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Recycling Of Beverages Tetra Pack Wastes into Value Added Composites

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ABSTRACT

Packing plays a valuable, often resource conserving role in the modern distribution of food, beverages and other goods. However, after unpacking, a large and perhaps growing fraction of packaging materials are rendered wasteful or environmentally problematic. As the tetra packs contain liquid content almost in less quantities after the disposal this is enough for the mosquitos to breed and causes large health problems. There is a need to learn how the package once used can be recycled to create products that minimize environmental degradation and make economic sense both in terms of production and purchase

Keeping this in view, IPIRTI explored a study to utilize this waste tetra packs for value addition. This project involved producing the useful products from the tetra pack waste which can be a substitute for the boards for application in furniture and construction. The process parameters for making composites using tetra packs particles by incorporating resins and without resins have been optimized. The strength properties of all the panels made using tetra pack waste confirms to the required physical and mechanical properties of Indian Standards IS 3087-(2005) “Particle boards of wood and other ligno cellulosic materials (medium density) for general purposes -Specification”. The comparison for both type of boards has been made as the sizing of the material of tetra packs cannot be defined through sieve. Utilization of the tetra packs waste for value added composite products finds wide application in furniture and construction industry.

Key words: Tetra pack, particle board, composite, panels

INTRODUCTION:

One of the most significant components, that threatens the future of the world are solid wastes. Unfortunately growing population and technological developments has resulted in an increase in solid wastes. In addition, the changes in consumption habits affect the composition of the waste.

Tetra Pack Aseptic is a commercial packaging material that is used to keep foods without spoiling and it consists of layers of carton, polyethylene (PE) and aluminium (Al). Carton layers provide stiffness, polyethylene layers provide durability and aluminium layers provide strength to the food against the effects of light and oxygen. Tetra Pack was founded by Ruben Rausing and Erik Wallenberg in 1951 in the Swedish city of Lund. As of January 2013, the company Tetra Pack has supplied approximately 173, 234 million packages so that 77,307 million litres of milk, juice, nectar and other products could be delivered to consumers around the world.

It is currently estimated that 2/3 of the food produced in the World is to be packed with Tetra Pack packages. Tetra Pack Aseptic, is the most commonly used subset of packaging materials and the first production was in 1969. Approximately 184 billion units Tetra Pack packaging materials were produced in 2015, and it is estimated that 24.5% was recovered. By the year 2020, it is aimed that the recycling of Tetra Pack packages will be reached to 40%. The recycling of waste Tetra Pack packages or similar types of other packaging materials provide to minimize the environmental impact of these waste materials. It is important in terms of the use of alternative raw materials.

Due to the significant and harmful effect of the global warming on our communities, health, and climate, the usage of sustainable, bio-based and green materials became an imperative. On the other hand, the utilization of waste and biomass resources for developing new bio based composite materials is attracting much attention for the environmental and socio economics.

Recycling saves energy, reduces raw material extraction and combats climate change. The vast majority of studies have found that recycling is better for the environment rather than incinerating or land filling it.

Tetra Pack packages are primarily paper-based and fully recyclable. A number of Life Cycle Analysis (LCA) studies have assessed the greenhouse gas emissions from different packaging formats (including glass bottles, PET and HDPE containers, Tetra Pack cartons, metal cans and stand-up pouches) and the Tetra Pack carton is generally attributed with the lowest environmental impact. The Tetra Pack package is primarily made of paperboard (75%), which has a low carbon footprint, as its main raw material – wood fibre, if well managed, is renewable.

Masoud Ebadi et.al., (2015) has investigated the effect of beverage storage carton (Tetra Pack™) waste and maleic anhydride-grafted polyethylene (MAPE), coordinated to light polyethylene on the mechanical properties of wood–plastic composites. A. H. Hassanin and Z.Candan (2016) have explored to enhance the mechanical and physical performances of Tetra Pack panels, sandwich structures. They have reported that the Mechanical

and physical tests results showed significant improvements due to using sandwich structure in compare to No-skin structure.

Flame retardancy and mechanical properties of thermal plastic composite panels made from Tetra Pack waste and high-density polyethylene has been studied by Changyan Xu etal., (2016) In their studies the flame retardancy thermoplastic composites were developed by extrusion followed by injection molding using recycled Tetra Pack packaging material (TPP) waste and high-density polyethylene (HDPE) with addition of ammonium polyphosphate (APP) and melamine (MEL) as intumescent flame retardants (FRs). The influences of intumescent FRs on the properties of composites were investigated.

