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# PYROLYSIS OF WASTE TETRA PACK

**Ebaa K. Jasim*, Myasoon J. Zaiter, Itimad K. Hassan, Ethar M. Jassar and Zeena Th. Salman**
Ministry of Science and Technology, Baghdad, Iraq
*Corresponding author email : ebaakareem82@gmail.com

## Abstract

Tetra pack cartons are the most common name for aseptic cartons, which are used for liquid food items. The tetra pack waste was pyrolysed in a Pyrex glass batch reactor at a temperature range of 375°C to 425°C and at a heating rate of 10°C min-1 to study the production of hydrocarbon liquid from waste Tetra pack. The maximum liquid yield was 43.9% at 400 ° C. The functional groups present in the liquid are Alcohols (substituted, primary, secondary, tertiary, and multi substituted), alkane (primary, secondary, and tertiary) Aldehydes, Ketones, Carboxylic acid, Amine (substituted, cyclic, and aliphatic) Ester, ethers, and alkene (very little percent). It was found that the pyrolytic liquid contains around 33 types of compounds having a carbon chain length in the range of C3-C34. The obtained liquid can be used as valuable chemicals feedstock.
***Keywords:*** Pyrolysis, Tetra Pack, Pyrolitic Oil

## Introduction

Municipal solid waste (also called trash or garbage) is defined at the national level as wastes consisting of everyday items such as product packaging, grass clippings, furniture, clothing, bottles and cans, food scraps, newspapers, appliances, consumer electronics, and batteries. These wastes come from homes; institutions such as schools and hospitals; and commercial sources such as restaurants and small businesses Joseph (2002). The energy-to-waste is the only solution of the present scenario and the options are landfilling, incineration, pyrolysis, and gasification of MSW; out of which landfilling and incineration having adverse impact on environment and so pyrolysis is preferably good option, which is a significant and growing problem in many urban areas of the developing world Kumar (2000), Morcos (1989), Saxena & Jotshi (1994), Alvarenga *et al.* (2012), and David *et al*. (2003) discussed pyrolysis phenomenon on the basis of a series of TGA experiments for glossy paper also determined kinetics parameters for cardboard Wu, *et al.* (1997), studied kinetics and pyrolysis of a mixture of four types of papers (uncoated and coated printing paper, newsprint and tissue paper) for heating rates 1, 2, 5 K/min and results indicated that decomposition occurred in two stages. Sriram (2005) has also studied the degradation of four types of papers and five different plastics at a heating rate of 100C/min Biswal *et al.* (2013). Along with landfill, $CO_2$ and $CH_4$ emissions, potential groundwater pollution, the reduction of space available for landfilling has led to policy and legislation to increase the recycling and reuse of wastes. Municipal solid waste streams typically consist of 40 to 45 % of paper products which are a potentially valuable source of energy. Paper waste is easy to segregate from the solid waste stream; Tetra Pak cartons are the most common name for aseptic cartons, which are used for liquid food items so they can be stored for up to one year without refrigeration, is composed of 75% paper, 20% polyethylene and 5% aluminum Korkmaz (2009). Recycling is one of the alternatives for recovering the long-life packaging. The recycling starts in the paper industry where recycling fibers can be recovered by a repulping process. The polyethylene and aluminum separated in a hydropulper can be recovered in three different ways: energy generation from paraffinic oil, recovery of aluminum in pyrolysis ovens, recovery of polyethylene and aluminum by plasma technology, and the processing of the mixtures of polyethylene and metal to obtain high-end plastic lumber products. Among these technologies, pyrolysis is considered to be a good alternative either to separate aluminum from polyethylene or to generate products with high heating value. Most of the current interest associated with pyrolysis is focused on the environmental issue since these processes represent attractive ways of utilizing agricultural and forestry residues, as well as a major part of the components in municipal solid wastes. The disposal of solid biomass and waste is becoming an enormous problem because they are very difficult and costly to manage. Pyrolysis has proved itself to be a new type of solid biomass and waste utilization technique that transforms biomass and waste material of low-energy-density into bio-oil of high-energy density and recover higher value chemicals. Shelf stable milk and juice is a genius idea — buy in bulk to always have at the ready, less food waste, and it is fresher than canned goods. But with all the benefits of shelf-stable packaging like Tetra Pak, they're difficult to recycle due to their multi-layer construction. Tetra Pack cartons are the most common name for aseptic cartons, which are used for liquid food items so they can be stored for up to one year without refrigeration Ucuncu and Veisilind (1993).

