ENVIRONMENT DEPARTMENT

EVALUATION OF THE IMPACT OF BIODEGRADABLE BAGS ON THE RECYCLING OF TRADITIONAL PLASTIC BAGS

CRIQ File n° 640-PE35461

Final Technical Report

RECYC-QUEBEC
7171, rue Jean-Talon Est, bureau 200
Anjou (Québec) H1M 3N2

Marc Brunet
INDUSTRIAL ADVISOR

DANIEL GRENIER, CHIM. PH.D
TECHNICAL SUPERVISOR
ENVIRONMENT DEPARTMENT

LAURENT COTE, ING. ET AGR.
DIRECTOR
ENVIRONMENT DEPARTMENT

QUÉBEC, August 28th, 2007

Centre de recherche industrielle Québec

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Executive Summary

The objective of this study was to evaluate the potential impact of various biodegradable bags which are available in the Quebec market on the recycling of conventional plastic bags and on the quality of the recycled plastic. In fact, it was possible to recover in the recycling stream a certain quantity of biodegradable bags mixed with traditional bags (non-biodegradable). The impact on the quality of recycled plastic wasn't as yet well known.

More particularly, the study evaluated the capacity to mix biodegradable bags with conventional bags in an extrusion production unit for the fabrication of profiles and films. The performance of these products was evaluated after accelerated aging by UV rays in a hot and humid environment.

In order to control the history of the materials, virgin commercial bags provided by local suppliers were used. Conventional bags were made of high density polyethylene (HDPE) and supplied by Hilex. As regards to the biodegradable bags, two types of oxo-biodegradable and two types of hydro-biodegradable bags were evaluated in this study. The oxo-biodegradable bags were "NeoSac" by the NeoSac Association and the bags made by Omniplast using the EPI additive. The hydro-biodegradable bags were "BioBag®" manufactured by Polar Gruppen and "Eco Film™" by Cortec Corporation.

The following experimental protocol was used in order to evaluate the influence of biodegradable bags when they were mixed with conventional bags:

- The 4 types of biodegradable bags were mixed with conventional bags in the proportions of 5, 10, 25 and 50% using a high shear rate mixer kept under an inert atmosphere. The discs obtained from the 16 mixtures were subsequently granulated.
- Profiles of 0.25 X 0.50 inches were produced by extrusion then films of thickness between 0.003 and 0.005 inches were blown from granules of the 16 mixtures and from granules of the conventional bags alone.
- Measurements of bending and impact resistance were done on the extruded profiles. Measurements of tensile properties, flexibility and tear resistance were done on the films.
- Finally, the same tests were repeated on the profiles and films following aging using heat, humidity and UV rays.

The following are the results of the various tests:

Preparation of mixtures and extrusion of profiles and films:

A. Conventional bags and oxo-biodegradable bags have similar chemical compositions and comparable thermal and rheological behaviours. Compatibility was therefore observed when preparing mixtures and in extrusion.
   The preparation of different mixtures between traditional and biodegradable bags revealed serious compatibility problems between traditional and hydro-biodegradable bags. In fact, for mixtures where the concentration of hydro-biodegradable bags is higher than 25%, it was necessary to modify the experimental mixing protocol and to readjust the two extruders when producing profiles and films. Differences in the chemical nature (polyethylene as compared to cornstarch), of thermal and rheological (fluidity) behaviour are probably at the origin of this incompatibility between traditional bags and hydro-biodegradable bags.
B. Consequently oxo-biodegradable bags are more compatible than hydro-biodegradable bags when they are mixed with traditional plastic bags.

<u>Initial mechanical performance of profiles and films:</u>

A. Profiles made form mixtures between traditional bags and oxo-biodegradable bags demonstrated similar or superior mechanical performance to profiles made from traditional bags alone.
B. Profiles made from hydro-biodegradable bags showed noticeably lower mechanical properties than profiles made from traditional bags.
C. The same observations were made for films for the mixtures with oxo-biodegradable bags compared with hydro-biodegradable bags. Mixtures with hydro-biodegradable bags showed a large drop in tear resistance. More precisely, bags fabricated from films containing more than 10% of “BioBag®” hydro-biodegradable bags and films containing more than 25% of “Eco Film™” hydro-biodegradable bags were not able to resist tearing when they were filled with water. Only films containing low quantities of hydro-biodegradable bags were able to resist tearing for a period of 100 days.
D. All bags made from films containing oxo-biodegradable bags (5, 10 , 25 and 50%) filled with water, resisted to leakage for more than 100 days.

<u>Mechanical performance of profiles and films following accelerated aging:</u>

A. Accelerated aging of profiles for a maximum period for 28 days caused no important changes in mechanical properties in the group of samples produced, including the traditional bag control.
B. All the films, including the traditional bag control, showed a large drop in properties following 7 days of accelerated aging.
C. More particularly, the films made from mixtures of traditional bags and oxo-biodegradable bags showed a large loss of properties.
D. The mixtures of traditional bags and “NeoSac” oxo-biodegradable bags seemed particularly affected by accelerated aging since these films were, for all practical purposes, completely destroyed after 4 days of exposure. The drop in performance of mixtures containing “EPI” bags was similar to that observed for traditional bags alone.
E. Films made from mixtures of traditional bags and hydro-biodegradable bags likewise showed a significant drop in performance, but these were less severe than that

observed from mixtures with oxo-biodegradable bags. It should be noted that the initial mechanicals performances of these mixtures were inferior to that measured with mixtures of traditional and oxo-biodegradable bags.

F. In summary, the results showed that films exposed to UV rays in a warm and humid atmosphere have more obvious consequences than those observed for profiles.

The results show that the two hydro-biodegradable bags studied “Eco Film™ ”and “BioBag®”” are not compatible with the traditional plastic bag recycling stream, due to numerous problems that were observed in the preparation of mixtures with the extrusion of profiles and films. Moreover, mixtures of these bags with traditional bags induce a large fall in mechanical performance of films, particularly as relates to tear resistance.

Oxo-biodegradable bags “NeoSac” and “EPI” showed excellent compatibility with traditional bags during the preparation of mixtures and during extrusion of profiles and films. However, the films obtained from mixtures of “NeoSac” bags and traditional bags showed a rapid and considerable degradation after only a few days of accelerated aging. Bags from these cannot be considered as being perfectly compatible with the traditional plastic bag recycle stream.

The “EPI“ oxo-biodegradable bags can be considered as being compatible with the traditional plastic bag recycling stream, because of the results obtained during the preparation of mixtures and during the extrusion of profiles and films as well as the initial performance of profiles and films and the performance of these following accelerated aging.

1. Background:

For several years, plastic bags qualified as biodegradable have been found in the Quebec market. There are mainly two types of bags, classified according to their composition – bags composed of biopolymers and bags containing a special additive.

Bags made of biopolymers are mainly made of cornstarch and are considered hydro-biodegradable. The degradation of these bags results from the action of naturally occurring micro-organisms. The second types of biodegradable bags are oxo-biodegradable bags made of petroleum based polymers to which an additive is added. This additive allows the plastic to be affected rapidly by UV rays, heat and/or mechanical stress.

The arrival in the market of biodegradable bags could have an impact on the recovery and recycling of plastic bags. It could be possible to find in the recycling stream a certain quantity of these biodegradable bags mixed with traditional bags (non biodegradable) and the impact on the quality of the recycled plastic is not well known.

Concerned with this problem, the state agency *RECYC-QUÉBEC* approached the *Centre de recherche industrielle du Québec* (CRIQ) to do some test in order to evaluate the potential impact of hydro-biodegradable (cornstarch) and oxo-biodegradable (polyethylene with additive) on the recycling of plastic bags and on the quality of the recycled plastic.

2. Project Objectives

The proposed project sought primarily to evaluate technically the potential impact of hydro-biodegradable and oxo-biodegradable bags on the recycling of plastic bags. More specifically, the project consisted in evaluating the mechanical properties of recycled plastics made using different formulations of hydro-biodegradable, oxo-biodegradable and conventional plastic bags.

In order to achieve this objective, the work was divided according to the following steps:

- Description of the bags evaluated in the study
- Preparation of mixtures of conventional and biodegradable bags
- Production of profiles and films
- Description of performance testing and of accelerated aging
- Initial characterization of profiles and films
- Characterization of profiles and films after accelerated aging
- Water resistance of bags

This technical report presents the results obtained after completion of all of the steps of the project. The main observations and conclusions are then presented.

3. Description of bags evaluated in this study

For this study, a single type of traditional plastic bag has been evaluated. These are HDPE (#2 HDPE) bags provided by HILEX.

As for biodegradable bags, two types of hydro-biodegradable and two types of oxo-biodegradable bags were evaluated in this study. The oxo-biodegradable bags are the “NeoSac” of the NeoSac Association and the bags made by Omniplast containing the additive from the company EPI, hereafter called “EPI”. The hydro-biodegradable bags are the “Bio-Bag®” made by Polar Gruppen and “Eco Film™ ” of Cortec Corporation.

In order to control the history of each bag, all the bags used in the course of this project were new.

4. Preparation of mixtures of traditional and biodegradable bags

The first step to achieve the project objective consisted of producing mixtures of traditional plastic bags containing different proportions of hydro-biodegradable or oxo-biodegradable bags and evaluating their mechanical properties after they have been exposed to conditions of accelerated aging (heat, humidity, and UV rays), well known to initiate the degradation of biodegradable plastics.

In order to ensure uniform mixtures, the bags were melted and homogenized with the assistance of a thermo-kinetic mixer. The mixtures contained 5%, 10%, 25% and 50% of biodegradable bags. Following, the melted mixtures were recooled in a steel mould mounted in a hydraulic press and granulated in order to be able to feed the extruders. There were 16 mixtures of bag granules to prepare (4 concentrations X 4 types of biodegradable bags) as well as granules from traditional bags without biodegradable bags which will serve as the control.

The thermo-kinetic mixer (see figure 1) utilized for mixing, heating and homogenizing the various bags is essentially comprised of a cylindrical chamber (mixing chamber) in which a rotor armed with blades which do the work turns. This cylindrical chamber is clearly the heart of the mixer because it is here that the most critical production process operations take place. To feed primary material to the cylindrical chamber, the motor rotor is elongated beyond the cylindrical chamber to allow the installation of an endless screw section (feed screw). In this way it is possible to introduce the different plastic bags into the mixing chamber without stopping the feed. Thanks to centrifugal force plastic bags are projected randomly against the walls of the chamber, against the rotor blades or one against the other. As long as the rotor speed is very high, the different plastic bags encounter various obstacles several hundreds of times a second. The kinetic energy of the bags is transformed into thermal energy and all the material is heated very quickly – generally between 20 and 40 seconds - to the critical temperature. It is the only source of heat in this type of mixer. When the batch on the inside reaches the preselected temperature a device set to this automatically releases a discharge door. From the centrifugal force of the rotor, the melted material is totally expelled rapidly.

In order to avoid degradation of the different bags during homogenization, the mixing chamber was continually purged with nitrogen in order to completely eliminate oxygen. The experimental protocol adopted to make the mixtures consisted of the introduction into a thermo-kinetic mixer equipped with a 3 liter mixing chamber (Gelimat S3 from Draiswerke), of 600 gm of plastic bags. During the introduction of the plastic bags, the angular speed of the rotor was set at 600 rpm. After all the material was introduced the speed was progressively increased to 2000 rpm, the speed at which the temperature rapidly passes from ambient to 210°C, the temperature at which the door to the mixing chamber opens.

