Study of Fruit Wastes used in the Production of Biofuel

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Abstract : Nearly 1.3 billion tonnes of the food produced in the world for human consumption is wasted every year. The food with the highest wastage rates are fruits and vegetables including roots and tubers, constituting about 40-50% of global quantitative food loss and wastage. Eighteen percent of India's fruit and vegetable production is wasted annually. The utilisation of waste for the generation of different bioactive compounds is a significant advance towards economical growth. Fruit residues are rich in carbohydrates, crude proteins and reducing sugars and therefore can serve as a potential feedstock for ethanol production. The principle fuel used as a petrol substitute for road transport vehicles is bioethanol. Bioethanol fuel is mainly produced by the sugar fermentation process. Fruit wastes are capable of providing sugar for the process of fermentation and hence can be economically exploited for bioethanol production. This study highlights the problems of food wastage across India and attempts to promote the idea of turning food wastage into the environment-friendly renewable energy source, bioethanol. This research has undertaken the study the various fruit wastes across India to obtain a comprehensive picture of the finest source of bioethanol production using *Saccharomyces cerevisiae*.

Index Terms **- fruit wastes, bioethanol, production, fuel, *Saccharomyces cerevisiae.***

I. INTRODUCTION

According to the United Nations, nearly 40% of the food produced in India is wasted or lost every year. The Ministry of Food Processing estimates that agricultural produce worth 580 billion rupees is wasted in India each year (Lundqvist et al., 2008). India is the leading producer of fruits across the globe. 12 million tonnes of fruits and 21 million tonnes of vegetables and 23 million tonnes of food cereals are lost each year, with a total estimated value of 240 billion rupees. Roughly half of all fruit and vegetables produced globally are wasted each year. Lack of proper handling methods and infrastructure and higher production and growth, are some of the factors that have attributed to the wastage and losses. These significant huge amounts of lost and wasted fruits and vegetables, and their components, represent not only losses of edible food materials but also the wasting of by-products including bioactive compounds of great potential benefits for various industries and uses (Sagar team al., 2018). In fact, there is a need to recover value added products from these wastes. Fruits after consumption leave a peel which renders a problem to the environment as a solid waste but these may be turned useful by their use as a substrate for bioactive compounds, phenolic antioxidants, organic acids, enzymes, biofertilizer, production of energy and as adsorbents (Pathak et al, 2017).

Ethanol or ethyl alcohol (C_2H_5OH) is a colourless liquid, produced naturally by the fermentation of sugars by yeasts or by petrochemical processes. The uses of ethanol are multifarious. It has found use in medicine as an antiseptic, disinfectant and solvent. The biggest single utilisation of ethanol is as a motor fuel and fuel additive. Unlike petroleum, it is a renewable source of energy that can be produced from livestock (Singh & Jain, 1995). Ethanol fuel is the usage of ethyl alcohol as fuel. It is most commonly used as a motor fuel, mainly as a biofuel additive for gasoline. Ethanol is a high octane fuel and has replaced lead as an octane enhancer in petrol. By blending ethanol with gasoline, the fuel mixture gets oxygenated so it burns more completely and reduces polluting emissions. Ethanol fuel blends are widely sold in the United States. The most common blend is 10% ethanol and 90% petrol (E10). Vehicle engines require no modifications to run on E10 and vehicle warranties are unaffected also. Only flexible fuel vehicles can run on up to 85% ethanol and 15% petrol blends (E85).

Bioethanol has a number of advantages over conventional fuels. It comes from a renewable resource, i.e. crops which can grow well in the region. Another benefit over fossil fuels is the greenhouse gas emissions (Tiwari & Jadhav, 2014). Through the use of bioethanol, some of these emissions will be reduced as the fuel crops absorb the carbon dioxide they emit through growing. Blending bioethanol with petrol will help extend the life of the country's diminishing oil supplies and ensure greater fuel security, avoiding heavy reliance on oil producing nations. By encouraging bioethanol's use, the rural economy would also receive a boost from growing the necessary crops. Bioethanol is also biodegradable and far less toxic that fossil fuels. In addition, by using bioethanol in older engines can help reduce the amount of carbon monoxide produced by the vehicle thus, improving air quality. Another advantage of bioethanol is the ease with which it can be easily integrated into the existing road transport fuel system. In quantities up to 5%, bioethanol can be blended with conventional fuel without the need of engine modifications. Bioethanol is produced using familiar methods, such as fermentation and fruit wastes constitute the most inexpensive and easily available source for the production of bioethanol and are the preferred raw materials for its production by using *Saccharomyces cerevisiae.*

II. BACKGROUND STUDY

Pathak et al. (2017) "Fruit peel waste: its characterisation and its potential uses" suggests that fruit peels can be used for generating wealth from waste and as an efficient solid-waste abatement. Fruit peel waste can be used for the extraction of valuable compounds (bioactive chemicals, phenolic antioxidants, enzymes, carboxylic acid, etc.), as a feedstock for energy

generation (bioethanol, biomethane, biohydrogen, bio-oil, gasification, etc.) and other uses such as biofertilizer, bioadsorbents, etc. Carbon and nitrogen are present in high amounts in fruit peels, making them good substrates for enzymatic processes.

