municipalities comply with both national and international regulations [21-24].

This paper aims to determine the composition of the various FVWs produced at the Johannesburg Fresh Produce

Manuscript received June 12, 2016; revised June 20, 2016. This work was supported in part by the University of Johannesburg, Process, Energy and Environmental Technology Station (PEETS) in conjunction with South African National Energy Development Institute (SANEDI) and the City of Johannesburg.

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Market (JM) as a baseline for the waste to energy (WtE) proposition in the City of Johannesburg (CoJ).

II. Description of the Study Area

JM was founded in 1887 and it started at the Market Square. About three thousand traders traded FFVs at the commencement of the market. The rapid growth of the city was proportional to the trade of FFVs and that prompted the building of a new facility in Newtown in 1913. As the population of the city continues to grow, the facility in Newtown could not meet up with the demand, hence a standard facility was erected in 1974 and it was relocated there and is currently at the new facility in City Deep [25]. Currently, at JM, between 9500 and 11000 buyers do patronize the market daily. This depends on the season since FFVs are also seasonal. Buyers also come from different parts of SA and other South African Development Community (SADC). On average, about 5000 producers do market their products at the JM per time. This provides an opportunity for buyers to have access to assorted FFVs. The number of employees at JM is currently 285 personnel in different departments which include Finance, Strategy and Transformation, Agricultural Intelligence, Core Operations, Corporate Services and Operational Support [26] . There are currently 7 regions in the CoJ, Region F is one of them and City Deep is located in Region F (Figure I) [27].

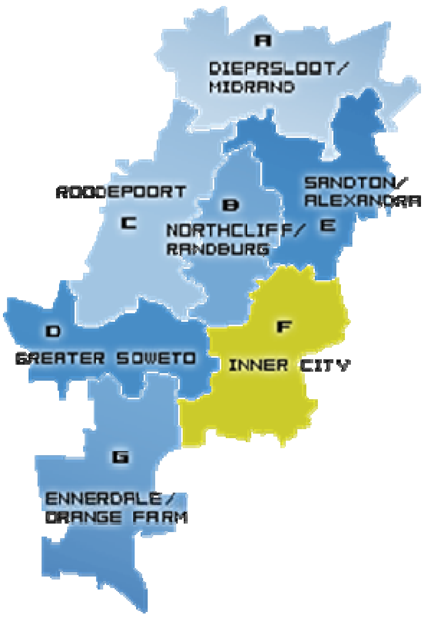

Fig. 1 New Regions in CoJ

III. Preliminary Site Assessment

Prior to the composition exercise, JM was visited. The reasons for the visit was to meet with the management so that thereafter the Research Team can be introduced to the workers who are working by the skip of wastes in order to enjoy maximum cooperation from them. It was also used as an avenue to be allocated a space for the exercise and to also make the place ready for the sorting exercise to be carried out. All these were done in order to evaluate the amount of FVWs that are generated daily at the market as a starting point for waste to energy (WtE) proposition for the City of Johannesburg (CoJ).

IV. Sampling and Number of Samples Determination

The sampling exercise was carried out in agreement with ASTM D5231 – 92 (ASTM - Standard Test Method for Determination of the Composition of Unprocessed Municipal Solid Waste (MSW) D5231 – 92 – 2008) and UNEP/IETC - Developing Integrated Solid Waste Management Plan, Volume 1, Waste Characterisation and Quantification with Projections for Future (2009). The number of samples depends on the number of the waste components to be sorted. The weight of the sorting samples is expected to be within the range of 91 to 136 kg [28] . Samples were hand sorted and this was done at the JM disposal facility[29]. The number of samples (n) sorted is given by Equation 1 and this is required in order to attain a level of precision.