When the mixture exits the thermo-kinetic mixer, the hot material was immediately transferred to a cylindrical steel mould (10” diameter) and compressed for 10 minutes with a closing pressure of 500 lb/sq. in., being 20 tonnes (100 tonne hydraulic press, model 100-18-2TMAC provided from the company Wabush Hydraulic Press). This operation was done to protect the material as it rapidly cooled to room temperature without being exposed to oxygen.

Finally the discs obtained were granulated in order to obtain an acceptable form for the extruders used in the production of profiles and films (Angelo Anceschi, model 730/GT with a sorting sieve of 8 mesh).

For traditional bags as well as for the 8 mixtures of traditional and oxo-biodegradable bags (Neo-sac and EPI) the experimental protocol described above was followed to the letter without problem.

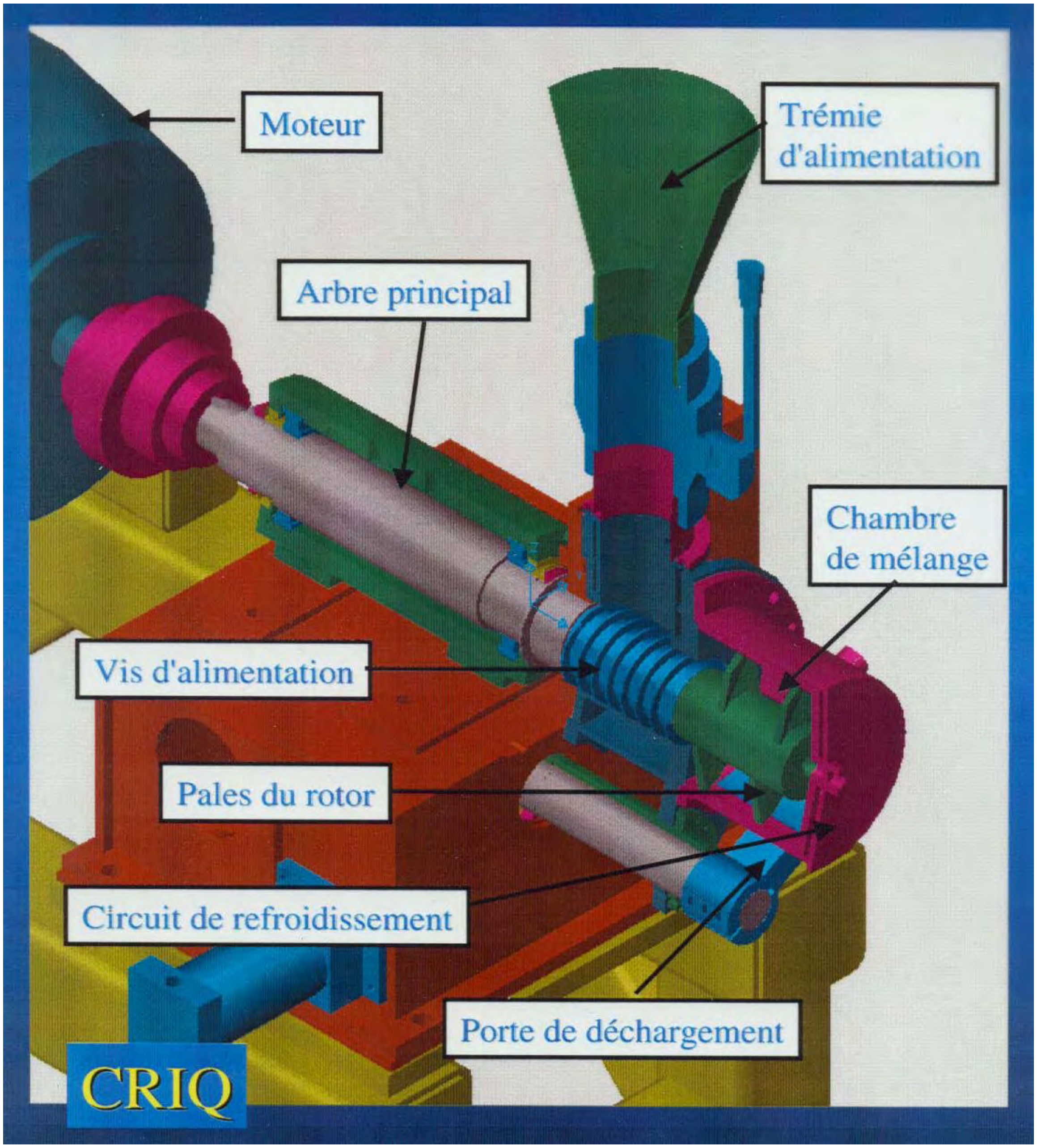

Figure 1 : Principal parts of the thermo-kinetic mixer

As regards the hydro-biodegradable bags (BioBag® and Eco Film™) the mixtures with traditional bags were made with no problem as long as the concentrations of hydro-biodegradable bags were small (5% and 10%). Nevertheless, mixtures more concentrated with hydro-biodegradable bags (25% and 50%) could not be made with the thermo-kinetic mixer because it was impossible to obtain homogeneous mixtures despite efforts made to modify the experimental protocol in order to adapt it to the 4 problem mixtures. This observation is probably due to the fact that the hydro-biodegradable bags melt at a much lower temperature than traditional bags and that they are much more fluid than the latter ones. Table 1 shows that the melting point of traditional bags is around 130°C with a well defined crystalline melting point; however, that of the hydro-biodegradable bags is poorly defined with a less intense melting peak, which shows that this type of bag doesn't have an important crystalline characteristic (see the heating curves of Appendix A). Extrusion trials with traditional bags and the two types of hydro-biodegradable bags have shown that the minimum extrusion temperature of traditional bags is around 180°C, however, that of the hydro-biodegradable bags is 60°C lower, around 120°C. The indices of fluidity measured on hydro-biodegradable bags are in the best case 194 times higher than those of traditional bags and in the worst case 428 times higher. These results demonstrate beyond doubt the higher fluidity of hydro-biodegradable bags as compared to traditional or oxo-biodegradable bags.

The four mixtures rich in hydro-biodegradable bags were simply made with granules produced from granules of traditional bags and granules of hydro-biodegradable bags made individually. Granules of traditional bags were produced using the thermo-kinetic mixer according to the established experimental protocol. The granules of hydro-biodegradable bags could not be produced in the thermo-kinetic mixer because the melted bags stuck to the wall of the mixing chamber and it was necessary to disassemble this chamber in order to remove the melted material. In order to produce these granules 150 gm of hydro-biodegradable bags were compressed in a silicone mould and placed for 2 hours in an oven preheated to 150°C. After this period, the mould was removed from the oven and a period of at least 16 hours was allowed to permit the assembly to return to ambient temperature. The blocks of melted hydro-biodegradable bags obtained by this procedure were granulated according to the same conditions already described.

We should mention that the traditional and oxo-biodegradable bags have similar chemical makeups, and comparable thermal and rheological behaviour.

TABLE I: THERMAL PROPERTIES OF PLASTIC BAGS

Bags	TYPE	Melting Point (°C) *see Note 1*	Threshold of Fluidity (°C) *see Note 2*	Melt Index (g/10 min) *See Note 3*
Hilex	Traditional	132	180	0,12
NeoSac	Oxo	135	- - -	0,35
EPI	Oxo	128	- - -	1,09
BioBag®	Hydro	Not defined	120	23,3
Eco Film™	Hydro	Not defined	120	51,4

Note 1 : Melting Points are Obtained by DSC (Differential Scanning Calorimeter).

Note 2 : The threshold of fluidity corresponds to the minimum extrusion temperature without problem.

Note 3 : Melt indices were measured using ASTM D-1238 using conditions ”E “ (190 °C and 2,16 kg)

5. Production of Profiles and Films

Starting with different granules prepared in the preceding step, profiles were produced by extrusion and films by blow molding.

5.1 Extrusion of Prototype Profiles

Prototype profiles were produced in a simple screw extruder. The extruder used was an AMUT with a maximum exit diameter of 1 7/8”. The ratio of the length and the diameter of the main screw was 24:1. At the exit of the extruder a 40” long bath with circulating water allowed cooling of the profiles. Finally a traction system and a cutting unit completed the extrusion system. Figure 2 is a view of the profile extrusion system.

Preliminary trials done using granules from traditional bags allowed the definition of the die and draw plate in order to obtain a rod of 0.5” thickness and 0.25” width. These preliminary trials permitted the definition of experimental conditions in order to obtain quality profiles. Excellent results were obtained in adopting the following conditions for granules of traditional bags.

Extruder: 5 heating stages at temperatures of 188, 195, 230, 195 and 185°C
Extruder: Speed of rotation of the main screw –17 rpm
Draw rate: speed of extrusion – 4.3 feet per minute

For granules providing the 8 mixtures of traditional and oxo-biodegradable bags (NeoSac and EPI) the same experimental conditions were used produce necessary profiles as the in the trials.

Figure 2: Extrusion system for production of profiles

Concerning the hydro-biodegradable (BioBag® and Eco Film™), the experimental conditions adopted for the traditional bags allowed the production of quality profiles for mixtures containing 5% and 10% of hydro-biodegradable bags. As earlier noted, the mixtures that were richer in hydro-biodegradable bags (25% and 50%) caused many extrusion problems and it was necessary to modify the experimental conditions in order to obtain quality profiles. It was already demonstrated that hydro-biodegradable bags have a melting point much lower than traditional bags and that these bags are very much more fluid in the molten state than traditional bags. At these elevated extrusion temperatures the profiles from granules with high hydro-biodegradable bag content are so soft that it is impossible to connect them to the cooling bath without breaking them. In fact, these profiles were more in a liquid state rather than solid.

Supplementary trials determined new heating temperatures in order to obtain quality profiles with the granules of the 4 problematic mixtures of traditional and hydro-biodegradable bags. These conditions are:

Extruder: 5 stage temperature profile – 145, 150, 157, 140 and 140°C.

Other extrusion parameters remained the same.

When the extrusion of one type of mixture was ended, it was necessary to pass another type in avoiding all forms of contamination between mixtures. To do this, the extruder's head was taken off and completely cleaned manually. Further, the heart of the extruder, i.e. the cylindrical part with the continuous screw, was entirely emptied of its contents. Then, on the introduction of a new mixture, the first 24 feet were systematically rejected in order to permit the extrusion system to stabilize. Between 11 and 14 pieces 8 feet long were then produced for testing.

All of the profiles produced were placed in airtight black bags in order to avoid as much as possible any premature degradation caused by ambient air and by light.

5.2 <u>Film blowing</u>

Prototype films were produced by film blowing. The equipment used was identical to the profile production equipment except as concerned the die at the exit of the extruder which was adapted for film blowing. Figure 3 gives a picture of the production system for film blowing.

