PHYSICO-CHEMICAL CHARACTERIZATION OF PRIMARY FOOD PACKAGING IN PLASTIC FILMS

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ABSTRACT

Currently, plastic packaging waste is poorly recyclable in which films are the major source of the non-recyclable. One of the important criteria for developing a recovery process for this waste is the preliminary characterization of the raw materials in order to study beforehand the influence of the impurities on the envisaged process. For these reasons, analyzes with a view to determining the content of organic and inorganic compounds as well as the additives and basic polymers of this material were carried out. The analysis results have shown that plastic film packaging is composed of polymers (86, 5%), mineral additives (2, 30%), organic fillers (11, 5%) as well as aluminum to the trace state.

Keyword: *Plastic films, primary packaging, organic compounds, mineral compounds.*

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1. Introduction

In recent years, the production and consumption of plastic packaging has increased significantly around the world. [1] Consequently, their waste presents inevitable damage with dramatic consequences for nature and daily life, hence the importance of recycling in order to reduce it. [2] The idea of developing a process for recovering this waste is based on the availability and quality of raw materials in which its composition and its content of impurities must be taken into account. Which require the preliminary characterization of the raw material used in order to study beforehand these influences on the various process parameters and the quality of the finished products.

2. Materials and methods

2.1 Raw materials

The main uses of the films produced are bags and sachets (small, medium and large capacity), single films for overwrapping and primary packaging films for automatic packaging machines.

In this study, we will highlight the waste from primary packaging films because they are generally eliminated from industrial recycling processes when they represent a significant amount in nature [3].

Visually, these raw materials are specified by the presence of printing ink, dyes and glues, and optionally a metallic layer. Therefore, the particular characterization of these constituents is difficult because of their very varied nature, which depends on the choice of their supplier and the method of production. In fact, analyzes for the determination of the content of organic and inorganic compounds are possible depending on the difference between their behaviors. [3] [4]

2.2 Calcination of raw materials

Calcination consists of heating the sample to high temperature (typically 500 to 1000 °C) in air to cause physical and chemical reactions. Above a decomposition limit temperature which is relatively low, all organic compounds degrade by volatilizing. On the other hand, mineral compounds can withstand high temperatures and metals undergo oxidation. [5]

Around 550 °C, in air or an oxidizing atmosphere: the organic matter burns giving carbon dioxide (CO_2) or graphite (C); carbon oxidizes slowly to form carbon dioxide or carbon monoxide; carbonates decompose, and metals oxidize. [5]

If such phenomena occur, a reduction in mass due to the departure of volatile species may take place: it is the loss on ignition which relates to the organic compounds, the steps to be continued to determine its content are such as:

- Weigh a mass of the sample m0;
- Calcine the sample at a temperature of 800 °C for about 4 hours;
- Leave the solid residues to cool after calcination, then weigh;
- Determine the loss on ignition, the content of organic compounds and mineral compounds.

By definition, the loss on ignition is therefore simply the difference in mass of the sample before calcination and that after calcination, which is the residue.

Thus, the loss on ignition due to the calcination of film waste can allow us to distinguish organic and inorganic compounds where the content of organic compounds is none other than the yield in loss on ignition, while that of inorganic compounds is the yield. In residues, according to the formula:

$$\eta_{min} = \frac{m_{rs}}{m_{DCF}} \times 100 \quad (1)$$

$$\eta_{org} = 100 - \eta_{min} \quad (2)$$

With : η_{org} and η_{min} are respectively the content of organic compounds and the content of mineral compounds, while m_{DCF} and m_{rs} are the respective mass of the sample of film waste considered and solid residue.

2.3 Removal of additives from the raw material

The removal of printing ink, dyes and glues can be considered by washing, but this has an impact on the treatment of effluents [4]. The main methods for removing these additives are:

- Water;
- Friction;
- Temperature;
- Chemicals like caustic soda, organic solvents.

During processing, the process can take place slowly in cold (room temperature) or fast in hot requiring heating.

2.4 Polymers and additives constituting the raw material

Note that polymers are highly resistant to attack by acids or bases. By attacking a basic solution, the discolored virgin films are expected to be obtained while the dyes and other additives dissolve. Which makes it possible to determine the content of polymer and additives in the film packaging by evaluating the mass of discolored films which are polymers.