$$n = \left(t * s / e \cdot \bar{x}\right)^2 \quad \textbf{(1)}$$

Where n is the number of samples to be sorted, t* is the student t statistic corresponding to the desired level of confidence, s is the estimated standard deviation, e is the desired level of precision, $\bar{x}$ is the estimated mean. For this study, at t* = 1.645 and n = ∞, s was 0.07, $\bar{x}$ was 0.1, confidence level was 90% and precision level, e was 10% and n^0 =132. Also, when n^0 =132, $t*_{90}$ = 1.657, s = 0.07, e = 10%, $\bar{x}$ was 0.1; n^1 was obtained as 135 which was the number of samples chosen for this study. The number of samples can be determined by the proportion of waste stream in a sample. For instance, if a particular waste stream in a sample has lower percentage compared to other streams, it therefore means the number of samples to be chosen will be very large in order to confirm the amount of such waste stream when compared with other waste streams with higher percentages. Newsprint was chosen as the governing component since FVWs appear more like residential wastes. Its range of samples is from 58-600 at 90% confidence level. The number of samples for this study is 135 and it falls within this range[28, 29].

V. Methodology

The exercise was conducted from the 11th of November to 20th of November of 2015 (a period of 10 days) at the JM disposal facility in agreement with the standards. The first three days was for site preparation and to promote support and cooperation from workers. The sorting exercise was conducted for a period of 7 days in agreement with the standards. Waste samples were collected and sorted manually for that period at the market. A sample of 100kg of each waste stream was chosen and weighed as stipulated in the standard[28, 29] . The activity ran through the week days from Monday to Friday. A sum of one hundred and thirty-five samples were analyzed as stated in ASTM and UNEP/IETC standards in order to provide statistical accuracy of 90% confidence level. Cardboard was selected as the governing component [29]. The waste samples were classified based on the colour of the FVWs (Table I to Table V) [30]. These groups were further sub-divided into one hundred and thirty-five divisions including the inorganic wastes like metals, paper, cardboard, corrugated boxes etc. There are about 11 skips where wastes are dumped at the disposal facility at the JM before trucks will later transport the wastes to the landfill sites. Samples were collected from the skips and were moved with wheel barrows to the sorting area and were discharged on the tarps. 100kg of each of the load of the waste transported in the wheel barrow was sampled and weighed in refuse bin containers designated for the activity. Then the University of Johannesburg Research Team began the sorting and characterization and weighing of the waste samples. Data were then recorded on the sampling form. The data recorded comprise of origin of the waste, type of truck, date, and season [28].

Table I

RED FRUITS AND VEGETABLES

Fruits	Vegetables
Red Apples	Beets
Blood Oranges	Red Peppers
Cherries	Radishes
Cranberries	Radichio
Red Grapes	Red Onions
Pink/Red Grapefruit	Red Potatoes
Red Pears	Rhubarb
Pomegranates	Tomatoes
Raspberries	
Strawberries	
Watermelon	

Table II

TAN/BROWN FRUITS AND VEGETABLES

Fruits	Vegetables
Bananas	Cauliflower
Dates	Garlic
White Nectarines	Ginger
White Peaches	Jerusalem Artichokes
Brown Pears	Jicama
	Kohlrabi
	Mushrooms
	Onions
	Parsnips
	Potatoes (White Fleshed)
	Shallots
	Turnips
	White Corn

Table III

YELLOW FRUITS AND VEGETABLES

Fruits	Vegetables
Yellow Apples	Yellow Beets
Apricots	Butternut Squash
Cape Gooseberries	Carrots
Cantaloupe	Yellow Peppers
Yellow Figs	Yellow Potatoes
Grapefruits	Pumpkins
Golden Kiwifruit	Ruta bagas
Lemons	Yellow Summer Squash
Mangoes	Sweet Corn
Nectarines	Sweet Potatoes
Oranges	Yellow Tomatoes
Papayas	Yellow Winter Squash
Peaches	
Yellow Pears	
Persimmons	
Pineapples	
Tangerines	
Yellow Watermelon	

