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Investigation into Alternative Energy Sources from Waste Citrus Peel (Orange): Approach to Environmental Protection

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Abstract-
An experimental study has been carried out on an alternative source of energy from citrus peel waste. A widely used material, pectin, has been extracted from orange peel (OP) and subsequently converted into ethanol with the use of a bacteria and fungi. Dried peels were split into several particle sizes of 0.075, 0.5, 1.0 and 5 mm. It was noted that OP with 0.75 mm particle size produced pectin of low volume while larger 1.0 mm OP particle size produced a high pectin volume. OP of 802 g was used to produce 1,770 ml of pectin, this illustrate that citrus fruit (specifically orange) contains pectin in a large quantity. A mixture of *E.coli* (bacteria) with yeast (fungus), and their individual components were used on pectin obtained. However, it was observed that a mixture of pectin, *E.coli* & *S. cerevisiae*, and a combination of sample pectin with *E.coli* produced an encouraging volume of ethanol as against no ethanol produced when a mixture of sample pectin, yeast and pectin sample only. The amount of energy contained in the gross ethanol produced was 1526.6 btu, this can be combined with purified gasoline so as to attain the optimum energy content that can be used to run an indigenous processing plant for citrus fruit in Nigeria.

Key words: *Escherichia coli;* Ethanol; Pectin; Orange peel, Citrus

1. Introduction

In food processing companies, wastes are generated during the production process of a desired product from an undesired byproduct [1, 2]. The industrial wastes produced from these products have specific composition with no remarkable variations. [3]. Several works have converted the biodegradable portion of food waste such as orange peel to produce essential products [4]. One of the most beneficial components of biomass waste is the orange peel. Globally, oranges take about 75% of the overall types of citrus fruit, a major producer of these is China [5]. Orange peel is disposed from industries producing orange juice and soft drinks. These wastes accumulates in industries, occupying useful expanse of land that would have been used for other purposes and thus, causing problem due to improper disposal of the waste [6].

The abundance of orange peel in nature account for the reason why it is essential to convert it into a more suitable product [5]. Orange peel essentially comprise of chlorophyll pigments, pectin substances, lignin, hemicellulose, cellulose and low MW compounds like limonene which essentially contain several OH groups that makes it a capable sorbent for various kind of pollutants [5, 6]. The large amount of orange peel available at a very low cost from several fruit manufacturing industries has intensified research on its usefulness as sorbent for removal of several pollutants in aquatic medium [6]. However, researchers have continued to investigate the production of other products from orange peel. Orange peel waste has been used for cellulose extraction [7], production of extracellular enzymes [8], adsorption of dyes [9, 10], as a bio-sorbent material [11, 12], for lactase production [13], citric acid production [14], biogas production, [15, 16], and pectin extraction [17-20].

Pectin is often used as a food additive; it exists in a large proportion in plant materials. It can be used as a stabilizer, an emulsifier, a texturizer, a gelling and thickening agent [21]. It has also been applied in several applications such as in ice creams, its used for substituting fats in spreads, and emulsifying meat products [18]. Pectin is also applied in pharmaceutical firms to reduce gallstones and heart disease, to reduce pain and reduce blood fat [22]. As a result of its nutritional and functional characteristic, the request for pectin is in surplus of about 30,000 tons yearly, with about 4-5% growth rate per annum [19]. The high demand has led to a rise in the number of studies investigating the production of pectin from various sources. Several reports have been documented on pectin extraction from agricultural by-product through reaction with several types of inorganic acid solutions [23, 24]. Generally, production of pectin takes place by a physiochemical process starting with removal of mineral acid succeeded by recycling by alcohol precipitation [25]. Although, the use of mineral acids for extracting pectin have raised the cost of production and increase its hazardous effects on the environment [23]. Extraction of pectin without the use of mineral acid is an environmentally friendly process [26]. The use of water as an extraction solvent has been applied by Hosseini [26]. The industrial procedure of converting these waste into a rich-pectin has generated a beneficial biomass for the production of ethanol [27].

Various studies have reported the production of ethanol from orange peel [28-32] but this research has been limited due to the surplus availability of petroleum fuel [33]. However, in recent times, ethanol produced from orange peel has been used as a substitute for methyl tertiary butyl ether (MBTE), a fuel additive, so as to reduce environmental pollution [34]. Also, it has been documented that ethanol fuels produced from biomass is environmentally friendly and sustainable [33]. The use of ethanol can improve energy security by reducing a nation dependence on imported fuels [33, 35].