### Packaging Materials

Tetra Packs are constructed from 6 layers of materials as shown in Fig. (1):

1. Polyethylene - protects against outside moisture
2. Paper - for stability and strength
3. Polyethylene - adhesion layer
4. Aluminum foil - oxygen, flavor, and light barrier
5. Polyethylene - layer
6. Polyethylene - seals in the liquid

The biggest layer is the paper layer, which makes up 75% of the packaging, otherwise, 20% is polyethylene and 5% is aluminum. The paper part is what can be recycled relatively easily and is used to create other items like paper and tissue products [10].

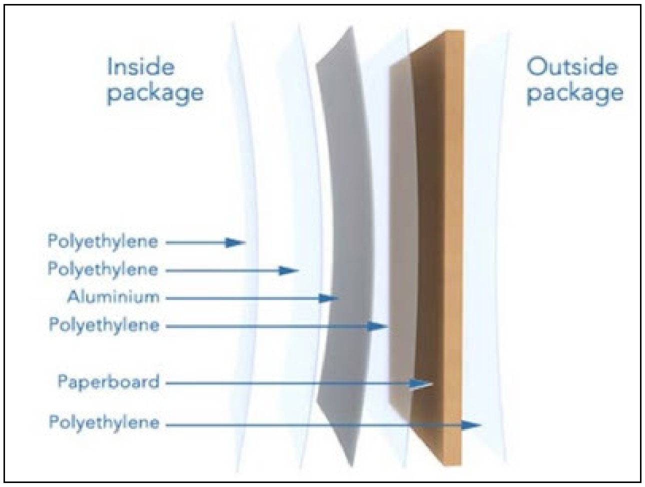



**Fig. 1:** Tetra pack materials

## Materials and Methods

Tetra pack wastes were cut into small pieces (about 1 cm diameter). A known weight of the sample was packed in a stainless steel basket; this basket fixed inside Pyrex reactor and placed a tube furnace then heated at a constant heating rate of 10°C/min operating in a stream of nitrogen gas. The pyrolysis setup consists of Pyrex reactor made of stainless steel tube (length 70 cm, internal diameter 13 cm and outer diameter 26 cm). The reactor is heated externally by an electric furnace, with the temperature being measured by a thermocouple fixed inside the reactor, and the temperature is controlled by an external PID controller as shown in Fig. (2). 40 g of waste Tetra pack sample was loaded in each pyrolysis reaction experiment. After heating for 2 hours the system was stopped and after cooling the condensable liquid products/ wax were collected through the condenser and weighed. After pyrolysis, the solid residue left out inside the reactor was weighed. Then, the weight of the gaseous/volatile product was calculated from the material balance. Reactions were carried out at different setting temperatures ranging from 375–425°C.

**Fig. 2:** Pyrolysis reactor

Gas chromatography-mass spectrometry (GC-MS) is an analytical method that combines the features of gas-chromatography and mass spectrometry to identify different substances within a test sample. Fourier – transform infrared spectroscopy (FTIR) is one of the most important techniques used in the interpretation and diagnosis of chemical compounds. The GC-MS analysis and Fourier – transform infrared spectroscopy (FTIR) of the pyrolytic oil sample is carried out.