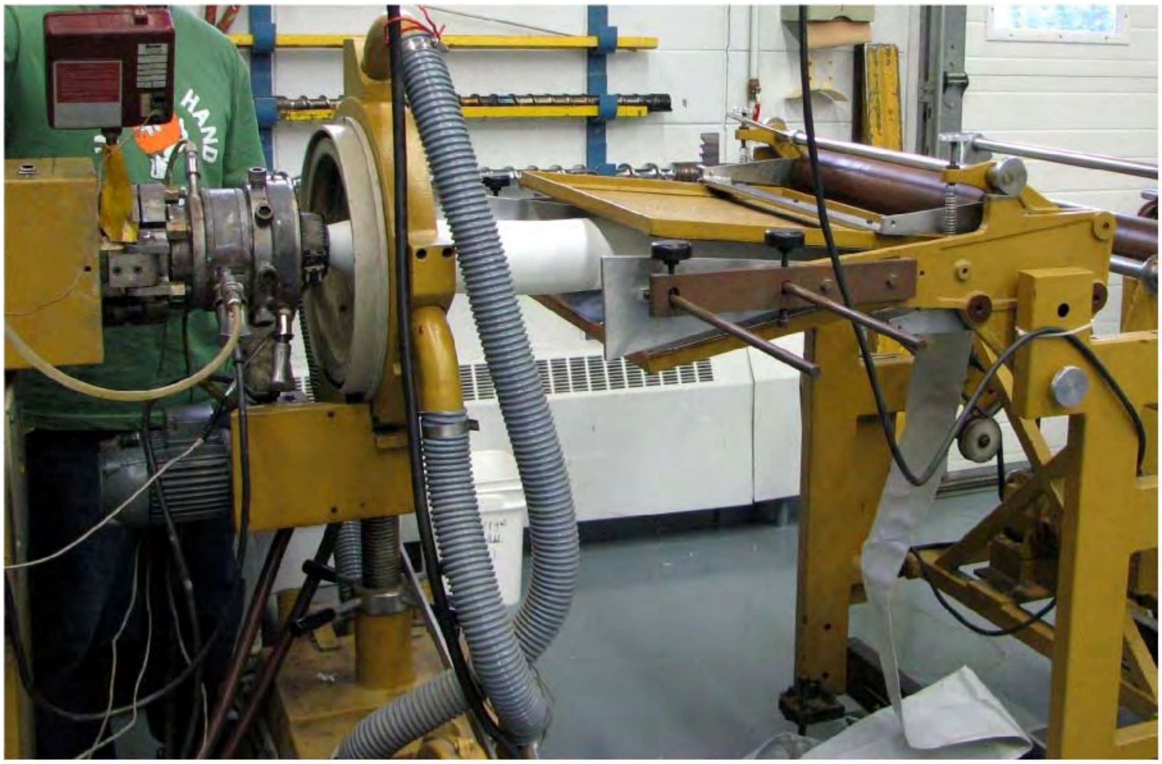

FIGURE 3: Film blowing system

Preliminary trials allowed the definition of experimental conditions in order to obtain quality films with a thickness of between 3 and 5 thousandths of an inch. Excellent results were obtained using the following conditions for granules of traditional bags:

- Five heating stages at temperatures of 188, 195, 230, 195 and 185°C
- Speed of the main screw – 17 rpm
- At the extruder exit, the die with a diameter of 2" with an opening of 0.015". Internal air pressure increased the diameter of the bubble to 6.37".

For granules from the traditional bags as well as the 8 mixtures of traditional and oxo-biodegradable bags ("NeoSac" and "EPI") the same experimental conditions were used to produce the films for the tests.

Concerning the hydro-biodegradable bags (BioBag® and Eco Film™) the same conditions allowed us to produce quality films for mixtures containing 5% and 10% of hydro-biodegradable bags. As before, mixtures containing more of the hydro-biodegradable bags (25% and 50%) caused several problems in blow extrusion and it was necessary to modify the experimental conditions in order to obtain quality films.

By lowering the temperatures of the 5 stages of the heating system of the extruder to 145, 150, 157, 140 and 140°C, it was possible to produce quality films with 25% of both types of hydro-biodegradable bags and with 50% of “BioBag®” type hydro-biodegradable bag. However, the thickness of the films had to be increased to between 5 and 7 thousandths of an inch by lowering the internal blowing pressure in order to obtain quality films. By maintaining the blowing pressure higher in order to obtain films whose thickness was between 3 and 5 thousandths of an inch the films produced were fragile and tore easily.

Despite numerous efforts, it was impossible to make quality films with 50% of “Eco Film™” hydro-biodegradable bags. The films obtained were very fragile and tore easily when manipulated.

A supplementary trial with only granules from “Eco Film™” hydro-biodegradable bags showed that it was possible to produce quality films from this material. The temperatures of the 5 heating stages of the extruder were however reduced to 120, 125, 125, 120 and 120°C. The results of this trial show that it isn’t the “Eco Film™” hydro-biodegradable bag granules that cause problems but rather the 50:50 mixture with granules from traditional bags.

In order to avoid all forms of contamination between mixtures, the extruder was completely emptied of its contents when blow extrusion of one type of mixture was finished and it was necessary to pass another type of mixture. After the production of one type of film, 3 kg of granules were put into the feed hopper and production was maintained until elimination of the base material. In this way about 58 meters of film were produced, more than sufficient to do the characterization trials. To be even more certain of the integrity of the mixtures the necessary samples for the various trials were taken at the end of the blow extrusion in order to eliminate the possibility that the early production might be contaminated by the preceding production or that the thickness of the films might not be constant due to instability at the start of production.

As previously the films produced were stored in airtight black bags in order to avoid as much as possible their exposure to ambient air and to light.

6. Description of Performance Trials and Accelerated Aging

The samples needed for the trials were prepared by cutting and making prototype extruded profiles and by cutting the prototype extruded films.

6.1 Performance Tests for the profiles

Bending resistance and impact resistance of samples from the prototype profiles was measured.

The mechanical bending resistance tests (maximum tensile, deflection at break and elastic module) were done using an Instron dynamometer, Model 4206 equipped with a load cell of 0-200 lb. These tests were done according to ASTM D-790 (Test Method for Flexural Properties of Unreinforced and reinforced Plastics and Electrical Insulating

Materials) at ambient temperature according to Method "B" (flex at 3 points). The samples used had a length of 6 inches, the range adopted for the tests was 4 inches and the test speed was 0.5 inch per minute. The test was repeated 6 times for each type of sample.

The measurement of "Izod" impact resistance were done at ambient temperature using a Tinius Olsen Model 66 pendulum hammer according to the conditions of ASTM D-256 (Standard Test Methods for Determining the Impact Resistance of Notched specimens of Plastics, Test Method A, Cantilever Beam Izod Type Test). These tests were done using samples with a notch. The tests were done 6 times for each type of sample.

6.2 Performance Tests for Films

Performance in tensile, tear resistance and flexibility were measured for prototype extruded films.

Tensile testing (tensile strength at yield point, elongation at yield point, maximum tensile strength, elongation at break, energy of break) was done using an Instron, model 4206 equipped with a 0-200 lb load cell. These tests were done according to ASTM D882 (Test Method for Tensile Properties of Thin Plastic Sheeting) at ambient temperature according to method "B" (constant draw rate). The samples used had a length of 6" and a width of 0.875". The draw speed was 2.0" per minute for all tests. The tests were repeated 6 times for all samples.

Tear resistance was done with an Instron Model 4206 equipped with a load cell of 0-200 lb. These tests were done according to ASTM D-1938 (Test method for Tear Propagation Resistance of Plastic Film and Thin Sheeting by a Single Tear Method) at ambient temperature. The samples used had a length of 6" and a width of 1". The draw speed was 5" per minute for all trials. The tests were repeated 6 times for each type of sample.

Flexibility testing was done with a cantilevered fleximeter – Taber V-5 Stiffness Tester, Model 150-B. These tests were done according to ASTM D-747 (Test Method for Apparent Bending Modulus of Plastics by Means of a Cantilever Beam) at ambient temperature. The samples used had a length of 4" and a width of 1.5". The tests were repeated 6 times for each type of sample.

6.3 Accelerated Aging

In order to accelerate the degradation of profiles and films, a group of samples was exposed to UV rays in a warm and humid environment. The experimental protocol used was the ASTM D-5208 (Practice for Operating Fluorescent Ultraviolet and Condensation Apparatus for Exposure of Photo-degradable Plastics) according to procedure "A" (20 hours of UV rays with UVA-340 lamps at 50°C followed by 4 hours of humidity at 40°C for each exposure cycle). The humidity was about 60% during the UV exposure phase and 100% during the condensation phase.

The profile samples were subjected to 7, 14 and 28 cycles (1, 2 and 4 weeks) of accelerated aging. The profile samples were placed in the middle of the apparatus in order that the 4 faces were exposed to UV rays.

The film samples were subjected to 2, 4 and 7 cycles (2, 4 and 7 days) of accelerated aging. The samples were placed in metal supports supplied with the apparatus for the accelerated aging tests.

7. Initial Characterization of Profiles and Films

7.1 Initial Characterization of Profiles

Flexibility and impact resistance tests were done on samples from traditional bags and 16 mixtures of traditional and biodegradable bags. These tests were done on samples not submitted to accelerated aging by UV exposure in a hot and humid atmosphere. The results are presented in Table 2.

The mixtures of traditional bags and “NeoSac” oxo-biodegradable bags gave no large modifications to flexibility properties. Indeed, a regular lowering of the maximum tensile strength and of the elastic module is easily observed with higher concentrations of “NeoSac” bags but this lowering is of little importance. As concerns maximum deflection, it remains constant at 7.9 +/- 0.1% for all concentrations of this type of bag. Impact resistance increases regularly form 37 joules per meter for mixtures containing 5% of “NeoSac” bags to 89 joules per meter for richer mixtures (50%).

The same observations apply for mixtures of traditional bags and the other type of oxo-biodegradable bags (EPI), except that the effects are clearly more consequential. Clearly the maximum tensile strength of mixtures containing 50% of oxo-biodegradable bags is 3203 pounds per square inch for “NeoSac” bags (10% lower as compared to traditional bags) however, it is 2648 pounds per square inch for “EPI” bags (26% lower as compared to traditional bags). The same conclusions apply for elastic modulus which equals 102100 pounds per square inch for mixtures containing 50% of “NeoSac” bags (11% lower than for conventional bags) however is 75700 pounds per square inch for the same concentration of “EPI” bags (34% lower as compared to traditional bags). As previously, the maximum deflection stays relatively constant around 8.0% for all mixtures of “EPI” bags. The impact resistance follows the same tendency since it increases regularly with increases in the concentration of “EPI” bags, but at a more significant rhythm than with “NeoSac” bags. For a concentration of 50% “EPI” bags, the impact resistance measured is 193 joules per meter (3.3 times higher than traditional bags) being the highest result obtained in the course of this study.