Different types of microorganism have been reported to perform various functions ranging from waste conversion to bioremediation of both crude oil polluted water and soil [36-40].

2. Methodology

Waste orange peels were collected from the Covenant University Cafeteria where they juice the pulp into orange fruit drink for students.

2.1 Material Processing

2.1.1 Preparation of Samples: The orange pith was blanched with hot water for less than 6 minutes and blender using Binatone blender. Sieve analysis was carried out with various sizes of mesh [40].

2.1.2 Preparation of Inocula: *S. cerevisiae* and *E. coli* were prepared according to the method of [41-47].

2.1.3 Extraction of Pectin: Pectin was extracted from the processed pith using method [40].

Different conditions were used for the production of ethanol from pectin:

Experiment 1: Using Pectin and Yeast only to produce Ethanol
400 mL of the obtained pectin was put in a 500 ml conical flask with 2g *S. cerevisiae* and thoroughly mixed with the liquid pectin. Fermentation was allowed to take place on the mixture for 14 days using ambient temperature. Distillation was used to separate the mixture.
Experiment 2: Using Pectin and *E.coli* only to produce Ethanol
Same quantity as above was put in a 500 ml conical flask and 2 wire loop *E. coli.* The mixture was allowed to ferment anaerobically for 14 days. Distillation was used to separate the mixture.
Experiment 3: Using Pectin, *E.coli* and Yeast
Same as above quantity was put in a 500 ml conical flask, hydrolyzed with 2 wire loop *E.coli*. After 48 hours, 2g *S. cerevisiae* was used, and the mixture fermented anaerobically for 14 days.
Experiment 4: This is the Control where only Pectin only was used.

3. Result and discussions

Table 1: Mass of the varying particle size after sieve analysis

Particle Size (mm)	Weight of Pith (kg)
0.75	0.078
0.5	0.094
1.0	40.9
5.0	10.4

Table 1 shows the quantity of pith obtained using various sieve sizes.