## Result and Discussion

The pyrolysis of Tetra pack waste yielded three different products, that is, oil, gas, and residue (solid). The appearance of the oil is dark brownish free from visible sediments as shown in Fig. (3). The distributions of these fractions are different at different temperatures and are shown in Table 1. The oil and gas/volatiles constituted major product as compared to the solid residue fractions. The maximum liquid product was 43.9% at the temperature 400ºC. The maximum yield of char 37% was obtained at the temperature 375 °C. The yield of gas was decreased with increasing pyrolysis temperature up to 400ºC and then increases. The highest yield of gas 34.875 % was obtained at a pyrolysis temperature of 425 °C. Effect of Temperature on product yield is shown in Fig. (4). It has been observed from GC- mass analysis that the pyrolytic oil contains around 33 compounds as shown in Fig. 5 is summarized in Table (2). Taking into account the area percentage, the highest peak areas of total ion chromatogram (TIC) of the compounds were (5Z)-9-Methyl-5-undecane, 3,5-Dimethyl pyrazole-1-carbinol, (3E)-3-Heptenoic acid, Isoxazole, 3-amino-5-methyl-,1-Cyclopropyl-1-pentanol, 3-Aminodihydro-2(3H)-furanone, and Propane-1,3-diol. The components present in tetra pack waste pyrolytic oil are mostly furan derivatives of Alcohols (substituted, primary, secondary, tertiary, and multi substituted),alkane (primary, secondary ,and tertiary) Aldehydes, Ketones, Carboxylic acid, Amine (substituted ,cyclic and aliphatic), Esters, ethers, and alkene (very little percent)) with carbon number C3–C34.

**Fig. 3:** Pyrolytic oil.

**Table 1:** Distribution of different fractions at different temperatures in thermal pyrolysis of Tetra pack waste.

| Temperature (°C ) | Oil (Wt. %) | Solid (Wt. %) | Gas (Wt. %) |
|---|---|---|---|
| 375 | 29.85 | 37 | 33.5 |
| 390 | 35.625 | 32.725 | 31.65 |
| 400 | 43.9 | 28.25 | 27.85 |
| 415 | 42.225 | 27.45 | 30.325 |
| 425 | 38.45 | 26.675 | 34.875 |