TABLE II INITIAL PERFORMANCE OF PROFILES

BAGS		BENDING TEST			IMPACT
Traditional	**Biodegradable**	**Maximum Tensile Strenght (psi)**	**Maximum Deflection (%)**	**Elastic Module (psi)**	**Izod (J/m)**
100 %	- - - - -	3 576	7,8	115 200	32
95 %	5 % NeoSac (Oxo)	3 455	7,9	112 800	37
90 %	10 % NeoSac (Oxo)	3 397	7,9	109 500	50
75 %	25 % NeoSac (Oxo)	3 281	7,9	105 900	79
50 %	50 % NeoSac (Oxo)	3 203	8,0	102 100	89
95 %	5 % EPI (Oxo)	3 488	7,9	111 400	64
90 %	10 % EPI (Oxo)	3 377	8,0	106 500	78
75 %	25 % EPI (Oxo)	3 079	8,0	94 400	86
50 %	50 % EPI (Oxo)	2 648	8,4	75 700	193
95 %	5 % Eco Film™ (Hydro)	3 127	8,1	94 700	38
90 %	10 % Eco Film™ (Hydro)	2 712	8,8	74 300	64
75 %	25 % Eco Film™ (Hydro)	2 668	8,6	73 700	58
50 %	50 % Eco Film™ (Hydro)	1 595	5,7	44 300	44
95 %	5 % BioBag® (Hydro)	3 674	7,8	125 000	44
90 %	10 % BioBag® (Hydro)	3 435	8,0	112 600	64
75 %	25 % BioBag® (Hydro)	3 021	8,5	88 600	52
50 %	50 % BioBag® (Hydro)	1 872	4,7	61 600	26

Of all the mixtures studied, it is those with “Eco Film™” hydro-biodegradable bags which gave the most significant drop in flexibility performance. The drop in maximum tensile strength and elastic modulus are important, even for concentrations as low as 5% in “Eco Film™” bags. In fact, the results for these two properties with 5% “Eco Film™” are inferior to those of mixtures containing 50% of “NeoSac” bags. For mixtures containing 50% of “Eco Film™” bags the reduction in maximum tensile strength and elastic module are 55% and 62% respectively with respect to traditional bags. For mixtures with this type of bag, the impact resistance increases regularly reaching almost double the performance by comparison with traditional bags when the concentration of “Eco Film™” is 10%. However, for higher concentrations in hydro-biodegradable bags, the results show a declined impact performance.

The reduction in flexibility properties are equally important for the other type of hydro-biodegradable bag, “BioBag®”, although less spectacular than with “Eco Film™” bags. These reductions are nevertheless more important than those observed with the two types of oxo-biodegradable bags. The impact behaviour of mixtures with “BioBag®” bags is similar to that observed with “Eco Film” bags.

7.2 Initial Characterization of Films

Tensile strength, tear strength and flexibility testing was done on film samples made from traditional bags and from 15 mixtures of traditional and biodegradable bags. These tests were done on samples not having been subjected to accelerated aging by UV rays in a hot and humid atmosphere. The results are presented in Table 3.

The mixtures of traditional bags and “NeoSac” oxo-biodegradable don’t exhibit very large deviations in tensile properties. Clearly a regular reduction of the yield point was observed with an increase in the concentration of “NeoSac” bags but this decrease is unimportant. It is the same thing for elongation at yield point where a small increase in performance was observed with an increase in the concentration of “NeoSac” bags.

As concerns the three measured properties at break (maximum tensile strength, elongation at break and energy of break) there is an increase in performance with an increase in the concentration of “NeoSac” bags. This increase is more marked with the break properties than with the yield point properties. The results obtained for tear resistance and flexibility of films made from mixtures of traditional bags and “NeoSac” oxo-biodegradable bags follow the same tendency, in the sense that a significant increase, but one of little importance, in performance is observed with an increase in the concentration of “NeoSac” bags.

The same observations apply for mixtures of traditional bags and the other type of oxo-biodegradable bags, EPI bags, except that the effects are more important as concerns the tensile properties. Clearly, the reduction in tensile strength at yield point is more important with mixtures containing EPI bags that with those containing “NeoSac” bags. At the same time, the increase in measured properties for elongation at yield point, maximum tensile strength, elongation at break and energy of break are significantly more important with mixtures containing EPI bags than with those containing “NeoSac” bags. Results for tear resistance of various mixtures with EPI bags are excellent since all measurements are over 900 pounds per inch of thickness. The results do not always progress regularly with an increase in the concentration of EPI bags. This situation probably arises from the fact that since carrying out the tear strength tests with the samples from traditional and oxo-biodegradable bags (NeoSac and EPI), it has been observed that there is effectively a regular progression of the tear to a level of the splits but at the same time appearance of the phenomenon of yield. This yield provoked torsion in the sample which resulted into a variability that is more important than normal in the basic results.

The flexibility tests on the different samples show that the rigidity of mixtures increases as soon as the concentration of EPI bags reaches 10%. The rigidity then decreases progressively. All mixtures made with EPI bags offer superior flexibility performance to those from pure traditional bags.

The mixtures studied which contained 5% and 10% of “Eco Film” hydro-biodegradable bags show a significant but minimally important decline of tensile strength at yield point. A slight increase in elongation at yield point is observed when the concentration of “Eco Film™” bags is increased. For the mixture containing 25% of “Eco Film™” bags, no yield point phenomena were observed. Recall that the mixture with 50% “Eco Film™” bags could not be produced by film blowing.

The three tensile properties which bring the samples at break show a significant decrease in performance with an increase in concentration of “Eco Film™” bags. For the mixture containing 25% of “Eco Film” bags this reduction is very important for elongation at break and break energy. Clearly when the mixtures go from 10% to 25% of “Eco Film™” bags, elongation at break fell from 338 to 18% and the energy at break fell from 73 to 2 joules/cm^3. By comparison, the elongation at break and the break energy of traditional bags is 615% and 114 joules/cm^3 respectively.

Tear resistance undergoes an important drop in properties as a function of the concentration of “Eco Film™” bags. They go from 868 lb/in for traditional bags to 324 lb/in for a mixture containing 5% of “Eco Film™” bags and to 21 lb/in for a mixture of 25% of “Eco Film™” bags. An equally important drop in flexibility was observed with an increase in the concentration of “Eco Film™” bags.

Properties measured with mixtures containing the other type of hydro-biodegradable bag, “BioBag®” bags, present the same performance as those measured with “Eco Film™” bags. However, the effects are more marked with this type of bags than bags with “Eco Film™”. Tensile strength and elongation at yield increase for mixtures containing 5% and 10% of “BioBag” bags. No yield point phenomena were observed for mixtures containing 25% and 50% “BioBag®’s”. The maximum tensile strength remains relatively constant at 3000 lb/sq.in for mixtures containing 5, 10 and 25% of “Bio-Bag®” bags but falls dramatically to 1669 lb/sq.in. for the mixture at 50%. Elongation at break goes from 615% for traditional bags to150% for the mixtures low in “BioBag®” bags (5% and10%) and then falls brutally to attain 5% for the mixture containing 50% of “BioBag®” bags. The energy at break follows the same pathway as elongation at break. It goes from 114 J/cm^3 for traditional bags to 0.3 J/cm^3 for the mixture containing 50% of “BioBag®” bags. Finally the tear resistance as well as the flexibility equally show very important drops in performance when the concentration of “BioBag®” bags is increased.

TABLE III INITIAL PERFORMANCE OF FILMS

BAGS		TENSILE PROPERTIES					Tear Strength	Flexibility
Traditional	Biodegradable	Tensile at yield Point (psi)	Elongation at yield point (%)	Maximum Tensile (psi)	Elongation at Break (%)	Energy of Break (J/cm^3)	(lb/in)	at 7,5° Initial (psi)
100 %	- - - - -	3 352	9,4	3 083	615	114	868	154 200
95 %	5 % NeoSac (Oxo)	3 203	10,2	3 162	673	120	875	168 200
90 %	10 % NeoSac (Oxo)	3 148	11,0	4 005	709	137	897	162 800
75 %	25 % NeoSac (Oxo)	3 056	11,3	4 313	716	145	829	162 200
50 %	50 % NeoSac (Oxo)	3 023	12,7	4 461	770	151	973	180 600
95 %	5 % EPI (Oxo)	2 997	12,3	3 809	731	132	947	267 500
90 %	10 % EPI (Oxo)	2 905	12,9	4 787	750	147	921	234 200
75 %	25 % EPI (Oxo)	2 771	12,8	5 150	780	155	969	211 500
50 %	50 % EPI (Oxo)	2 521	14,8	5 456	820	163	918	185 900
95 %	5 % Eco Film™	3 365	11,0	2 986	476	92	324	111 600
90 %	10 % Eco Film™	3 181	14,6	2 774	388	73	164	102 500
75 %	25 % Eco Film™	-----	-----	2 556	18	2,2	21	97 700
50 %	50 % Eco Film™	-----	-----	-----	-----	-----	-----	-----
95 %	5 % BioBag® (Hydro)	3 430	14,3	2 934	149	37	285	135 600
90 %	10 % BioBag®	3 624	21,4	3 185	152	39	140	138 60
75 %	25 % BioBag®	-----	-----	2 993	13	1,9	15	73 700
50 %	50 % BioBag® (Hydro)	-----	-----	1 669	5,1	0,3	8,0	54 100

8. Characterization of Profiles and Films After Accelerated Aging

A portion of the profiles and films were subjected to a special conditioning where they were exposed to many cycles of an accelerated aging, where each cycle corresponded to 20 hours of UV rays with fluorescent lamps UVA-340 at 50°C followed by 4 hours of humidity at 40°C. Following this conditioning the samples of profiles and films were characterized and their performance was compared with those of samples not having been subjected to this particular conditioning.

8.1 Characterization of profiles after accelerated aging

Flexibility and impact resistance tests were done on samples of profiles made from traditional bags and of 16 mixtures of traditional and biodegradable bags. These tests were done on samples having been subjected to accelerated aging for one, two and four weeks according to an exposure to UV rays in a hot and humid atmosphere. Then results of the flexibility tests are presented in tables IV, V and VI, and the results of the impact resistance tests are presented in table VII.

Accelerated aging doesn't seem to have had a significant impact on the samples made only from traditional bags, because the results of all trials after this accelerated aging within experimental error are identical to those of the controls (without accelerated aging). Nevertheless, a significant increase in the impact performance was registered following an exposure of 4 weeks to UV rays in a hot and humid atmosphere.

The results of trials of impact resistance show that mixtures of traditional and oxo-biodegradable bags (NeoSac and EPI) are little affected by one week of accelerated aging. Nevertheless a significant drop in impact performance is observed for exposures of 2 and 4 weeks to UV rays in a hot and humid environment. This drop is however greater for mixtures with EPI bags than for those with Neo-Sac bags. However, it must be underlined that all the results of impact resistance of samples containing the two types of oxo-biodegradable bags (NeoSac and EPI) and which were subjected to 4 weeks of accelerated aging were superior to the initial result (without accelerated aging) of impact resistance for samples made purely from conventional bags.

Important changes were observed when impact resistance trials were done with mixtures of traditional and hydro-biodegradable bags Eco Film™ and BioBag® and that is the same for an exposure period of 1 week to UV rays in a hot and humid environment.. Actually, very important decreases were observed for all these mixtures, with the exception of the mixture of 5% of "Eco Film™" bags. These decreases can attain up to 64% of the initial value. For accelerated aging of 2 and 4 weeks a drop in impact performance was observed for all mixtures of Eco Film™ and BioBag biodegradable bags

The accelerated aging didn't seem to have any impact on the bending performance (maximum tensile strength, maximum deflection and elastic modulus) of the samples made from traditional bags alone and from mixtures of traditional and oxo-biodegradable bags (NeoSac and EPI). In fact the performance variations are 8% less for the group of samples studied. Accelerated aging has no large impact on bending performance of mixtures of traditional and hydro-biodegradable bags (Eco Film™ and BioBag®) following 1 week of exposure to UV rays in a hot humid atmosphere. For longer exposure periods only the mixtures containing 5 and 10% of Eco Film™ bags showed significant changes of maximum tension and elastic modulus (1 and 2 weeks).