Hidalgo, (2011) has studied the feasibility of using recycled low density polyethylene (LDPE) and aluminum of Tetra Pack to manufacture composite rigid board using a hot press. Hlavac et.al., (2013) have made boards from recycled laminated cartons and they have used as alternatives to the traditional ones as that of gypsum boards which are used in sandwich building envelope. They presented methodology and long term experiment in facade panels which are exposed to real external conditions and have reported the aging test results.

It has been reported by Mohamed Alla and Elsharie (2014) that the amount of feedstock in larger quantity available is waste which is to be processed and need to produce usable products from it. They have explored the methodology to identify the utilization of unsorted waste and to evaluate the design of possible equipment and secondly improving the blending of the various components of the waste, to convert into a better product.

Bekhta et.al., (2016) have manufactured tetra pack composite boards from waste packing materials without any external binders and evaluated the properties of the boards.

Izekor and Mordi (2014) have evaluated the effects of densities and ratios of mixing on mechanical and physical properties of the wood-plastic composites boards. They have made boards with the mixing ratios in the range 1:1.1-1:1.4 of nominal densities in between 700 kg/m^3 – 800 kg/m^3. The amount of saw dust and high density polyethylene (HDPE) are used in the production of boards.

San, et.al., (2018) have particularly focused in solving the major constraints which is injection molding employed to produce wood-plastic composites and using the different kind of commercially available coupling agents at various percentages in order to produce wood plastic composites.

MATERIALS AND METHODS

In the present study, the processing of tetra packs in the initial stage of the composite making viz., size-reduction (chipping), screening and pre-wetting before taking to mat formation have been studied. The process

parameters for making composites using tetra pack particles by incorporating resin and also without resin have been optimized. The various process adopted in making composite from tetra pack wastes are described below.

Raw Material and Chipping:

Waste tetra packs are collected from hostel and local juice Shops. The Tetra packs are cut into roughly 10mm pieces . The particles are dried in oven to optimize the moisture content to 2-4%. The oven dried materials are taken for mat forming directly for controlled panel while for the other boards the materials were blended with various resins. The percentages of resin are varied. Conventional Phenol formaldehyde and Urea formaldehyde resins were used in minimal percentages. The properties of the Phenol formaldehyde and Urea formaldehyde resins used in this study are given in **Table 1 & 2** respectively.

Table-1: Properties of Phenol Formaldehyde Resin

Sl. No.	Particulars	Results
1.	Flow time of resin in B4 flow cup	24 ±4 seconds
2.	Water tolerance	1:8- 1:10
3.	Solid content	48%
4.	Shelf life	One month @ ambient temperature

Table-2: Properties of Urea Formaldehyde Resin

Sl. No.	Particulars	Results
1.	Flow time of resin in B4 flow cup	22 ±2 seconds
2.	Water tolerance	1:2- 1:3
3.	Solid content	50%
4.	Shelf life	One month @ ambient temperature

Mat Forming and Pre Pressing:

The tetra pack particles were placed into a mat forming box as indicated in **Figure 1** with base dimensions of 330mm × 330mm. Aluminum/ SS plates spread with BOPP film were placed on either sides of the mat furnish. Prepressing and compression of the fibers were done by pressing a matching wooden plate on the fiber mat in the forming box by applying pressure manually as shown in **Figure 1**. BOPP film which can withstand 160° C is used on top and below the tetra pack particles mat.

Figure 1. Tetra pack material in mat forming box

Figure 2. Pre pressed mat of tetra pack material

Hot Pressing:

The pre pressed mat assembly of the tetra pack waste sized material was then loaded into a hot press of size 350mm x 350mm wherein temperature of the platens were maintained at 145 - 155° C. Supporting rods to control the thickness to 12mm were placed on either ends of the assembly. Pressure of 25 kg/ cm^2 for compression cycle and 12 -16 kg/ cm^2 for curing cycle for stipulated curing time was employed.