Babbar et al. (2011) "Total phenolic content and antioxidant capacity of extracts obtained from six important fruit residues" showed the antioxidant capacity of the fruit residues and should be regarded as potential nutraceutic resources. This study showed that the extracts obtained from residues of kinnow, litchi and grapes have a tremendous potential in food and pharmaceutical industry. The extracts from fruit residues hold promise in food industry as sources of bioactive compounds. In addition, an established use of the fruit residues will also help alleviate pollution problems caused because of the poor disposal of such residues.

B.C. Akin-Osanaiye, H.C. Nzelibe & A.S. Agbaji (2008) "Ethanol Production from Carica papaya (Pawpaw) Fruit Waste". This study investigated the production of ethanol from pawpaw fruit waste harvested after the tapping of papain using *Saccharomyces cerevisiae* the dried active baker's yeast strain. The fruit waste being very high in carbohydrate, although not all of it is available as fermentable sugar, shows its promise in being a good source of ethanol production. The study determined the optimum pH for fermentation is 4.5, optimum fermentation period was 72h with an increase in the percentage alcohol yield with increase in yeast concentration that improved with addition of nutrient supplements. The fermented pawpaw fruit waste produced 2.82-6.60% (v/v) of ethanol.

Khandaker et al (2018) "Bio-Ethanol Production from fruit and vegetable waste by using *Saccharomyces cerevisiae"* proved bioethanol could be produced from fruits and vegetables waste through a fermentation process using yeast by recording the best wastes that led to the highest bioethanol production. It was observed that the pH did not affect the yield of ethanol in the range of 3.5-6.0 in pineapple effluents although the rate of its production was the highest when the fermentation was carried out at around pH 3.0-4.0. At the end of the fermentation, the total soluble solids content of fruit and vegetable wastes decreased due to the conversion of the sugar to ethanol after fermentation. The bioethanol yield of pineapple waste showed the highest with 5.371% followed by orange with 4.452%.

Shubhra Tiwari, S.K. Jadhav, Mayuri Sharma and K.L. Tiwari (2014). "Fermentation of Waste Fruits for Bioethanol Production" deals with bioethanol production from rotten fruits with inoculation of bacteria isolated from different fruits. Rotten fruits serve as potential feedstock for bioethanol production due to high sugar content and cost elective substrate. Results indicate that among 5 fruits rotten sapota (Manilkara zapota) produced highest amount of bioethanol 9.40% on 5th day of incubation.

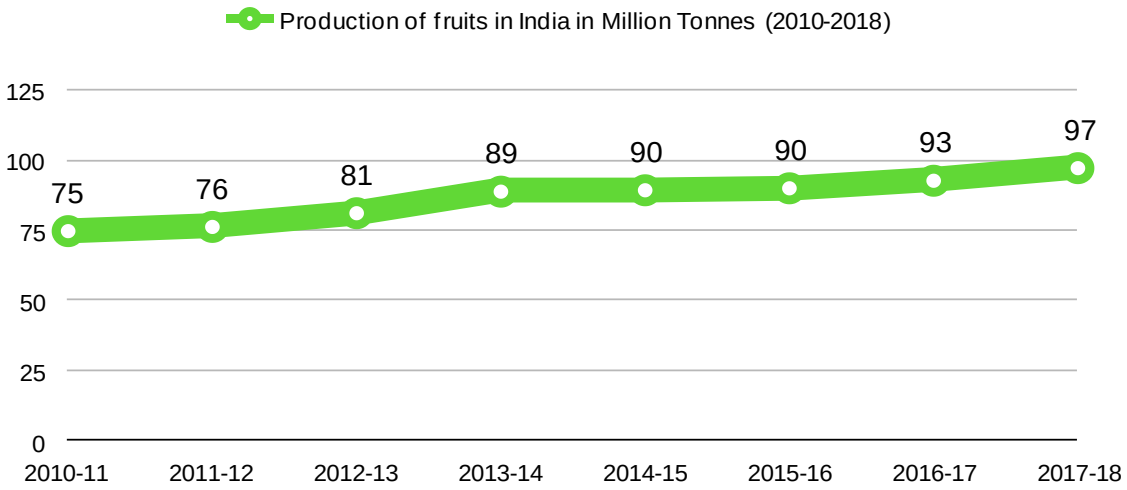
Debajit Borah and Vimalendra Mishra (2011). "Production of Bio Fuel from Fruit Waste" tried to obtain a higher concentration of alcohol using fruit wastes (apple pomace and rotten banana) by fermenting them with the help of common baker's yeast Saccharomyces cerevisiae. As they could obtain 48% alcohol after distillation so they can predict that a higher concentration of alcohol can be obtained after re distillation of the product obtained. A higher concentration of alcohol can be use as a bio fuel. Since this process is cost effective and does not yield any toxic residues, this technique can be developed and bioethanol can be produced at an industrial level.