TABLE IV: MAXIMUM TENSILE STRENGTH IN BENDING (psi) OF PROFILES FOLLOWING ACCELERATED AGING

BAGS		Length of Accelerated Aging			
Conventional	**Biodegradable**	**Initial**	**7 days**	**14 days**	**28 days**
100 %		3 576	3 570 (-0)	3 478 (-3)	3 684 (+3)
95 %	5 % NeoSac	3 455	3 629 (+5)	3 450 (-0)	3 655 (+6)
90 %	10 % NeoSac	3 397	3 406 (+0)	3 454 (+2)	3 537 (+4)
75 %	25 % NeoSac	3 281	3 475 (+6)	3 297 (+1)	3 386 (+3)
50 %	50 % NeoSac	3 203	3 414 (+7)	3 088 (-4)	3 329 (+4)
95 %	5 % EPI	3 488	3 565 (+2)	3 302 (-5)	3 587 (+3)
90 %	10 % EPI	3 377	3 480 (+3)	3 269 (-3)	3 597 (+7)
75 %	25 % EPI	3 079	2 949 (-4)	3 018 (-2)	3 285 (+7)
50 %	50 % EPI	2 648	2 653 (+0)	2 617 (-1)	2 732 (+3)
95 %	5 % Eco Film™	3 127	3 205 (+3)	3 596 (+15)	3 737 (+20)
90 %	10 % Eco Film™	2 712	2 992 (+10)	3 169 (+17)	3 162 (+17)
75 %	25 % Eco Film™	2 668	2 865 (+7)	2 897 (+9)	2 899 (+9)
50 %	50 % Eco Film™	1 595	1 697 (+6)	1 754 (+10)	1 677 (+5)
95 %	5 % BioBag®	3 674	3 498 (-5)	3 707 (+1)	3 893 (+6)
90 %	10 % BioBag®	3 435	3 600 (+5)	3 589 (+5)	3 831 (+11)
75 %	25 % BioBag®	3 021	3 213 (+6)	3 031 (+0)	3 231 (+7)
50 %	50 % BioBag®	1 872	1 868 (-0)	1 831 (-2)	1 812 (-3)

Note : Values in parentheses indicate the variation of properties from their initial values.

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TABLE V: MAXIMUM DEFLECTION IN BENDING (%) OF PROFILES AFTER ACCELERATED AGING

Bags		Length of Accelerated Aging			
Conventional	**Biodegradable**	**Initial**	**7 days**	**14 days**	**28 days**
100 %		7,8	7,8 (0)	8,0 (+3)	8,3 (+6)
95 %	5 % NeoSac	7,9	7,9 (+1)	8,0 (+2)	7,9 (+1)
90 %	10 % NeoSac	7,9	8,2 (+3)	8,2 (+3)	8,1 (+2)
75 %	25 % NeoSac	7,9	8,2 (+3)	8,3 (+5)	8,1 (+2)
50 %	50 % NeoSac	8,0	8,2 (+2)	8,1 (+1)	8,1 (+1)
95 %	5 % EPI	7,9	8,1 (+2)	8,1 (+2)	8,3 (+5)
90 %	10 % EPI	8,0	8,2 (+3)	8,3 (+4)	8,7 (+8)
75 %	25 % EPI	8,0	8,2 (+3)	8,7 (+8)	8,7 (+9)
50 %	50 % EPI	8,4	8,5 (+1)	8,8 (+4)	9,0 (+6)
95 %	5 % Eco Film™	8,1	8,7 (+7)	8,2 (+1)	8,4 (+4)
90 %	10 % Eco Film™	8,8	9,5 (+7)	8,1 (-8)	8,6 (-2)
75 %	25 % Eco Film™	8,6	9,6 (+11)	9,0 (+5)	9,0 (+5)
50 %	50 % Eco Film™	5,7	6,0 (+5)	5,9 (+3)	5,5 (-4)
95 %	5 % BioBag®	7,8	8,1 (+4)	8,2 (+6)	8,0 (+3)
90 %	10 % BioBag®	8,0	8,3 (+3)	8,2 (+3)	8,4 (+5)
75 %	25 % BioBag®	8,5	9,1 (+7)	8,6 (+2)	8,3 (-2)
50 %	50 % BioBag®	4,7	4,5 (-5)	4,5 (-3)	3,8 (-18)

Note : Values in parentheses indicate the variation of properties from their initial values

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TABLE VI: ELASTIC MODULUS IN BENDING (psi) OF PROFILES AFTER ACCELERATED AGING

BAGS		Length of Accelerated Aging			
Conventional	**Biodegradable**	**Initial**	**7 days**	**14 days**	**28 days**
100 %		115 200	112 800 (-2)	112 200 (-3)	117 100 (+2)
95 %	5 % NeoSac	112 800	117 800 (+4)	109 800 (-3)	116 100 (+3)
90 %	10 % NeoSac	109 500	107 600 (-2)	107 500 (-2)	108 700 (-1)
75 %	25 % NeoSac	105 900	109 400 (+3)	100 600 (-5)	103 900 (-2)
50 %	50 % NeoSac	102 100	107 300 (+5)	95 700 (-6)	102 800 (+1)
95 %	5 % EPI	111 400	112 500 (+1)	102 900 (-8)	113 000 (+1)
90 %	10 % EPI	106 500	106 900 (+0)	102 100 (-4)	110 400 (+4)
75 %	25 % EPI	94 400	87 600 (-7)	90 000 (-5)	96 100 (+2)
50 %	50 % EPI	75 700	74 600 (-2)	73 800 (-3)	76 600 (+1)
95 %	5 % Eco Film™	94 700	93 800 (-1)	117 200 (+24)	120 000 (+27)
90 %	10 % Eco Film™	74 300	77 600 (+4)	97 100 (+31)	92 800 (+25)
75 %	25 % Eco Film™	73 700	72 900 (-1)	77 600 (+5)	79 300 (+8)
50 %	50 % Eco Film™	44 300	44 400 (+0)	44 100 (-0)	47 300 (+7)
95 %	5 % BioBag®	125 000	115 500 (-8)	117 800 (-6)	131 600 (+5)
90 %	10 % BioBag®	112 600	117 100 (+4)	115 400 (+2)	123 000 (+9)
75 %	25 % BioBag®	88 600	89 000 (+1)	88 500 (-0)	100 200 (+13)
50 %	50 % BioBag®	61 600	63 900 (+4)	62 500 (+1)	71 700 (+16)

Note : Values in parentheses indicate the variation of properties from their initial values

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TABLE VII IZOD IMPACT RESISTANCE (J/m) OF PROFILES AFTER ACCELERATED AGING

BAGS		Length of Accelerated Aging			
Conventional	**Biodegradable**	**Initial**	**7 days**	**14 days**	**28 days**
100 %		32	30 (-5)	32 (+1)	45 (+43)
95 %	5 % NeoSac	37	35 (-5)	36 (-4)	32 (-13)
90 %	10 % NeoSac	50	53 (+6)	41 (-17)	39 (-23)
75 %	25 % NeoSac	79	85 (+7)	71 (-11)	63 (-21)
50 %	50 % NeoSac	89	88 (-1)	80 (-10)	77 (+14)
95 %	5 % EPI	64	62 (-3)	38 (-40)	39 (-38)
90 %	10 % EPI	78	77 (-1)	54 (-31)	54 (-31)
75 %	25 % EPI	86	90 (+6)	67 (-21)	63 (-27)
50 %	50 % EPI	193	170 (-12)	129 (-33)	120 (-37)
95 %	5 % Eco Film™	38	35 (-7)	30 (-21)	30 (-22)
90 %	10 % Eco Film™	64	41 (-37)	40 (-38)	35 (-46)
75 %	25 % Eco Film™	58	36 (-39)	37 (-37)	33 (-43)
50 %	50 % Eco Film™	44	25 (-43)	26 (-42	21 (-53)
95 %	5 % BioBag®	44	28 (-35)	28 (-36)	30 (-32)
90 %	10 % BioBag®	64	23 (-64)	27 (-58)	29 (-55)
75 %	25 % BioBag®	52	31 (-40)	36 (-32)	30 (-42)
50 %	50 % BioBag®	26	16 (-38)	17 (-36)	14 (-47)

Note : Values in parentheses indicate the variation of properties from their initial values

8.2 Characterization of Films After Accelerated Aging

Tests of tensile strength, tear resistance and flexibility were done on samples of films made from traditional bags and from 15 mixtures of traditional and biodegradable bags. These tests were done on samples having been subjected 2, 4 and 7 days of accelerated aging involving exposure to UV rays in a hot and humid atmosphere. The results of the tensile testing are presented in tables 8-12 and the results of the tear resistance and flexibility are presented in tables 13 and 14 respectively.

In the group, the accelerated aging has had a major effect on all of the samples tested. In fact, all the samples including those from traditional bags and of mixtures between traditional and oxo-biodegradable bags (NeoSac and EPI) show no phenomenon of stretchiness following 7 days of accelerated aging. The samples elongate under the effect of mechanical force and break when this force is higher than the elastic limit of the materials without ever stretching. After 2 and 4 days of exposure, the samples from mixtures with EPI bags show stretchiness, but only the mixture containing 5% of NeoSac bags shows this phenomenon after 2 days of exposure. The other mixtures of NeoSac bags show no phenomenon of stretchiness for exposure times of 2 days or more.

After 4 days of exposure to UV rays in a hot and humid environment, films containing 50% of NeoSac bags are extremely fragile such that it is impossible to manipulate them without breaking (see figure 4). After 7 days exposure, films containing 25% and 50% of “NeoSac” bags are completely destroyed as illustrated in figure 5. These films are extremely friable and break at the slightest touch. No performance measure can be made on these films.

The performances obtained as maximum tensile strength are given in table 10. Maximum tensile strength of mixtures of “NeoSac” bags fall very rapidly with amount of biodegradable bags, while it remains relatively constant for samples from traditional bags. Maximum tensile strength falls in an equally important way for mixtures made with EPI bags, but less rapidly. For mixtures prepared with the two types of hydro-biodegradable bags (Eco Film™ and BioBag®) the maximum tensile strength falls regularly with an increase in the concentration of biodegradable bags but remain relatively constant when each measure is compared to those mixtures not having been subjected to accelerated aging.

The performance obtained regarding elongation at break and energy of break are presented in tables 11 and 12 respectively. For traditional bags, all the mixtures with oxo-biodegradable bags (NeoSac and EPI) as well as the mixtures containing 5% and 10% hydro-biodegradable bags (Eco Film™ and BioBag®) the elongation at break and the energy of break fell in a catastrophic manner and this for an exposure as short as 2 days. Clearly the initial elongation at break of these samples is equal to several hundreds of percent and it falls by 90% after 4 days of exposure in the best case. It is the same thing for the energy of break which goes from about 150 J/cm^3 for mixtures with oxo-biodegradable bags to values in the neighbourhood of several J/cm^3 following accelerated aging of 4 days ore more.