Table IV

GREEN FRUITS AND VEGETABLES

Fruits	Vegetables
Avocadoes	Artichokes
Green Apples	Arugula
Green Grapes	Asparagus
Honey dew	Broccoli
Kiwifruit	Broccoli Rabe
Limes	Brocco flower
Green Peas	Brussels Sprout
	Chinese Cabbage
	Celery
	Chayote Squash
	Cucumbers
	Endives
	Leafy Greens
	Leeks
	Lettuce
	Green Onions
	Okra
	Peas
	Green Peppers
	Snow Peas
	Spinach
	Sugar Snap Peas
	Watercress
	Zucchini

Table V

BLUE/PURPLE FRUITS AND VEGETABLES

Fruits	Vegetables
Blackberries	Black Olives
Blueberries	Purple Asparagus
Black Currants	Purple Cabbage
Concord Grapes	Purple Carrots
Dried Plums	Eggplant
Elderberries	Purple Belgian Endive
Grape Juice (100%)	Purple Peppers
Purple Figs	Potatoes (purple fleshed)
Purple Grapes	Black Salsify
Plums	
Raisins	

VI. EQUIPMENT

The lists of equipment and materials used for the exercise are as follows; A crane scale with capacity of 500kg (Model: STS-QAL) was used to weigh the samples. Heavy-duty tarps were spread on the ground at the area allocated for the exercise and sorting of waste samples were carried out on the tarps to prevent contamination of waste samples with the soil. Shovels were also used for thoroughly mixing of the wastes before samples were taken. Hand brooms were used to gather the residual FVWs samples after characterization. Twenty-one refuse bin containers of 140 liters' capacity provided by University of Johannesburg in conjunction with Process, Energy and Environmental Technology Station were used. One large First Aid kit was provided in order to use to attend to any emergency or minor accident. Personal Protective Equipment was provided for the Research Team which includes over-all, gloves, rubber boots, disposable face masks, helmets and safety goggles. Washing-hand basins with liquid soap and disinfectant were also provided to be used for washing of hands after each day exercise.

VII. RESULTS AND DISCUSSIONS

The composition study was conducted on about 135 samples of the FVWs including the inorganic wastes like packaging, metals, papers, plastic crates and many more. It was observed that all the wastes generated at the JM were deposited in about 11 different skip bins. Most of these were well packaged while they are dumped inside the skips at the disposal facility. It was observed that about 11 tons of FVWs are disposed of at the landfill site from the JM on daily basis since each skip is estimated to be around 1 ton. All these wastes are transported to Robinson Deep landfill site. About 93% of the wastes generated are FVWs while the remaining 7% constituted the inorganic wastes. From the analysis of the result, fruits constituted 55% and vegetables Fig. 4 Percentage distribution of Fruits Based on Colour at JM

38% (Figure II). Figure III shows the percentage distribution of vegetable wastes based on colours, Figure IV shows the percentage distribution of fruit wastes based on colours and Figure V shows the percentage distribution of the inorganic wastes at the JM. Fruit wastes constituted the dominant class with 55% (Figure II). Based on colours; green vegetables constituted the dominant group with 34% from the vegetable categories (Figure III); red fruits constituted the dominant group with 49% from the fruit categories (Figure IV) and from the other wastes categories, corrugated boxes/newsprint constituted the dominant group with 46% percentage composition.