III. RESEARCH DESIGN AND METHODS

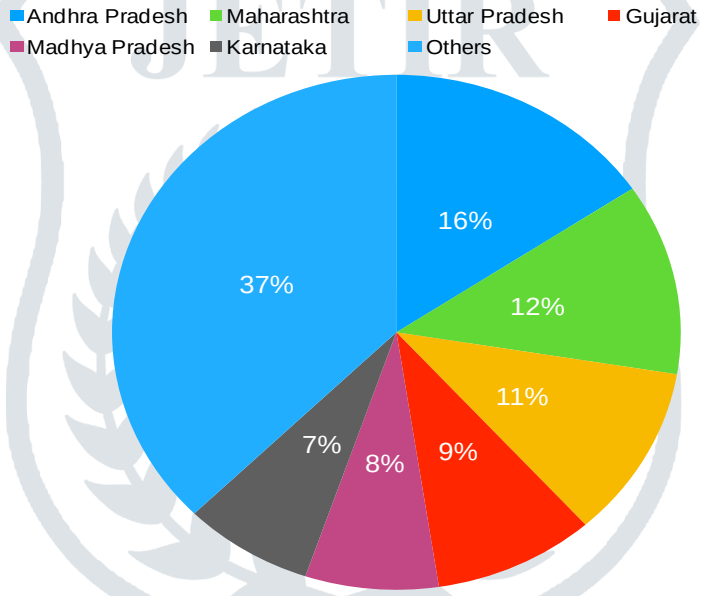
This research employed secondary data from existing research studies from across the world in the production of ethanol from various types of fruit wastes using different microorganisms. The researcher has used secondary sources drawn from existing literature on food waste studies and bioethanol production to form the basis of the research analysis. The researcher has also cited relevant data which analyse, elaborate and provide information concerning the topic of research.

IV. RESULTS AND DISCUSSION

India has witnessed increase in horticulture production over the last few years. Significant progress has been made in area expansion resulting in higher production. Over the last decade, the area under horticulture grew by 2.6% per annum and annual production increased by 4.8%. During 2017-18, the production of horticulture crops was 311.71 Million Tonnes from an area of 25.43 Million Hectares (Department of Agriculture, Cooperation & Farmer's Welfare, Government of India, 2018). The production of fruits has increased from 74.9 Million Tonnes to 97.35 Million Tonnes since 2010-11to 2017-18 as depicted in the graph below:



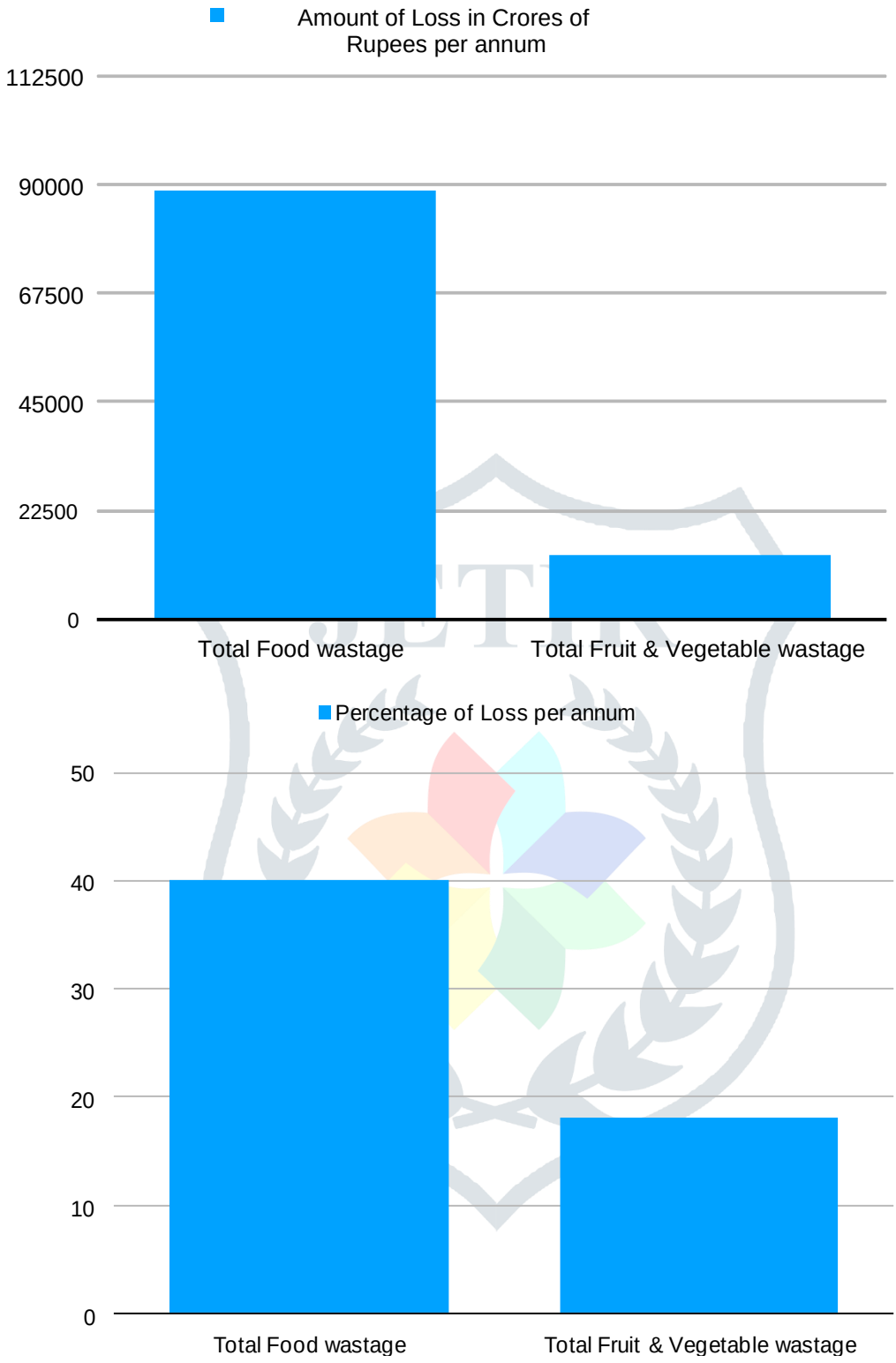
The major fruit producing states in India are depicted in the figure 2 below. As depicted in the following figure, the total production of fruits is highest in case of Andhra Pradesh (152.15 Lakh Tonnes) followed by Maharashtra (117.28 Lakh Tonnes).



The amount of food waste in India per year is worth Rs. 88,800 crore and per day is Rs. 244 crore per day. The percentage of total food wasted in India amounts to 40% per year (Reuters, Economic Times, 2018). India, being the second largest producer of vegetables and fruits waste fresh produce amounting to Rs 13,300 crore every year due to the lack of adequate cold storage facilities and refrigerated transport. Rs. 44,000 crore is the amount of wastage of fruits, vegetables and grains annually. Fruits and vegetables account for the largest portion of food wastage - 18% overall.

The amount in rupees and the percentage of loss of food wastage and fruits and vegetables wastage is depicted in figure 3 and figure 4 respectively.

The staggering amounts of waste show the need for them to be utilised effectively and waste products from fruits especially could be converted to useful products, thereby, minimising loss. One way of using fruit wastes is to convert them to an economically and environmentally viable product like bioethanol.



Source for Figures 1-5: Horticulture Statistics at a Glance, 2018

A large variety of fruits are grown in India, of which mango, banana, citrus, guava, grape, pineapple, sapota, papaya and apple are the major ones. To understand the best possible fruit waste source for the production of bioethanol, this study looks to explore various research undertaken over the past few years using the fruits most commonly produced by India. The source for data on rotten banana, apple, grape and papaya samples was obtained from studies conducted by Janaki K. et al, 2013 and on pineapple and orange from studies by Khandekar et al, 2018. The following table (Figure 5) below provides data regarding the fruits that are mentioned in this study in the Indian context:

Figure 5

	Banana	Pineapple	Orange	Grapes	Apple	Papaya
Highest Producing State	Gujarat	West Bengal	Andhra Pradesh	Maharashtra	Jammu & Kashmir	Andhra Pradesh
Area in '000 Ha	68.15	11.41	82.89	105.50	158.15	18.01
Production in '000 MT	4472.32	345.15	2003.11	2286.44	1808.33	1687.82

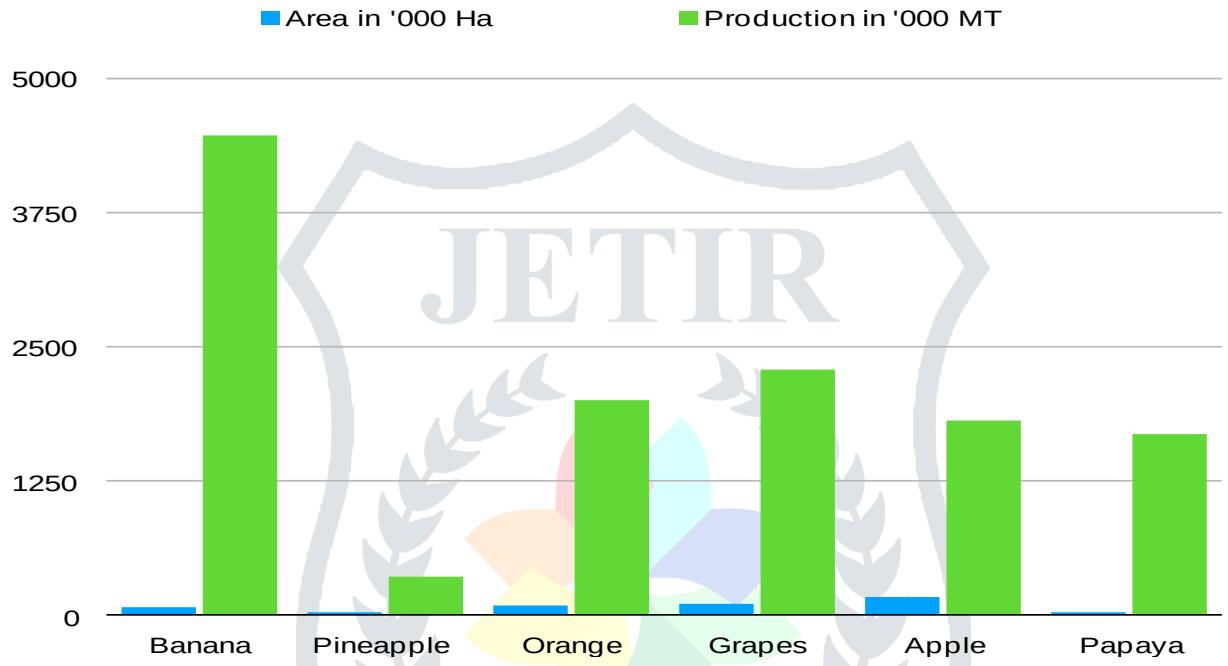


Figure 6 compiles relevant data to understand the amount of bioethanol produced from these fruit wastes using *Saccharomyces cerevisiae*. Figure 7 shows the optimum level of pH and temperature for the production of bioethanol and figure 8 shows the amount of bioethanol produced after 72 hours of incubation.

Figure 6

	Banana	Pineapple	Orange	Grapes	Apple	Papaya
Amount of Bioethanol Produced (%)	5.4	5.371	4.452	6.21	4.73	4.19
Optimum pH	5.1	3.82	4.28	5.4	4.5	4.3
Optimum Temperature (Degree Celsius)	30	30	30	30	28	27

Figure 7: Optimum pH and temperature for the production of bioethanol:

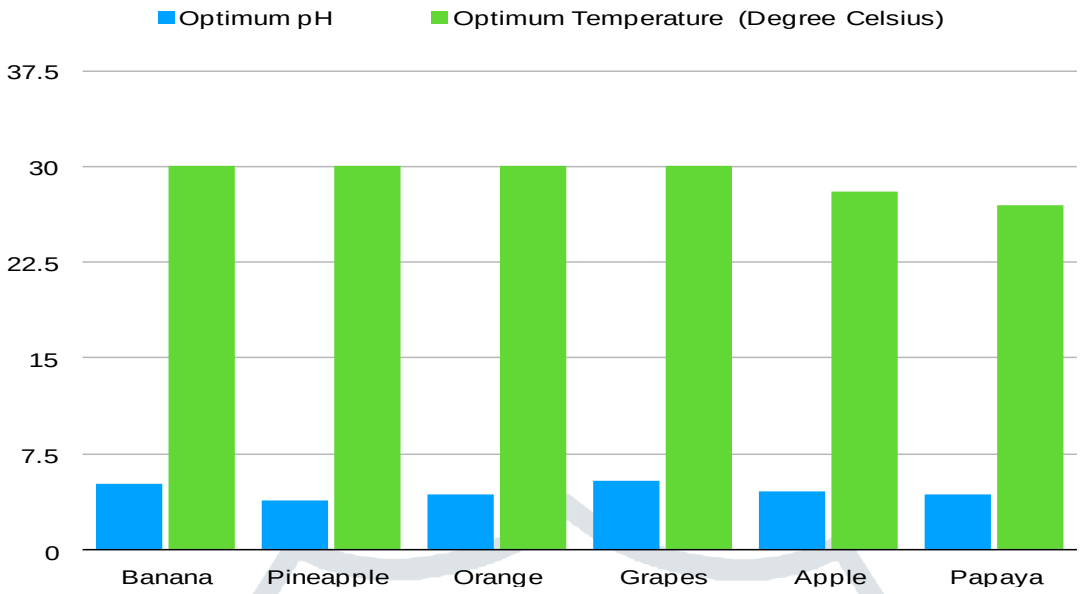
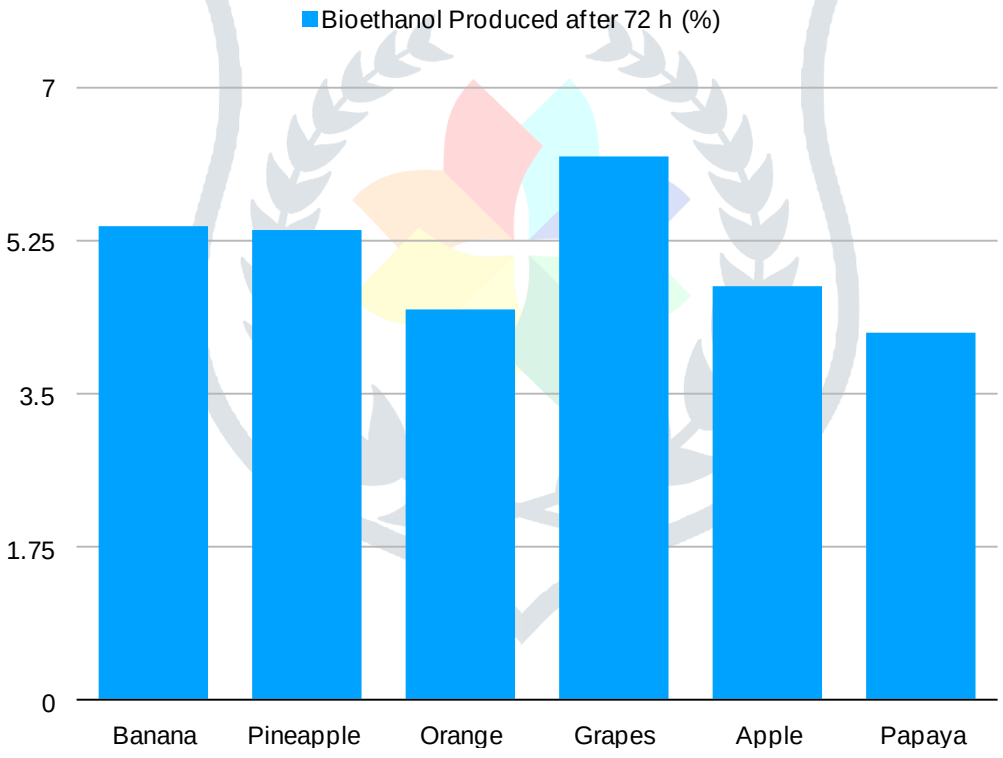


Figure 8: Amount of bioethanol produced in percentage after 72h :



Source for figures 6, 7 & 8: Janaki. K et al. (2013) and Khandekar et al. (2018)

India is the largest producer of banana, accounting for 27% of the world's total banana production. Banana (Musa paradisiaca) which when rotten is commonly discarded as waste is a good source of energy feedstock that may be suited for ethanol production. The amount of ethanol produced from rotten banana is 5.4% at a pH of 5.1 with optimum temperature being around 30°C.