The drop in performance of these two properties is less spectacular for mixtures with 25% and 50% of hydro-biodegradable bags (Eco Film™ and BioBag®) but it must be understood that the initial values were already relatively low and that the accelerated aging only lowers these performances further.

The results of tear resistance, presented in table 13, show that the group of films show similar properties to those already observed for elongation at break and energy of break.

Then results of flexibility trials (table 14) show that in general, there is a lowering of the performance of his property. That is to say that the samples having been subjected to accelerated aging are more flexible than those not subjected to a similar treatment. The changes in flexibility are nevertheless less important than those observed for the elongation at break, energy of break and tear resistance.

Figure 4 : Film Containing 50% NeoSac bags after 4 days exposure to UV rays in a hot and humid atmosphere.

Figure 5 **Films containing 25 % and 50 % of "NeoSac" bags after exposure of 1 week to UV rays in a hot and humid atmosphere**

TABLE VIII : TENSILE STRENGTH AT YIELD POINT (psi) OF FILMS AFTER ACCELERATED AGING

BAGS		Length of Accelerated Aging			
Conventional	**Biodegradable**	**Initial**	**2 days**	**4 days**	**7 days**
100 %		3 352	3355 (+0)	(---)	(---)
95 %	5 % NeoSac	3 203	3425 (+7)	(---)	(---)
90 %	10 % NeoSac	3 148	(---)	(---)	(---)
75 %	25 % NeoSac	3 056	(---)	(---)	(---)
50 %	50 % NeoSac	3 023	(---)	(---)	(---)
95 %	5 % EPI	2 997	3032 (+1)	3336 (+11)	(---)
90 %	10 % EPI	2 905	3147 (+8)	3210 (+10)	(---)
75 %	25 % EPI	2 771	2851 (+3)	2998 (+8)	(---)
50 %	50 % EPI	2 521	2609 (+3)	2774 (+10)	(---)
95 %	5 % Eco Film™	3 365	3334 (-1)	(---)	(---)
90 %	10 % Eco Film™	3 181	3264 (+3)	(---)	(---)
75 %	25 % Eco Film™		(---)	(---)	(---)
50 %	50 % Eco Film™		(---)	(---)	(---)
95 %	5 % BioBag®	3 430	3534 (+3)	(---)	(---)
90 %	10 % BioBag®	3 624	3574 (-1)	(---)	(---)
75 %	25 % BioBag®		(---)	(---)	(---)
50 %	50 % BioBag®		(---)	(---)	(---)

Note : Values in parentheses indicate the variation of properties from their initial values

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TABLE IX : ELONGATION AT YIELD POINT (%) OF FILMS AFTER ACCELERATED AGING

BAGS		Length of Accelerated Aging			
Conventional	**Biodegradable**	**Initial**	**2 days**	**4 days**	**7 days**
100 %		9,4	8,9 (-5)	(---)	(---)
95 %	5 % NeoSac	10,2	12,9 (+26)	(---)	(---)
90 %	10 % NeoSac	11,0	(---)	(---)	(---)
75 %	25 % NeoSac	11,3	(---)	(---)	(---)
50 %	50 % NeoSac	12,7	(---)	(---)	(---)
95 %	5 % EPI	12,3	8,0 (-35)	10,0 (-19)	(---)
90 %	10 % EPI	12,9	12,7 (-1)	12,5 (-3)	(---)
75 %	25 % EPI	12,8	13,8 (+8)	7,3 (-43)	(---)
50 %	50 % EPI	14,8	14,4 (-2)	8,1 (-45)	(---)
95 %	5 % Eco Film™	11,0	10,9 (-0)	(---)	(---)
90 %	10 % Eco Film™	14,6	11,2 (-24)	(---)	(---)
75 %	25 % Eco Film™		(---)	(---)	(---)
50 %	50 % Eco Film™		(---)	(---)	(---)
95 %	5 % BioBag®	14,3	12,6 (-12)	(---)	(---)
90 %	10 % BioBag®	21,4	14,6 (-32)	(---)	(---)
75 %	25 % BioBag®		(---)	(---)	(---)
50 %	50 % BioBag®		(---)	(---)	(---)

Note : Values in parentheses indicate the variation of properties from their initial values

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TABLE X : MAXIMUM TENSILE STRENGTH (psi) OF FILMS AFTER ACCELERATED AGING

BAGS		Length of Accelerated Aging			
Conventional	**Biodegradable**	**Initial**	**2 days**	**4 days**	**7 days**
100 %		3 083	2 610 (-15)	3 448 (+12)	3 328 (+8)
95 %	5 % NeoSac	3 162	3 369 (+7)	1 520 (-52)	1 132 (-64)
90 %	10 % NeoSac	4 005	3 260 (-19)	1 717 (-57)	895 (-78)
75 %	25 % NeoSac	4 313	3 219 (-25)	818 (-81)	(---)
50 %	50 % NeoSac	4 461	1 385 (-69)	0,0 (-100)	(---)
95 %	5 % EPI	3 809	3 098 (-19)	3 099 (-19)	3 269 (-14)
90 %	10 % EPI	4 787	4 412 (-8)	2 771 (-42)	3 197 (-33)
75 %	25 % EPI	5 150	5 050 (-2)	2 688 (-48)	2 926 (-43)
50 %	50 % EPI	5 456	5 015 (-8)	2 637 (-52)	2 354 (-57)
95 %	5 % Eco Film™	2 986	2 772 (-7)	3 410 (+14)	2 890 (-3)
90 %	10 % Eco Film™	2 774	2 731 (-2)	3 527 (+27)	3 129 (+13)
75 %	25 % Eco Film™	2 556	2926 (+14)	2 560 (+0)	2 417 (-5)
50 %	50 % Eco Film™		(---)	(---)	(---)
95 %	5 % BioBag®	2 934	3 146 (+7)	3 455 (+18)	3 444 (+17)
90 %	10 % BioBag®	3 185	3 388 (+6)	3 488 (+10)	3 087 (-3)
75 %	25 % BioBag®	2 993	3 261 (+9)	2 860 (-4)	2 355 (-21)
50 %	50 % BioBag®	1 669	1 827 (+9)	1 721 (+3)	1742 (+4)

Note : Values in parentheses indicate the variation of properties from their initial values

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TABLE XI : ELONGATION AT BREAK (%) OF FILMS AFTER ACCELERATED AGING **(%)**

BAGS		Length of Accelerated Aging			
Conventional	**Biodegradable**	**Initial**	**2 days**	**4 days**	**7 days**
100 %		615	421 (-32)	11 (-98)	8,0 (-99)
95 %	5 % NeoSac	673	16 (-98)	1,9 (-100)	1,6 (-100)
90 %	10 % NeoSac	709	16 (-98)	1,1 (-100)	1,4 (-100)
75 %	25 % NeoSac	716	10 (-99)	1,0 (-100)	(-100)
50 %	50 % NeoSac	770	1,9 (-100)	0,0 (-100)	(-100)
95 %	5 % EPI	731	580 (-21)	24 (-97)	8,0 (-99)
90 %	10 % EPI	750	736 (-2)	63 (-92)	7,7 (-99)
75 %	25 % EPI	780	765 (-2)	56 (-93)	7,0 (-99)
50 %	50 % EPI	820	797 (-3)	27 (-97)	4,7 (-99)
95 %	5 % Eco Film™	476	205 (-57)	19 (-96)	4,5 (-99)
90 %	10 % Eco Film™	388	122 (-69)	15 (-96)	5,7 (-99)
75 %	25 % Eco Film™	18	15 (+18)	8,3 (-54)	6,0 (-67)
50 %	50 % Eco Film™		(---)	(---)	(---)
95 %	5 % BioBag®	149	93 (-38)	20 (-87)	8,4 (-94)
90 %	10 % BioBag®	152	46 (-70)	14 (-91)	4,7 (-97)
75 %	25 % BioBag®	13	14 (+12)	8,6 (-32)	4,7 (-62)
50 %	50 % BioBag®	5,1	6,4 (+26)	5,7 (+11)	5,6 (+9)

. Note : Values in parentheses indicate the variation of properties from their initial values

TABLE XII : BREAK ENERGY (J/cm^3) OF FILMS AFTER ACCELERATED AGING

BAGS		Length of Accelerated Aging			
Conventional	**Biodegradable**	**Initial**	**2 days**	**4 days**	**7 days**
100 %		114	77 (-32)	2,1 (-98)	1,3 (-99)
95 %	5 % NeoSac	120	2,8 (-98)	0,1 (-100)	0,0 (-100)
90 %	10 % NeoSac	137	2,9 (-98)	0,0 (-100)	0,0 (-100)
75 %	25 % NeoSac	145	1,5 (-99)	0,0 (-100)	(-100)
50 %	50 % NeoSac	151	0,1 (-100)	0,0 (-100)	(-100)
95 %	5 % EPI	132	105 (-20)	6,8 (-95)	1,2 (-99)
90 %	10 % EPI	147	144 (-2)	13,6 (-91)	1,1 (-99)
75 %	25 % EPI	155	151 (-2)	6,5 (-96)	0,9 (-99)
50 %	50 % EPI	163	151 (-7)	4,4 (-97)	0,4 (-100)
95 %	5 % Eco Film™	92	45 (-52)	4,0 (-96)	0,5 (-99)
90 %	10 % Eco Film™	73	28 (-62)	2,9 (-96)	0,7 (-99)
75 %	25 % Eco Film™	2,2	2,3 (+6)	1,0 (-52)	0,6 (-74)
50 %	50 % Eco Film™		(---)	(---)	(---)
95 %	5 % BioBag®	37	24 (-34)	4,1 (-89)	1,4 (-96)
90 %	10 % BioBag®	39	12 (-70)	2,8 (-93)	0,5 (-99)
75 %	25 % BioBag®	1,9	2,4 (+26)	1,2 (-39)	0,4 (-79)
50 %	50 % BioBag®	114	0,5 (+70)	0,4 (+40)	0,3 (+16)

. Note : Values in parentheses indicate the variation of properties from their initial values

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TABLE XIII : TEAR RESISTANCE (lb/in) OF FILMS AFTER ACCELERATED AGING

BAGS		Length of Accelerated Aging			
Conventional	**Biodegradable**	**Initial**	**2 days**	**4 days**	**7 days**
100 %		868	576 (-34)	177 (-80)	53 (-94)
95 %	5 % NeoSac	875	319 (-64)	20 (-98)	18 (-98)
90 %	10 % NeoSac	897	128 (-86)	23 (-97)	14 (-98)
75 %	25 % NeoSac	829	38 (-95)	3,0 (-100)	(-100)
50 %	50 % NeoSac	973	5,3 (-99)	0,0 (-100)	(-100)
95 %	5 % EPI	947	878 (-7)	215 (-77)	33 (-97)
90 %	10 % EPI	921	905 (-2)	169 (-82)	30 (-97)
75 %	25 % EPI	969	1 024 (+6)	377 (-61)	42 (-96)
50 %	50 % EPI	918	1 079 (+18)	366 (-60)	10 (-99)
95 %	5 % Eco Film™	324	185 (-43)	71 (-78)	28 (-91)
90 %	10 % Eco Film™	164	88 (-46)	54 (-67)	29 (-83)
75 %	25 % Eco Film™	21	18 (-14)	10 (-52)	11 (-46)
50 %	50 % Eco Film™		(---)	(---)	(---)
95 %	5 % BioBag®	285	237 (-17)	67 (-76)	61 (-79)
90 %	10 % BioBag®	140	104 (-26)	44 (-69)	31 (-78)
75 %	25 % BioBag®	15	16 (+7)	13 (-13)	12 (-23)
50 %	50 % BioBag®	8,0	8,8 (+10)	8,0 (0)	6,9 (-14)