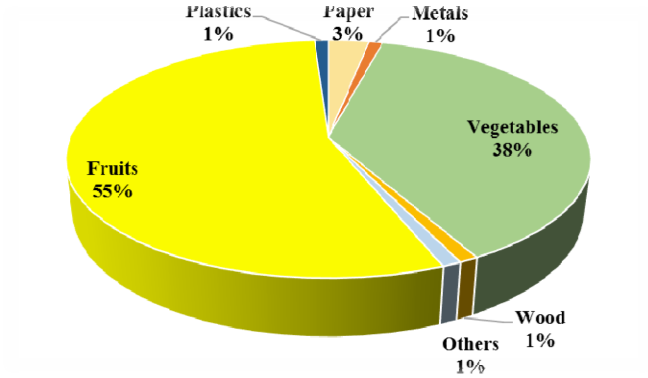

Fig. 2 Composition of waste from the Johannesburg Market

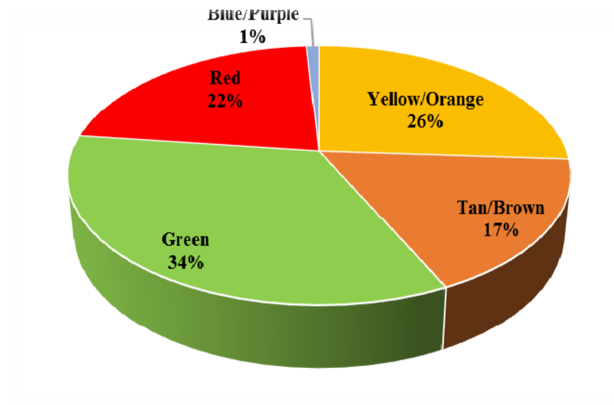

Fig. 3 Percentage distribution of Vegetables Based on Colour at JM

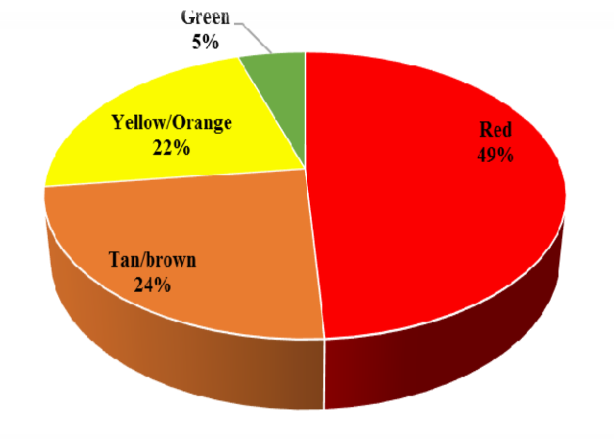

Fig. 4 Percentage distribution of Fruits Based on Colour at JM

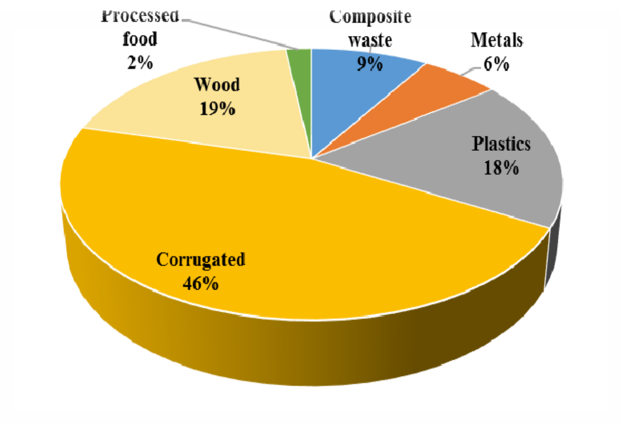

Fig. 5 Distribution of other inorganic wastes

VIII. CONCLUSION

It was observed that about 11 tons of FVWs are disposed of at the landfill site from the JM on daily basis. This is not healthy to the economy of the nation since resources can be recouped from these wastes either through converting it to fuel or generating electricity from it. Disposing the organic fraction of MSW to the landfills lead to the emission of CO_2 which is the primary source of greenhouse gases (GHG) which ultimately contributes to global warming and this poses threat to the health of the general public and it also impacts the environment negatively.

ACKNOWLEDGMENT

The authors wish to appreciate the management of Johannesburg Fresh Fruits and Vegetables Market (Joburg Market, City Deep) for providing a platform through which the composition exercise was carried out, the Department of Chemical Engineering, University of Johannesburg for their valuable inputs and supports and the University of Johannesburg Research Team for their tenacious efforts to make this project becomes a success.

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