The manipulation went as follows:

- Weigh a known mass m_0 of the film waste then cut into small pieces;
- Prepare a concentrated soda solution in a beaker;
- Cut into this soda solution, for the waste films;

- Leave to react until blank films are obtained (without dyes, inks or metal);
- Wash the discolored films obtained with water and then dry in an oven at 100 °C;
- Weigh the clean films m_1.
- Determine by calculation, the polymer content and the additive content according to the following formula:

$$\eta_{Pol} = \frac{m_{PD}}{m_{DCF}} \times 100 \quad (3)$$

$$\eta_{Add} = 100 - \eta_{Pol} \quad (4)$$

With: η_{Pol} and η_{Add} are respectively the polymer content and the additive content; m_{PD} and m_{DCF} are the respective mass of the film waste revealed and of discolored polymers obtained.

2.5 Determination of metallic compounds: attack by Ethylene Diamine Tetra-acetic (EDTA)

EDTA or Ethylene Diamine Tetra-acetic Acid is a substance that helps complex heavy metals. EDTA is therefore used to assay metal ions in solution by complexometry, according to the following manipulation [5]:

- Take the solution obtained by the previous sodium hydroxide attack and evaporate to dryness;
- Start the attack by gradually introducing 50 ml of 50% HCl;
- After gas evolution, evaporate the solution to dryness then allow to cool;
- Add 50 ml of 10% HCl and heat for 15 minutes.
- Filter by decantation through medium filter paper, receiving the filtrate in a 500 ml volumetric flask;
- Wash the precipitate on the filter with boiling distilled water until the reaction with the dyes subsides;
- Allow the filtrate to cool and then adjust to the mark with distilled water.
- Note A this solution

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a. Iron content

If the solution contains iron, the determination of the iron oxide content is as follows:

- Pipette 100ml of solution A and pour into a beaker, then add 200ml of distilled water;
- Stir with a magnetic stirrer;
- Add 6 drops of bromophenol blue (yellow);
- Add a few drops of 50% NH_4OH until the dark blue turn;
- Quickly pour 20ml of 0,1N HCl $^+$ 15ml of buffer solution
- Add 10 to 20 drops of salicylic acid (purple-black);
- Heat at 40 to 50 ° C for 1min 30s (do not exceed 50 ° C);
- Titrate with EDTA until the yellow-straw turn;
- Read the volume of EDTA poured on the graduated burette.

b. Aluminum content

The test protocol corresponds to each following step:

- To solution A, add: a few drops of $CH_3CO_2NH_4$ (blue color); 5 ml of acetic acid; 3 drops of copper complexonate; 10 drops of Pyridylazonaphtol or P.A.N (purplish pink);
- Bring the solution to a boil while stirring;
- Titrate with EDTA until a straw yellow color;
- Read EDTA Volume V.

For a sample mass of 0.5 g, the content can be calculated by the following formula:

$$\% Al_2O_3 = V \times f_{EDTA/Al_2O_3} \quad (5)$$

V: volume of EDTA poured for the assay

EDTA factor for Al2O3

3. Results and discussion

3.1 Content of organic and mineral compounds

Table -1: Results on the calcination of film waste

Sample mass (g)	**Compound content (%)**	
	Organics	Minerals
20	97,75	2,25
35	97,6	2,4
55	97,73	2,27
Average value	97,70	2,30

It is deduced from these results that:

- The loss on ignition proves the large proportion of organic compounds in the film waste analyzed. The 97.7% organic compounds are the binders and dyes in printing ink, and polymers presented as films.
- Residues 2, 30% represent inorganic compounds, generally inorganic fillers, inorganic pigments, and metal compounds while undergoing oxidation during calcination.

3.2 Elimination of additives

The various behaviors of the additives present in the film waste are given in the following table:

Table -2: Methods of treatment to remove additives

Treatment mode	**Cold process**	**Hot processes**
Water	No reaction	No reaction
Friction	No reaction	No reaction
Soda solution	24h per gram	2 to 5min per gram
H_2O_2 Solution	5 to 10 min per gram	1 to 3min per gram
Toluene	Very slow	-
HCl	Very slow	-

These results show that the additives present in food film packaging are compounds that are difficult to remove or separate from the body of the packaging:

- They are insoluble in cold or hot water;
- They are insensitive to friction;
- They react slowly, when cold, in the presence of chemicals such as caustic soda, hydrogen peroxide, strong acid and solvents;
- Only hot washing with soda and H2O2 seems effective.