. Note : Values in parentheses indicate the variation of properties from their initial values

TABLE XIV : FLEXIBILITY (psi) OF FILMS AFTER ACCELERATED AGING

BAGS		Length of Accelerated Aging			
Conventional	**Biodegradable**	**Initial**	**2 days**	**4 days**	**7 days**
100 %		154 200	187 400 (+22)	179 500 (+16)	167 300 (+8)
95 %	5 % NeoSac	168 200	133 500 (-21)	142 300 (-15)	135 300 (-20)
90 %	10 % NeoSac	162 800	173 0009 (+6)	180 100 (+11)	175 600 (+8)
75 %	25 % NeoSac	162 200	144 200 (-11)	178 300 (+10)	(---)
50 %	50 % NeoSac	180 600	171 400 (-5)	(---)	(---)
95 %	5 % EPI	210 700	194 900 (-8)	184 100 (-13)	189 000 (-10)
90 %	10 % EPI	219 800	202 200 (-8)	217 700 (-1)	184 200 (-16)
75 %	25 % EPI	211 500	229 600 (+9)	230 100 (+9)	163 700 (-23)
50 %	50 % EPI	185 900	191 900 (+3)	139 700 (-25)	172 700 (-7)
95 %	5 % Eco Film™	111 600	117 000 (+5)	115 600 (+4)	117 600 (+5)
90 %	10 % Eco Film™	102 500	110 900 (+8)	119 600 (-17)	117 800 (+15)
75 %	25 % Eco Film™	97 700	81 100 (-17)	81 400 (-17)	80 100 (-18)
50 %	50 % Eco Film™		(---)	(---)	(---)
95 %	5 % BioBag®	135 600	111 100 (-18)	116 000 (-14)	96 900 (-29)
90 %	10 % BioBag®	138 600	108 100 (-22)	101 600 (-27)	107 600 (-22)
75 %	25 % BioBag®	73 700	63 700 (-14)	57 500 (-22)	63 000 (-15)
50 %	50 % BioBag®	54 100	37 300 (-31)	51 400 (-5)	25 400 (-53)

. Note : Values in parentheses indicate the variation of properties from their initial values

9. Resistance of the bags to Water

In order to verify the integrity of the films, bags were made from the group of blown films and suspended after having been filled with water. To make the bags, the cylindrical films were cut into lengths of 15 inches. One of the ends was sealed using a thermal sealer 0.5 inches from the edge and a hole was made on the other end in order to simulate a handle. The hole had a diameter of 1.5 inches and the centre of the hole was 2 inches from the edge.

The group of bags was suspended from a copper pipe of 0.5 inch diameter as shown in figure 6. The bags were filled with water to a level of the hole and the level was checked daily. The bags contained about 2 liters of water each. Three bags were made and evaluated for each film.

The integrity of the bags was checked twice a day and the results are shown in table 15.

Bags made with films from traditional bags and oxo-biodegradable bags (Neosac and EPI) held water very well for a period of more than 100 days.

As concerns bags made from mixtures traditional and hydro-biodegradable bags "Eco Film™ only mixtures containing 25% of "Eco Film™" didn't give satisfactory results because they broke during the initial filing. Recall that it was impossible to make films with mixtures containing 50% of Eco Film™ bags.

Finally, for bags made with mixtures of traditional bags and BioBag®s, only the bags containing 5% of Biobag®s resisted the weight of the water for a long period. For bags containing 10% and 25% BioBag®s they broke quickly. For this test it was impossible to make bags containing 50% BioBag®s which had enough mechanical integrity to install them on the apparatus without breaking.

Figure 6 : APPARATUS USED TO SUSPEND BAGS FILLED WITH WATER

TABLE XV : LIFETIME OF BAGS FILLED WITH WATER

BAGS		Number of Days Before Observation of Breakage		
Conventional	**Biodegradable**	**Trial -1**	**Trial -2**	**Trial -3**
100 %		> 100	> 100	> 100
95 %	5 % NeoSac	> 100	> 100	> 100
90 %	10 % NeoSac	> 100	> 100	> 100
75 %	25 % NeoSac	> 100	> 100	> 100
50 %	50 % NeoSac	> 100	> 100	> 100
95 %	5 % EPI	> 100	> 100	> 100
90 %	10 % EPI	> 100	> 100	> 100
75 %	25 % EPI	> 100	> 100	> 100
50 %	50 % EPI	> 100	> 100	> 100
95 %	5 % Eco Film™	> 100	> 100	> 100
90 %	10 % Eco Film™	> 100	> 100	> 100
75 %	25 % Eco Film™	Note 1	Note 1	Note 1
50 %	50 % Eco Film™			
95 %	5 % BioBag®	> 100	> 100	> 100
90 %	10 % BioBag®	Note 1	Note 1	Note 1
75 %	25 % BioBag®	Note 1	Note 1	Note 1
50 %	50 % BioBag®	Note 2	Note 2	Note 2

Note 1 : *The bags fell before filling with water was complete.*

Note 2 : *It was impossible to make bags which were mechanically strong enough to do the test.*

10. OBSERVATIONS

This section outlines the main observations made according to the 3 main steps of the project being: the preparation of the mixtures, the initial mechanical performance of the profiles and films as well as the mechanical performance of the profiles and films following accelerated aging.

Preparation of mixtures and extrusion of profiles and films:

Oxo-biodegradables

Traditional and oxo-biodegradable bags are of a similar chemical structure and have similar comparable thermal and rheological (fluidity) behaviour. Compatibility was therefore observed in the preparation of mixtures.

Hydro-biodegradables

The preparation of different mixtures between traditional and hydro-biodegradable bags revealed serious problems of compatibility between hydro-biodegradable and traditional bags. As a result, for mixtures where the concentration of hydro-biodegradable bags is greater than 25%, it was necessary to modify the experimental mixing protocol and to readjust the two extruders during the production of profiles and films. Differences in the chemical nature (polyethylene compared to cornstarch), of thermal behaviour and of rheology are probably at the origin of this incompatibility between traditional and hydro-biodegradable bags.

General Observation

As a consequence, oxo-biodegradable bags are more compatible than hydro-biodegradable when they are mixed with traditional plastic bags.

Initial mechanical performance of profiles and films:

Oxo-biodegradables

Profiles made from mixtures between oxo-biodegradable and traditional bags, showed few changes in mechanical properties in bending. An increase in impact resistance was noted when the concentration of oxo-biodegradable bags was increased. As concerns films, only tensile strength at yield point, measured during the measurement of tensile properties, showed a decrease of performance with an increase in concentration of oxo-biodegradable bags. All other tensile properties, in flexibility and in tear resistance showed increased performance with an increase in the concentration of oxo-biodegradable bags. More precisely, all the bags made from films containing oxo-biodegradable bags (5, 10, 25 and 50%) were resistant during more than 100 days of filling with water without showing any leakage.

Hydro-biodegradables

Significant changes were noted from profiles made with mixtures of hydro-biodegradable and traditional bags. In particular, a significant fall in properties was observed overall as concerns the maximum bending strength and the elastic bending modulus for mixtures between “Eco Film™” bags and traditional bags.

As concerns films, appreciable changes were noted. The drop in performance is particularly important for the tensile testing when the samples were amenable to rupture, for the flexibility tests, but most particularly for tear resistance tests. More precisely, the bags made form films containing more than 10% of “BioBag®” hydro-biodegradable bags and the films containing more than 25% of “Eco Film™ hydro-biodegradable bags were not able to resist tearing when they were filled of water. Only films containing low amounts of hydro-biodegradable bags were able to resist tearing during a 100 day period.

Mechanical performance of profiles and films following accelerated aging:

Oxo-biodegradables

Following exposure to UV rays in a hot and humid atmosphere, the profiles made form mixtures of oxo-biodegradable and traditional bags did not undergo significant changes in the bending properties. A significant drop in impact performance was however observed for exposures of greater than 14 days.

Films made form mixtures of oxo-biodegradable and traditional bags showed an important loss of properties. The mixtures of “NeoSac oxo-biodegradable bags and traditional bags seemed particularly affected by accelerated aging since the films were for all practical purposes completely destroyed after 4 days exposure. The fall in performance of mixtures containing ”EPI” oxo-biodegradable bags was similar to that noted for traditional bags alone.

Hydro-biodegradables

Profiles made from mixtures of hydro-biodegradable and traditional bags did not show significant bending property changes. On the other hand, an appreciable drop in impact resistance was observed after only 1 week of exposure.

The films made from mixtures of hydro-biodegradable and traditional bags showed a significant loss of properties but these were less important than that observed for mixtures of with oxo-biodegradable bags. It must be noted that the initial performance of these mixtures was inferior to that measured with mixtures of oxo-biodegradable and traditional bags.

General Observation

In summary, accelerated aging of profiles for a maximum period of 28 days did not cause relatively important changes to the mechanical properties of the group of samples produced, including the control; sample from traditional bags. Oppositely, all the films, including the traditional bag control sample, showed an important drop in properties following 7 days of accelerated aging.

The results clearly demonstrated that exposure of films to UV rays had more marked consequences than those observed for profiles. It seems that the attack of UV rays and humidity affects only the surface of the samples and does not induce damage to more than a few micrometers in depth. It appears that these surface effects will have more importance on thin samples, like films which are only a few thousandths of an inch in thickness as compared to the thicker profiles which have a thickness of over 0.25 inch.

11. CONCLUSIONS

The objective of the present project consisted of evaluating technically the potential impact of hydro-biodegradable bags (Eco Film™ and BioBag®) and oxo-biodegradable bags (NeoSac and EPI) on the recycling of traditional plastic bags. More specifically, the study aimed to evaluate the changes in mechanical properties of profiles and films made from different mixtures of hydro-biodegradable and oxo-biodegradable bags with traditional bags.

In light of the results obtained, the principal conclusions of the study are as follows:

- The hydro-biodegradable bags studied (Eco Film™ and BioBag®) are incompatible with the recycle stream for traditional plastic bags in consideration of the proven difficulties during preparation of the mixtures with traditional bags and of the difficulties during the extrusion of profiles and films.
- During the preparation of mixtures and the extrusion of profiles and films, the mixtures made from the oxo-biodegradble bags studied (NeoSac and EPI) and traditional bags behaved in the same way as traditional bags alone. Consequently, the oxo-biodegradable bags studied are compatible with the traditional plastic bag recycle stream from the viewpoint of the preparation of mixtures as well as the extrusion of profiles and films.
- The profiles prepared from mixtures of oxo-biodegradable bags and traditional bags behave in a comparable manner to the control profile made from traditional bags alone and this at the moment of extrusion and after accelerated aging (UV rays, heat and humidity)
- Profiles prepared from mixtures of hydro-biodegradable bags and traditional bags show a significant drop in initial bending performance. However, these profiles do not seem to have been affected significantly by accelerated aging.
- The initial performance of films made from oxo-biodegradable bags and traditional bags are comparable to films made from traditional bags alone. Accelerated aging affects the films containing EPI oxo-biodegradable bags in a way similar to films made from traditional bags alone. However, the aging affects considerably the films containing NeoSac oxo-biodegradable bags.
- Films made from hydro-biodegradable bags and traditional bags, without accelerated aging, show an important loss of tear resistance with an increase in the concentration of hydro-biodegradable bags.