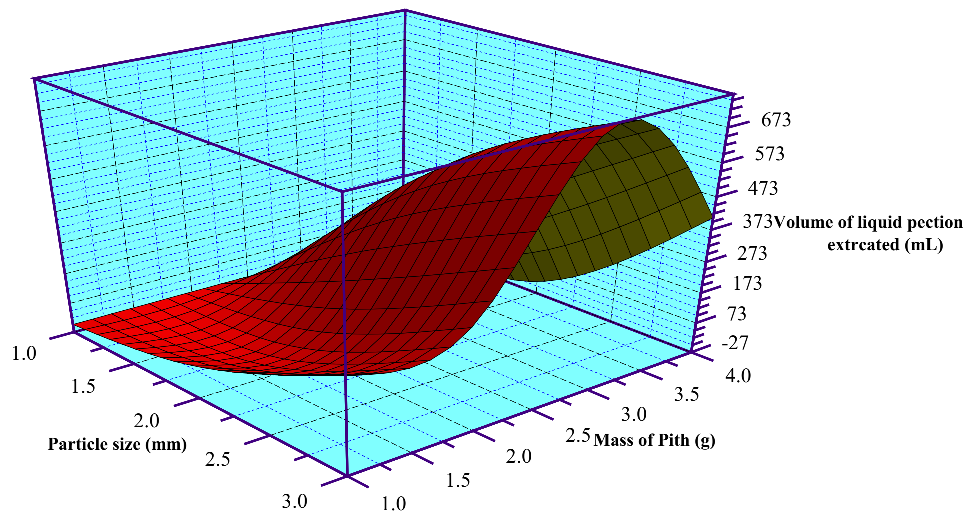

Figure 1: A 3D plot of Size, Mass of Pith and Volume of liquid

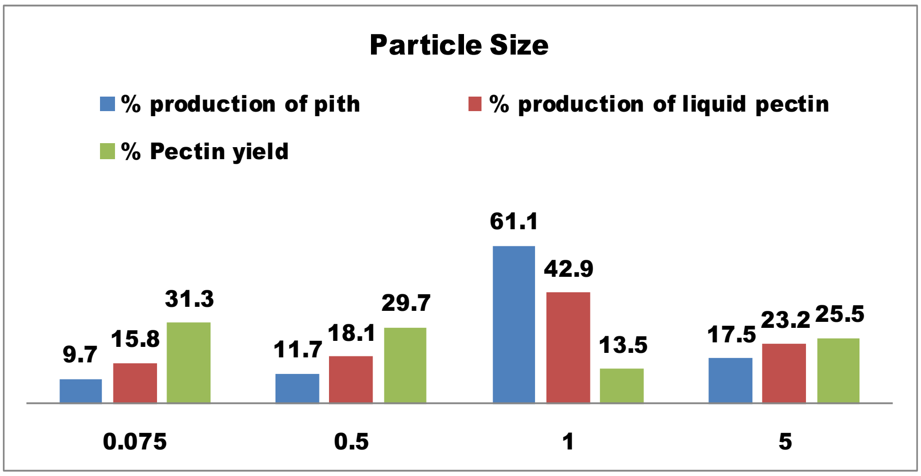

Figure 2**:** Particle size impact on the yield

Different sizes on the mass of the pith and the volume of pectin obtained was shown in figure 1. Particle size 1 mm with the pith mass of 0.49 revealed more pectin while figure 2 shows the impact of particle size on yield.

% yield of was calculated using equation below (1).

Y_{pec} (%) = $(P/_{Bi}) * 100$ Eq. (1)

Table 3 shows the % of pectin obtained from the pith.

The equations 2, 3, 4 and 5 for the particle size 0.075, 0.5, 1 and 5 are written as shown respectively below

$y = 10.8x - 2.6667$ Eq. (2)

$y = 9x + 1.8333$ Eq. (3)

$y = -23.8x + 86.767$ Eq. (4)

$y = 4x + 14.067$ Eq. (5)

The particle size x = 0.075 has the highest relationship of production pitch, pectin yield and liquid pectin. The particle size x = 1 had the highest variance in its relationship of production pitch, pectin yield and liquid pectin. Total yield of 22 and 40 ml was obtained.

Table 2: % yield of Pectin

Particle size (mm)	Weight of pith (g)	% production pith	Volume of extract (mL)	% production of liquid pectin	Pectin	% Pectin yield
0.075	78	9.7	280	15.8	358.97	31.3

0.5	94	11.7	320	18.1	340.43	29.7
1	490	61.1	760	42.9	155.10	13.5
5	140	17.5	410	23.2	292.86	25.5

Table 3: Percentage yield of ethanol

Days	Pectin only (ml)	Pectin + *E.coli* (ml)	(%) Pectin + *E.coli* (ml)	Pectin + yeast (mL)	Pectin + *E.coli* + S.c (ml)	(%) Pectin + *E.coli* + yeast
0	0.0	0.0	0	0.0	0.0	0.0
5	0.0	3.0	13.6	0.0	3.3	8.2
10	0.0	7.4	33.6	0.0	14.7	36.8
12	0.0	6.6	30.0	0.0	12.2	30.5
14	0.0	5.0	22.7	0.0	9.8	24.5
TOTAL YIELD		22			40	

3.1 Production of Ethanol

Table 3 shows that due to the vaporization of Ethanol during production decrease in the percentage ethanol yield were noticed. Pectin + *E.coli* had the highest ethanol yield on the 10th day of fermentation (33%) while Pectin + *E.coli* + yeast also had highest production of ethanol on the 10th day of fermentation (36 %) both yield decreases as fermentation progresses. Pectin and *S. cerevisiae* did not produce alcohol.

3.2 Production of Ethanol content

(1) For 40 ml:

3785.41178 ml = 1 gallon

40 ml = x gallon

This is equivalent to 0.011 gal

Thus 40 ml = 0.011 gal

But 1 gal of Ethanol = 76,330 btu of energy

Therefore, 0.011 gal = 76,330 * 0.011 = 839.63 btu of energy.

But a typical citrus processing plant will consume 180 Kw of energy annually.

1 Kw = 56, 86903 btu

Therefore 180Kw = 10236.4254 btu

Hence, 40 ml ethanol has an energy content of 839.63 btu of energy which can be mixed with gasoline to power a plant.

(2) For 22ml

ethanol produced during the experiment: (40ml + 22ml) = 62ml

62ml = 0.02 gal

Therefore, 0.02 gal = 76,330 * 0.02 = 1526.6 btu enegy

Hence, 62ml ethanol has energy of 153btu of energy used with gasoline to power a mini-plant.