In short, the elimination of dyes and printing inks, and also glues and adhesives on film packaging requires an increase in processing costs since they are insoluble in water and must be carried out hot with additive. On the other hand, their presence on the support can cause an undesirable coloring to the recycled material and also restrict the quality of the recycled product.

3.3 Polymer and additive content

Here are the results obtained by this basic attack using a soda solution:

Table -3: Results of polymer content and additive content

Sample mass (g)	Polymer content (%)	Additive content (%)
20	87,50	13,25
30	85,83	14,17
50	86,24	13,76
Average value	86,66	13,34

Food packaging in film form constitutes 86, 5% of polymers and 13, 5% of various additives such as colorants and glues, and metal. It is therefore important to note that plastic film packaging waste is raw material representing a significant amount of additives.

3.4 Metals content

When handling, the dosage has no effect on the solution to be identified. For this reason, the solution does not contain iron oxide. In our case:

- Sample mass = 10 g
- V = 0,9 ml
- f_{EDTA/Al_2O_3} = 0,5922

After calculation, we found:
Which corresponds to: % Al = 0, 01%

The presence of alumina leads us to deduce that the metal found in these waste films is aluminum which must have been transformed into alumina form during the acid attack carried out during the assay.
The results obtained previously can be schematized as follows:

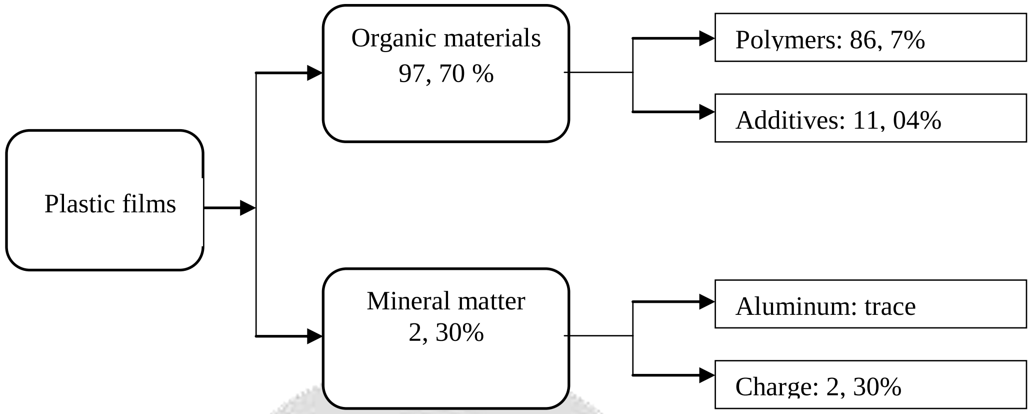

Fig -1: Composition of plastic film packaging

The plastic films of primary packaging are therefore very well known by the presence of printing inks and dyes on their external surface, which are generally made up of a coloring material (dye and organic or inorganic pigment) dispersed in a mixture of the binder and solvent (fatty binder, varnish dissolved in a solvent or in water) [4] [5].

According to the analysis results, the packaging films contain 86.70% polymers and 13, 34% additives of which 11, 04% are minerals and 2, 30% are organic fillers. In addition, the metallic layer, evidenced by the existence of a silver color on the inner surface of the packaging, is made of minimal aluminum.

4. Conclusion

This study allowed us to provide an overview of the composition of primary packaging film waste. The determination by EDTA showed us the existence of metallic aluminum in a trace state, while the calcination and the action of a base such as soda demonstrated the presence of mineral fillers, pigments and dyes in these raw materials, consisting essentially thermoplastic polymers. Analytical results indicated that this material is composed of approximately 86,5% polymers, 11,5% mineral additives, 2% organic dyes and pigments, and trace aluminum. Following this work, it turns out to be interesting to know the influence of these different constituents on the products made from this waste. Thus, it is important to know if these additives will bring advantages or disadvantages on the recycled materials.

5. REFERENCES

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