Initially the pressure is given higher so as to create a high surface density of the board. The core density was then formed by reducing the applied pressure to 12 -16 kg/ cm^2 and later the hot press temperature was cooled to below 100° C before downloading the board. After stipulated period the pressure was brought down to zero for few seconds to release the generated steam and gases from the boards before opening the press and then the final product was downloaded from the hot press. After downloading the board from hot press, the panels were stacked for 24 hrs for stabilization and then trimmed to required sizes. The final product of tetra pack composite is as given in **Figure 3.**

Figure 3. Tetra pack composite

The stabilized boards were further subjected to evaluate the physical and mechanical properties as per relevant specification. Since there doesn't exist any standard for tetra pack composites, the physical mechanical

properties of the composites made were evaluated as per the existing specification for particle board as the composite is similar to wood chip particle board.

The physical and mechanical properties of the panels are given in **Table 3**. The panels made with combination of wood particles blended and tetra pack particles by flat pressing do not yield the requisite product quality and also the surface quality is poor. Hence the further experiments were discarded. However, by extrusion process of combining the wood and tetra pack material would yield better surface finish and product quality.

The strength properties of all the panels made using tetra pack waste confirms to the requirement of IS 3087-(2005)- Specification for Particle Boards of wood and other ligno cellulosics materials (Medium Density) for general purpose" for flat pressed single layered board /Grade 1 and Grade 2 Medium Density Particle board. The panels bonded with resin yields superior properties when compared to the control panel (without resin). However, for tetra pack composites the density requirement is higher than that specified in IS 3087-2005 to achieve the desired strength properties. This is due to the inherent characteristics of the tetra pack waste materials.

RESULTS & DISCUSSIONS:

The boards were made aiming at various densities of the panels. Initially the material density of 700 -800 kg/ m^3 was targeted. The boards made with or without resin for panels of density 700 -800 kg/ m^3 could not yield the requisite compression of the product. This resulted in poor bond integrity between the particles. Hence further panels were made targeting a density greater than 850 kg/m^3. It has also been reported by Hashem Rhamin et.al., (2013) that composite carton boards can be made with or without the resin. In their study it has been found that the composite tetra pack carton board with a target of density 1g/cm^3 (1000 kg/ m^3) using melamine urea formaldehyde resin have yielded better physical and mechanical properties. **Table 3** indicates that the strength properties of the tetra pack composites are encouraging for the density of the panels ranging from 890 -1050 kg/ $m^{3.}$

Also during the composite making it has been observed that the application of oleic acid as a releasing agent on the caul plates was not effective to release the tetra pack waste composites from caul plates. Hence it is here recommended that BOPP film that can resist temperature up to 160°C needs to be used on either surfaces of the caul plates to have better release of the tetra pack waste composite after hot pressing. Also this enhances the surface finish of the final product.

Since the assembly of the panels made is in such a way that small size particles are laid on top and bottom and mixed sizes are taken in the central layer as core., the properties of the boards are being compared with the requirements of multi-layered particle board Grade 1 & Grade 2 and also for Flat pressed single layered board. The thickness swelling and water absorption rate of all the boards made meets the requirement of IS 3087 – (1985) Specification for Medium Density particle board irrespective of blending/ without blending the particles with resin. The thickness swelling of the tetra pack composites without resin is 2% which is very less compared to the other existing particle composites. This is due to the inherent behaviour of the tetra pack material. The polyethylene layers present within the tetra pack doesn't allow the water/moisture to penetrate inside. This composition of polythene layer has influenced on the thickness swelling and water absorption properties of tetra pack composite. M Hidalgo (2011) has reported that the compounds of aluminium/ low density poly ethylene present in tetra pack were greatly affected by the effect of compact pressure during processing, specifically in water absorption and tensile strength. The results obtained in this project has also indicated that the composition of the tetra pack material has yielded very less thickness swelling property. From **Table 3** it may also be observed that the water absorption takes place within 2 hours of immersion time. After 2 hours there is negligible level of water intake which value is indicated as water absorption after 24 hours of immersion. The water absorption rate remains constant after 2 hours of immersion time. This specific property of the composite would help the application of this product in high humid zones.