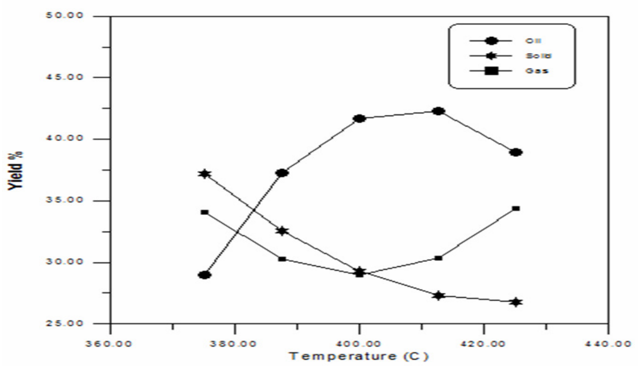



**Fig. 4:** Effect of Temperature on product yield.

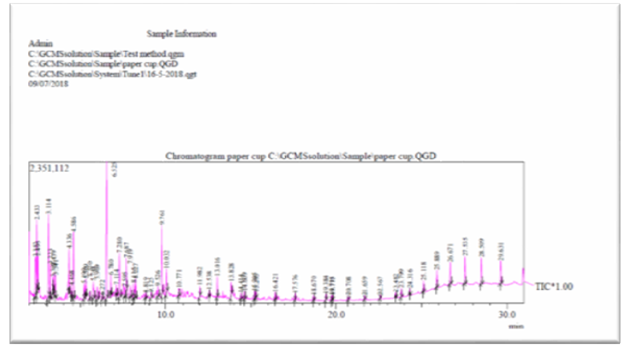



**Fig. 5:** Components of liquid product were analyzed using GMS

**Table 2:** GC-MS result of liquid product

| Peak# | Compound | Area% | Formula |
|---|---|---|---|
| 1 | 3-Aminodihydro-2(3H)-furanone | 4.84 | $C_4H_7NO_2$ |
| 2 | Propane-1,3-diol | 4.67 | $C_3H_8O_2$ |
| 3 | Pentose | 1.88 | $C_5H_{10}O5$ |
| 4 | 3,5-Dimethyl pyrazole-1-carbinol | 7.13 | $C_6H_{10}N_2O$ |
| 5 | 6-Nitro-2-hexanol | 2.34 | $C_6H_{13}NO_3$ |
| 7 | (E)-2,4-Pentadienoic acid | 1.05 | $C_5H_6O_2$ |
| 8 | Butane-2,3-dione | 1.38 | $C_4H_6O_2$ |
| 9 | gamma.-Crotonolactone | 3.85 | $C_4H_4O_2$ |
| 11 | Isoxazole, 3-amino-5-methyl- | 5.36 | $C_4H_6N_2O$ |
| 13 | Methoxypyrazine | 1.52 | $C_5H_6N_2O$ |
| 15 | Phenyl carbamate | 1.74 | $C_7H_7NO_2$ |
| 16 | Cyclohexanol, 2-methylene | 1.44 | $C_7H_{12}O$ |
| 18 | (5Z)-9-Methyl-5-undecene | 11.68 | $C_{12}H_{24}$ |
| 19 | Isobutylglycerol, nitro- | 1.10 | $C_4H_9NO_5$ |
| 20 | o-Hydroxytoluene | 0.69 | $C_7H_8O$ |
| 21 | 1-Cyclopropyl-1-pentanol | 5.14 | $C_8H_{16}O$ |
| 23 | Imidazole, 2-amino-5-[(2-carboxy)vinyl] | 3.25 | $C_6H_7N_3O_2$ |
| 24 | 3-Methyl-3-cyclohexene-1-carbaldehyde | 0.96 | $C_8H_{12}O$ |
| 25 | 5-Methyl-4,6-pyrimidinediol | 1.22 | $C_5H_6N_2O_2$ |
| 26 | 2,4-Pentadien-1-ol, 3-propyl-, (2Z)- | 1.46 | $C_8H_{14}O$ |
| 27 | 2,6-Dimethylphenol | 0.68 | $C_8H_{10}O$ |
| 28 | m-Tolyl carbinol | 0.92 | $C_8H_{10}O$ |
| 29 | 2-Methoxy-6-methylphenol | 0.93 | $C_8H_{10}O_2$ |
| 30 | (3E)-3-Heptenoic acid | 6.10 | $C_7H_{12}O_2$ |
| 31 | Cyclopentanecarboxylic acid, 4-tridecyl ester | 2.11 | $C_{19}H_{36}O_2$ |
| 32 | Benzyl alcohol, m-hydroxy | 1.06 | $C_7H_8O_2$ |
| 35 | 4-Oxononanal | 1.47 | $C_9H_{16}O_2$ |
| 36 | beta.-D-Allose | 1.33 | $C_6H_{12}O_6$ |
| 37 | 4a-Methyl-3,4,4a,5,8,8a-hexahydro-2(1H)-naphthalenone | 0.66 | $C_{11}H_{16}O$ |
| 54 | 11-n-Decyltetracosane | 1.31 | $C_{34}H_{70}$ |
| 55 | 10-Methylnonadecane | 1.81 | $C_{20}H_{42}$ |
| 56 | 2,6,10,15-Tetramethylheptadecane | 2.29 | $C_{21}H_{44}$ |
| 57 | Normal-heptadecane | 2.51 | $C_{17}H_{36}$ |
| | | 85.88 % | |

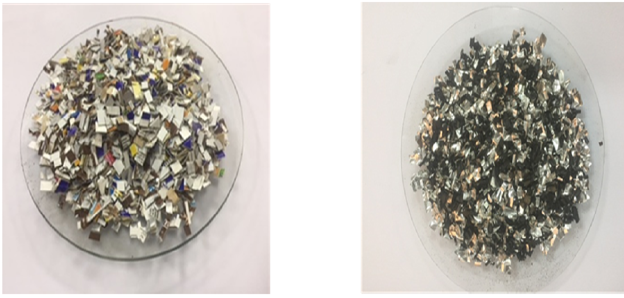
The FTIR spectra of tetra pack are an important analysis that identifies the various characteristic functional groups present in the samples A and B as shown in Fig. (6).