India ranks fifth with a share of 8.2% of the world production of pineapples with 1.96 million tonnes being produced in the year, 2016. Pineapple peel is a byproduct from extraction of pine apple juice and constitutes about 8% by weight of the original fruit. Approximately 4,00,000 tonnes of pineapple peel are produced annually by any country. Pineapple peel wastes, which are seasonal, comprise of peels and their disposal poses a serious environmental pollution problem. Since pineapple peel is rich in cellulose, hemicellulose and other carbohydrates it was found to be a potential substrate for methane generation by anaerobic digestion. It could also be explored for its ability to produce biofuel. Pineapple (Ananas comosus) waste produced a yield of 5.371% of bioethanol. The yield is highest when the fermentation is carried out at lower pH around 3 to 4 (Hossain et al., 2006).

Orange (Citrus sinesis, family Rutaceae) contains orange peel which is an important byproduct. India is the third largest producer of oranges in the world with a yield of 12.98 T/Ha. Orange peel comprises cellulose, hemicellulose, lignin, pectin (galacturonic acid), chlorophyll pigments and other low-molecular weight compounds (e.g. limonene). Traditionally, Orange peel is treated to obtain volatile and nonvolatile fractions of essential oils and flavouring compounds. In addition, Orange peel has been reported to have germicidal, antioxidant, and anticarcinogenic properties. The amount of ethanol produced from orange peel is 4.452% at an optimum pH and temperature of 4.28 and 30°C respectively. High concentration of elements are recorded in orange waste.

Carica papaya (pawpaw) is one of the common fruits available with the highest source of energy and invert sugar with India largest producer of papaya in the world. Apple (Malus pumila) is the oldest fruit known to man and is grown extensively throughout the temperate zones of the world with India being the fifth largest producer in the world. Papaya and apple fruit wastes can be used for the production of bioethanol by fermentation process. The yield of ethanol obtained from apple waste at pH 4.5 and temperature of 28°C is 4.73% whereas from papaya waste at pH 4.3 and temperature of 27°C was recorded at 4.19%.

India is the seventh largest producer of grapes in the world. Grapes are the fruit of a wine (Vitis vinifera). The whole fruit, skin, leaves and seed of the grape plant are used as medicine. Grape wastes can be used as a substrate for the production of ethanol. The yield of ethanol amounted to greater than 80% of the fermentable sugar consumed. The maximum yield of ethanol was obtained from grape wastes at pH 5.4, temperature 30°C and concentration of 6.21% which is appropriately close the constant value of ethanol.

V. CONCLUSION

As natural energy source depletion is inevitable probing into alternative source of energy is gaining lot of importance worldwide. Ethanol could become an inexhaustible source of energy produced through fermentation of sugars . Fruits like banana, pineapple and papaya leave a sizeable amount of residues after processing in the form of peels, seeds and pulp respectively. Such residues pose considerable disposal problems and ultimately lead to environmental pollution. Numerous studies have been carried out to use these fruit wastes for ethanol production.

India is the second largest producer of fruits in the world, closely following China. The amount of fruits that are wasted each day could be put to better use by utilising them as substrates for ethanol fuel production. Acceptable ethanol yield is produced using the peels of pineapple and orange and rotten banana, grapes, apples and papaya. Therefore ethanol can be produced by utilizing the fruit wastes which are currently viewed as biowaste and normally discarded. This study could thus establish that the best sources of the fruit peels and rotten fruits which have not been exploited commercially for much industrial application and are poorly disposed could effectively be used for the production of ethanol by the process of fermentation using *Saccharomyces cerevisiae*. Though the ethanol yield produced using the four fruit peels was acceptable, two fruit peels produced maximum ethanol yield.

The maximum concentration of alcohol was produced from rotten grapes (6.21%) which are capable of providing sugar for the process of fermentation and hence, can be economically exploited for bioethanol production. In rotten grapes, the concentration of fermentable sugar is high hence does not require any pretreatment with enzymes which are quite expensive, therefore, serve as the best source of production of bioethanol.

We can thus conclude that fruit wastes form potential substrates for production of alcohol as acceptable levels of alcohol can be produced from this biowaste without pretreatment with enzymes or alkali. This is process that is cost effective and does not result in toxic residues, hence, is an environment-friendly procedure.