The Modulus of rupture (MOR) of all the composites made meets the requirement of the Indian standards. However, the Modulus of Elasticity (MOE) value is less than the value prescribed in the standard. This is due to inherent characteristic of the tetra pack material composition. However, it has been noticed that the tetra pack composites are flexible without any breakage/ damage to the product when subjected to MOR & MOE testing. Even a considerable crack after the bending test was not observed, which indicated that boards are having significant unique feature. The significant values of MOR & MOE values achieved in this study are indicated in **Table 3.** The internal bond strength of the composites made without resin and with 3% UF/MUF resin meets the requirement of Grade 2 multi layered particle board while the composites bonded with 3% and 5% conforms to Grade 1. The composites bonded with 5% PF resin conforms to the requirement of Flat pressed single layered particle board.

Table 3. PHYSICAL AND MECHANICAL PROPERTIES OF COMPOSITES FROM TETRA PACK WASTES

Sl. No	Property	Prescribed value in IS 3087-2005 Single layer flat pressed	Tetra pack waste	Tetra pack Waste + 3% PF Resin	Tetra pack Waste + 5 % PF Resin	Tetra pack Waste + 3% MUF Resin	Tetra pack Waste + 3% UF Resin
1	Density kg/m^3	500-900	988	1032	996	889	974
2	Water absorption 2 hours 24 hours	 25 (40*) 50(80*)	 21.47 25.55	 24.42 25.85	 22.36 24.15	 26.14 27.86	 23.43 26.23
3	Swelling i) Length ii) Width iii) Thickness	 0-5% 0-5% 10%	 0.26 0.24 2.03	 0.18 0.14 4.3	 0.14 0.08 4.1	 0.19 0.1 3.9	 0.38 0.3 4.1
4	Modulus of rupture N/mm^2	11	13.67	16.11	15.11	11.83	13.33
5	Modulus of elasticity N/mm^2	2000	1124	1441	1391	1230	1359
6	Internal bond strength N/mm^2	0.8(SL) 0.3* 0.45**	0.34	0.608	0.84	0.43	0.5
7	Screw with drawal test , Edge N/mm^2	850(700*)	1140	1280	1560	1890	1321

* Denotes value for Grade 2 multilayered panels requirement as per specification
** Denotes value for Grade 1 multilayered panels requirement as per specification
PF – Phenol Formaldehyde
MUF – Melamine Urea Formaldehyde
UF –Urea formaldehyde
SL – Single layered

CONCLUSIONS

From the research findings, it is concluded that tetra pack waste material can be effectively utilized for converting into value added products viz., Tetra pack waste composite.

This study reveals that the raw material chipping has to be carried out by cutting process rather than processing through hammer mill. The process parameters for the manufacture of composite from the tetra pack waste using resin and without any resin in the mat formation has been optimized. The incorporation of minimum percentage of conventional phenol formaldehyde or urea formaldehyde resin to the tetra pack waste raw material yields superior physical and mechanical properties. The strength properties of all the panels made using tetra pack waste confirms to the required physical and mechanical properties of IS 3087-2005 "Specification

for Particle Boards of wood and other ligno cellulosics materials (Medium Density) for general purpose" for Single layered flat pressed particle board (6% resin) and Grade 1 (PF RESIN) /Grade 2 (UF RESIN) multi-layered Medium Density Particle board exception being for modulus of elasticity which is due to composition of the tetra pack raw material. Of all the formulations worked out, 3% resin on the weight of raw material tetra packs has yielded excellent properties and confirms to the relevant standards. However, the modulus of elasticity factor depends on end use applications. This study has indicated that the density of the final product has highly influenced on the quality of the product. The composites having density lower than 850 kg/m^3 results in poor bond integrity of the particles. From this study it is evident that the tetra pack composites density requirement should be higher than that specified in IS 3087- (2005) i.e., greater than 850 kg/m^3 to achieve the desired strength properties. This is due to the inherent characteristics of the tetra pack waste materials.

Utilization of the tetra packs waste for value added composite products finds wide application in furniture and construction industry. The waterproof characteristics of this composites make this board suitable for applications in humid conditions. This composites can serve as a alterative for wood particle boards in various end use applications based on the formulation adopted for composite making. Considering the adhesive cost being employed for wood particle board (10%) and comparing with the resin employed in this study i.e., 3% - 6%, it has been found that the composites made using tetra pack waste are cheaper by 40 -70% than the existing particle boards in the market w.r.t adhesive cost excluding the savings in energy and other processing costs.
The conclusions drawn in the report are based on lab scale experiments.

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