Note from spectrum for sample A (before pyrolysis) Fig. (7):

- Stretching vibrations for the O-H of frequency 3348 $cm^{-1}$, this indicates the presence of alcohol.
- Stretching vibrations for the C-H at frequency 2916 $cm^{-1}$, this indicates the existence of alkanes.
- Stretching vibrations for C=C at 1643 $cm^{-1}$, this indicates the presence of alkenes.
- The presence of stretching vibrations in the region between frequency (1400-1500 $cm^{-1}$) and shows medium intensity, this indicates the presence (C-C) in the ring.
- Starching vibrations for the C-O at frequency 1056 $cm^{-1}$, this indicates the presence of alcohol or Ether.
- Bending vibrations for the C-H at frequency 1033 $cm^{-1}$, this indicates the presence of Alkenes.

Sample B (after pyrolysis) Fig. (8):

In this sample, and within the FTIR spectrum, we can show that there are no effective groups to be observed.



Sample A (before) Sample B (after)

**Fig. 6:** Tetra waste before and after pyrolysis.

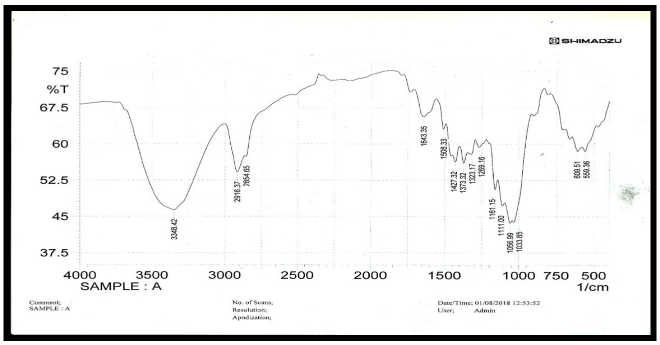



**Fig. 7:** FTIR of sample A

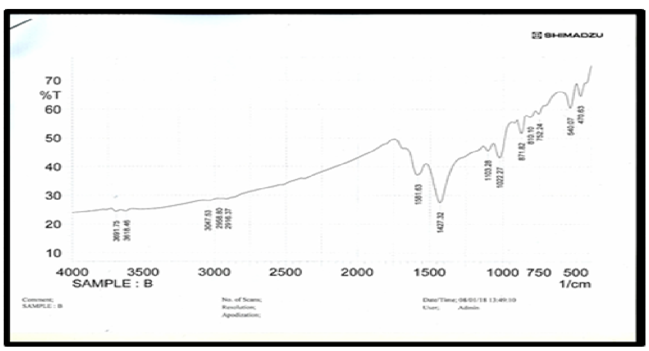



**Fig. 8:** FTIR of sample B

From the distillation report of the oil, it is observed that the boiling range of the oil is 187–369ºC, which infers the presence of a mixture of different oil components such as gasoline, kerosene, and diesel in the oil. From this result, it is observed that this hydrocarbon liquid could be possible feedstock for further upgrading or use of lighter compounds as diesel fuel.

## Conclusion

Thermal pyrolysis of tetra pack waste was performed in a Pyrex batch reactor at a temperature range from 375 °C to 425°C and at a heating rate of 10 °C/min. The maximum liquid yield was 43.9 % at temperature 400ºC; volatile products are mainly obtained at low temperature. The functional groups present in the pyrolytic oil are Alcohols (substituted, primary, secondary, tertiary, and multi substituted), alkane (primary, secondary, and tertiary). Aldehydes, Ketones, Carboxylic acid, Amine (substituted, cyclic, and aliphatic), Esters, ethers, and alkene (very little percent) It was found that the pyrolytic oil contains around 33 compounds having carbon chain length in the range of C3–C34. A simple batch pyrolysis method can convert tetra pack waste to liquid hydrocarbons with a significant yield which varies with temperature.

## Recommendation

Following are various recommendations that evolve from this study to improve the production of biofuel from tetra pack waste:

1. The pyrolysis process of waste Tetra Pack comes with the benefit of minimizing the need for raw material and reducing the emission of $CO_2$.
2. Simple batch pyrolysis method can be used in the production of biofuels (renewed energy).
3. The people should be aware to realize the importance of source segregation at generation point as biodegradables, inert and recyclable material for proper waste management.

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