References

[1] V. Nallathambi Gunaseelan, 2013. “Biochemical methane potential of fruits and vegetable solid waste feedstocks”. doi:10.1016/j.biombioe.2003.08.006
[2] Babbar. N, Oberoi. H. S, Uppal. D. S, Patil. T. S, 2010. “Total phenolic content and antioxidant capacity of extracts obtained from six important fruit residues”. doi:10.1016/j.foodres.2010.10.001
[3] Pathak P.D., Sachin A. Mandavgane, S.A., and Kulkarni B., 2017. “Fruit peel waste: characterization and its potential uses”. doi: 10.18520/cs/v113/i03/444-454
[4] Sharma. N, Kalra K.L, Oberoi. H.S, Bansal. S, 2007. “Optimization of fermentation parameters for production of ethanol from kinnow waste and banana peels by simultaneous saccharification and fermentation”. Indian J. Microbiol. (December 2007) 47:310–316
[5] Janani K., Ketzi M., Megavathi S. , Dr.Vinothkumar D. , Dr. Ramesh Babu N.G, 2013. “Comparative Studies of Ethanol Production from Different Fruit Wastes Using Saccharomyces cerevisiae” International Journal of Innovative Research in Science, Journal Engineering and Technology (An ISO 3297: 2007 Certified Organization) Vol. 2, Issue 12, December 2013
[6] Shubhra Tiwari, S.K. Jadhav, Mayuri Sharma and K.L. Tiwari, 2014. Fermentation of Waste Fruits for Bioethanol Production. Asian Journal of Biological Sciences, 7: 30-34.
[7] Akin-Osanaiye B.C., Nzelibe H.C., Agbaji A.S. (2005). Production of ethanol from Carica papaya (pawpaw) agro waste: effect of saccharification and different treatments on ethanol yield. Afr. J. Biotechnol. 4(7): 657 - 659.
[8] Association of Official Analytical Chemists (A.O.A.C.) (1970 and 1980). Official Methods of Analysis 13th Ed. Horwits, W., Ed. A.O.A.C., Washington D.C.
[9] Borah. D, Mishra. V, 2007. “Production of Bio Fuel from Fruit Waste”. International Journal of Advanced Biotechnology Research. Volume 1, Number 1 (2011), pp. 71-74

[10] J. Goettemoeller, A. Goettemoeller (2007). Sustainable Ethanol: Biofuels, Biorefineries, Cellulosic Biomass, Flex-Fuel Vehicles, and Sustainable Farming for Energy Independence (Brief and comprehensive account of the history, evolution and future of ethanol). Prairie Oak Publishing, Maryville, Missouri. ISBN 9780978629304.
[11] O. R. Inderwildi, D. A. King (2009).Quo Vadis Biofuel. Energy & Environmental Science 2: 343
[12] Mohammad Moneruzzaman Khandaker1*, KhadijahBinti Qiamuddin1, Ali Majrashi2,
Tahir Dalorima1, Mohammad Hailmi Sajili1and ABM Sharif Hossain (2018) Bio-Ethanol Production from Fruit and Vegetable Waste by Using Saccharomyces Cerevisiae. BIOSCIENCE RESEARCH, 2018 15(3):1703-000
[13] B.C. Akin-Osanaiye, H.C. Nzelibe and A.S. Agbaji, 2008. "Ethanol Production from Carica papaya (Pawpaw) Fruit Waste" DOI: 10.3923/ajb.2008.188.193 (http://dx.doi.org/10.3923/ajb.2008.188.193)
[14] Horticultural Statistics at a Glance 2018. Horticulture Statistics Division Department of Agriculture, Cooperation & Farmers' Welfare Ministry of Agriculture & Farmers' Welfare Government of India.
[15] Pilot Study for Estimation of Seed, Feed and Wastage Ratios of Major Food Grains, 2016. ICAR – Indian Agricultural Statistics Research Institute Library Avenue, Pusa, New Delhi.
[16] Food wastage crisis in India, 2018. Posted by: Clean India Journal - Editor May 12, 2018 in Waste Management https://www.cleanindiajournal.com/food-wastage-crisis-in-india/
[17] India wastes Rs 244 crore worth of food a day: Report by Economic Times Bureau, 2018. https://economictimes.indiatimes.com/wealth/personal-finance-news/india-wastes-rs-244-crore-worth-of-food-a-day-report/articleshow/62391489.cms
[18] Bhosale, J, 2013. India wastes fruits and vegetables worth Rs 13,300 crore every year: Emerson study https://economictimes.indiatimes.com/news/economy/agriculture/india-wastes-fruits-and-vegetables-worth-rs-13300-crore-every-year-emerson-study/articleshow/26523928.cms
[19] Food Loss and Food Waste, 2019. Food and Agricultural Organisation of the United Nations. http://www.fao.org/food-loss-and-food-waste/en/
[20] Deng, G. F., Shen, C., Xu, X. R., Kuang, R. D., Guo, Y. J., Zeng, L. S., … Li, H. B. (2012). Potential of fruit wastes as natural resources of bioactive compounds. *International journal of molecular sciences*, *13*(7), 8308–8323. doi:10.3390/ijms13078308