Table 4: Gas Chromatography for Pectin + *E.coli* + Yeast

Retention time	Compound	% Area
3.85	Benzene	0.79
4.363	Benzene, 1, 3-dimethyl	4.14
6.234	Benzene, 1,2,4-trimethyl	3.76
6.612	1-methyl 1-3-propyl	0.38
6.703	4-ethyl,1,2-dimethl	0.46
6.938	Benzene,1-methyl-4-(1-methylethyl)	0.69
7.413	Benzene 1,2,3,5-tetramethyl	2.03
10.073	Cyclopropane	25.72
11.761	Diethyl phthalate	7.68
15.137	n-hexadecanoic acid	1.52
20.499	Cholesterol	10.42
25.082	3-Eicosene	0.77

Table 5: Gas Chromatography for Pectin + *E.coli.*

Retention time	Compound	% Area
3.854	Benzene Ethyl	1.66
3.991	P-xylene	6.21
4.369	Benzene, 1,3-dimethyl	2.8
5.53	Benzene, 1,2,3-dimethyl	1.23
5.862	Benzene, 1,2,4-trimethyl	4.94
6.24	Benzene, 1,2,3-trimethyl	1.93
6.703	1-methyl-2-(1-methylethyl)	0.97
6.938	4-ethyl-1,2 dimethyl	1.23
7.018	Benzene,4-ethyl-1,2 dimethyl	1.21
7.413	1,2,4,5-trimethyl	2.84
10.073	Cyclopropane	52.82
11.761	Diethyl phthalate	8.36

Table 4 and 5 shows the components detected using GC-MS for pectin, *E.coli*, yeast and Pectin + *E.coli* samples with Cyclopropane having the highest % Area of 20.499 and 52.82 in samples with pectin, *E.coli*, Yeast and Pectin + *E.coli* respectively. It is also known as trimethylene. Cyclopropane is a colourless flammable gaseous hydrocarbon. It is a cycloalkane with molecules containing rings of three carbon atoms. It has a chemical formula C_3H_6 and Molecular weight**:** 42.0797. The structure of Cyclopropane was shows in figure 3. Figure 4 revealed the Mass Spectrum Cyclopropane.

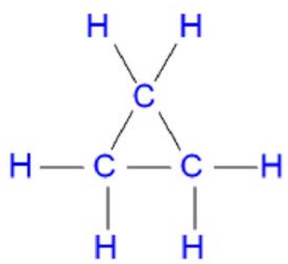

Figure 3: Structure of Cyclopropane

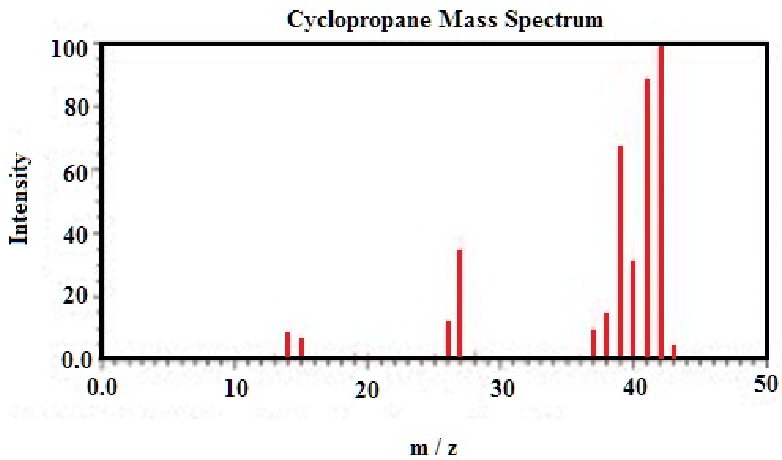

Figure 4: Cyclopropane Mass Spectrum

4. Conclusion

This research concluded that waste orange peel of 802 g will produce 1,770 mL of pectin which can serve as substitute for gasoline. It was observed that a mixture of pectin, *E.coli* & *S. cerevisiae*, and a combination of sample pectin with *E.coli* produced an encouraging volume of ethanol. The amount of energy contained in the gross ethanol produced was 1526.6 btu, this can be combined with purified gasoline so as to attain the optimum energy content that can be used to run an indigenous processing plant for citrus fruit in Nigeria.

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Conflict of interest

The authors declare that they have no conflict of interest.

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