In summary, the two hydro-biodegradable bags studied (Eco Film™ and BioBag®) are not compatible with the traditional plastic bag recycle stream because numerous problems were observed during the preparation of mixtures and the extrusion of profiles and films. Moreover, the mixture of these bags with traditional bags induces an important drop in mechanical performance of the films, principally related to tear resistance.

The oxo-biodegradable bags (NeoSac and EPI) show excellent compatibility with traditional bags during the preparation of mixtures and during the extrusion of profiles and films. However, the films obtained from mixtures of NeoSac and traditional bags show rapid and considerable degradation after only a few days of accelerated aging. These bags cannot be considered as being perfectly compatible with the traditional plastic bag recycling stream.

The “EPI“ oxo-biodegradable bags can be considered as being compatible with the traditional plastic bag recycle stream, in consideration of the results obtained during the preparation of mixtures and during the extrusion of profiles and films as well as the initial performance of profiles and films and the performance of these following accelerated aging.

Table XVI summarizes the main observations and conclusions relative to the different types of bags studied in this project.

Finally, this study has also permitted the illumination that biodegradable bags do not all behave the same when they are mixed with traditional bags. The chemical nature of biodegradable bags (oxo and hydro) has a clearly significant influence on the final performance. Also, biodegradable bags of the same category likewise show significant differences, as it has been possible to show in comparing the performance of mixtures of “NeoSac” and “EPI” oxo-biodegradable bags with traditional bags following exposure to UV rays in a hot and humid atmosphere.

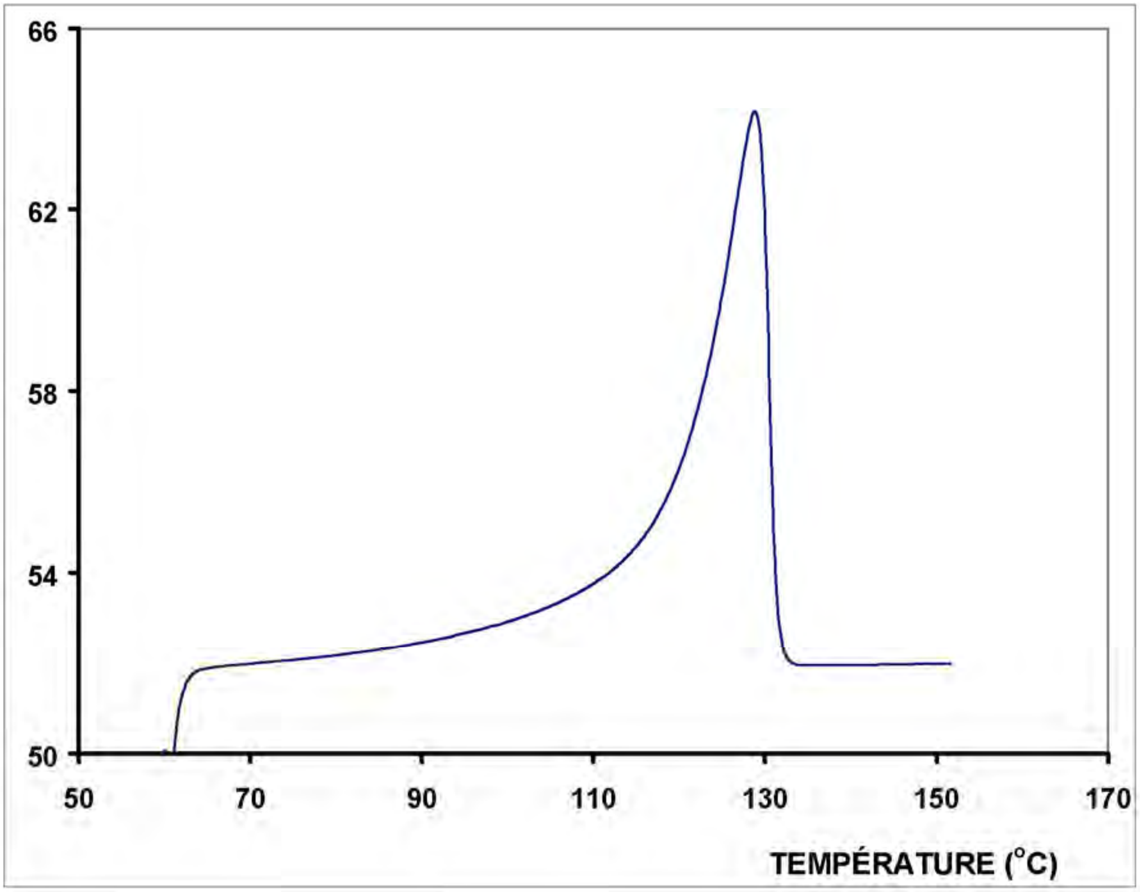
TABLE XVI : SUMMARY OF OBSERVATIONS AND CONCLUSIONS

CATEGORY AND TYPE OF BAG	FORM	COMPATIBILITY OF MIXTURE AND INITIAL MECHANICAL PERFORMANCE	MECHANICAL PERFORMANCE AFTER ACCELERATED AGING (UV + HEAT + HUMIDITY)	COMPATIBILITY WITH THE TRADITIONAL PLASTIC BAG RECYCLE STREAM
Traditionnel (control) HDPE	Profile		▪ No important changes after 28 days of accelerated aging.	
	Film		▪ Important drop in properties after 7 days of accelerated aging.	
Oxo-biodegradable NeoSac EPI	Mixing	▪ Compatible with traditional bags because of chemical nature and comparable thermal and rheological behaviour.		**<u>NeoSac oxo-biodegradable bags cannot be considered as being perfectly compatible with the traditional plastic bag recycling stream</u>** because of rapid and considerable degradation of films following accelerated aging. **<u>EPI oxo-biodegradable bags EPI studied are compatible</u>** with the traditional plastic bag recycle stream considering the level of preparation of mixtures, of extrusion of the initial mechanical performance and following accelerated aging.
	Profile	▪ Little change in mechanical bending properties; ▪ Increase in impact resistance with increase in concentration of oxo-biodegradable bags.	▪ No significant change of bending properties; ▪ Significant drop of performance of impact resistance for exposure time greater than 14 days.	
	Film	▪ Lower performance in tensile strength at yield point; ▪ Increase in tensile performance, flexibility and tear resistance with increase in concentration of oxo-biodegradable bags	**<u>NéoSac</u>** ▪ Films affected considerably by accelerated aging; nearly completely destroyed after 4 days of exposure.. **<u>EPI</u>** ▪ Performance fall similar to that observed for the traditional bag control..	
Hydro-biodegradable BioBag® Eco Film™	Mixing	▪ Incompatibility with traditional bags necessitated a modification of the experimental mixing protocol; and an adjustment of the extruders.		**<u>The hydro-biodegradable bags studied (Eco Film™ et BioBag®) are</u> <u>incompatible</u>** with the traditional plastic bag recycle stream mainly because of the proven difficulties during the preparation of mixtures with traditional bags and of the extrusion of profiles and films.
	Profile	▪ Significant drop in overall properties as concerns maximum bending strength and elastic bending	▪ No significant change of bending properties following accelerated aging.; ▪ Appreciable drop in impact resistance after only 1 week of exposure..	
	Film	▪ Important drop in mechanical performance in terms of tensile, flexibility and overall tear resistance.	▪ Significant loss of performance.	

Appendix A

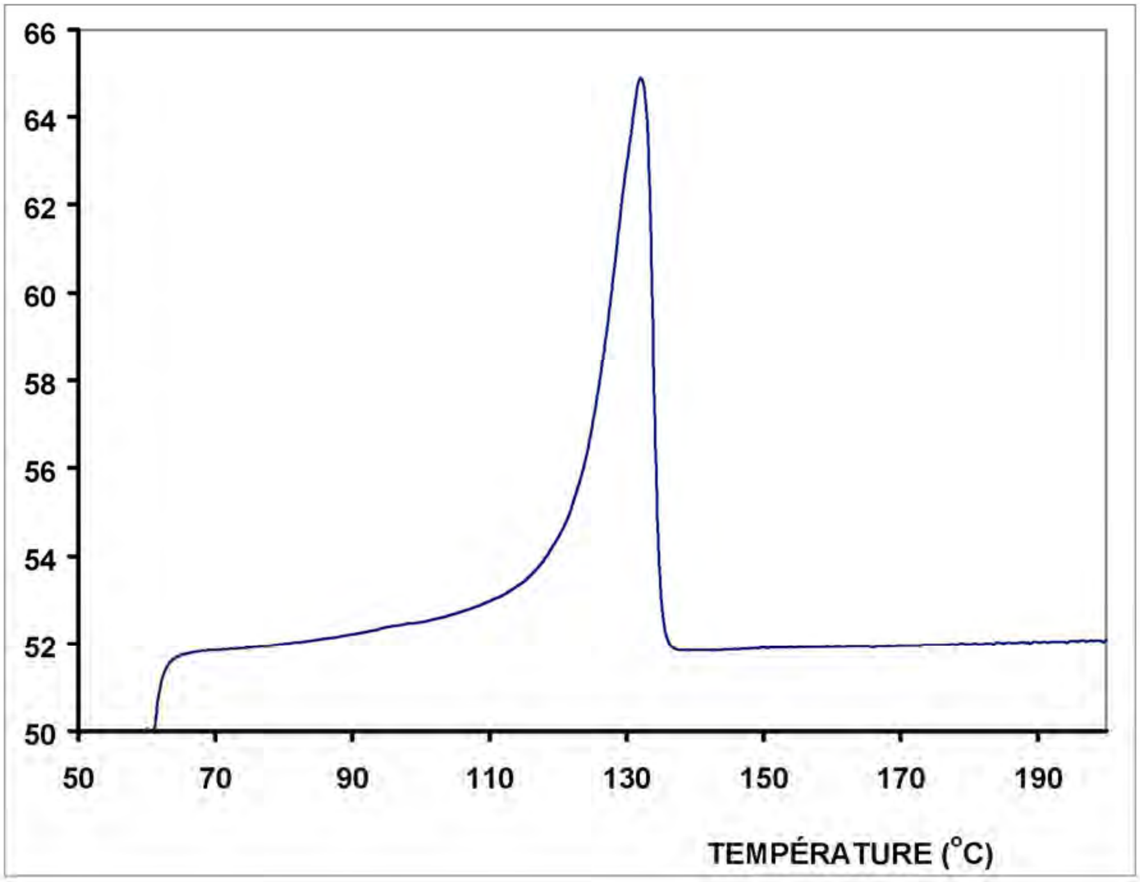
Thermal Behaviour by “DSC” (Differential Scanning Calorimeter)
of Plastic Bags

COMPORTEMENT THERMIQUE PAR DSC DES SACS TRADITIONNELS

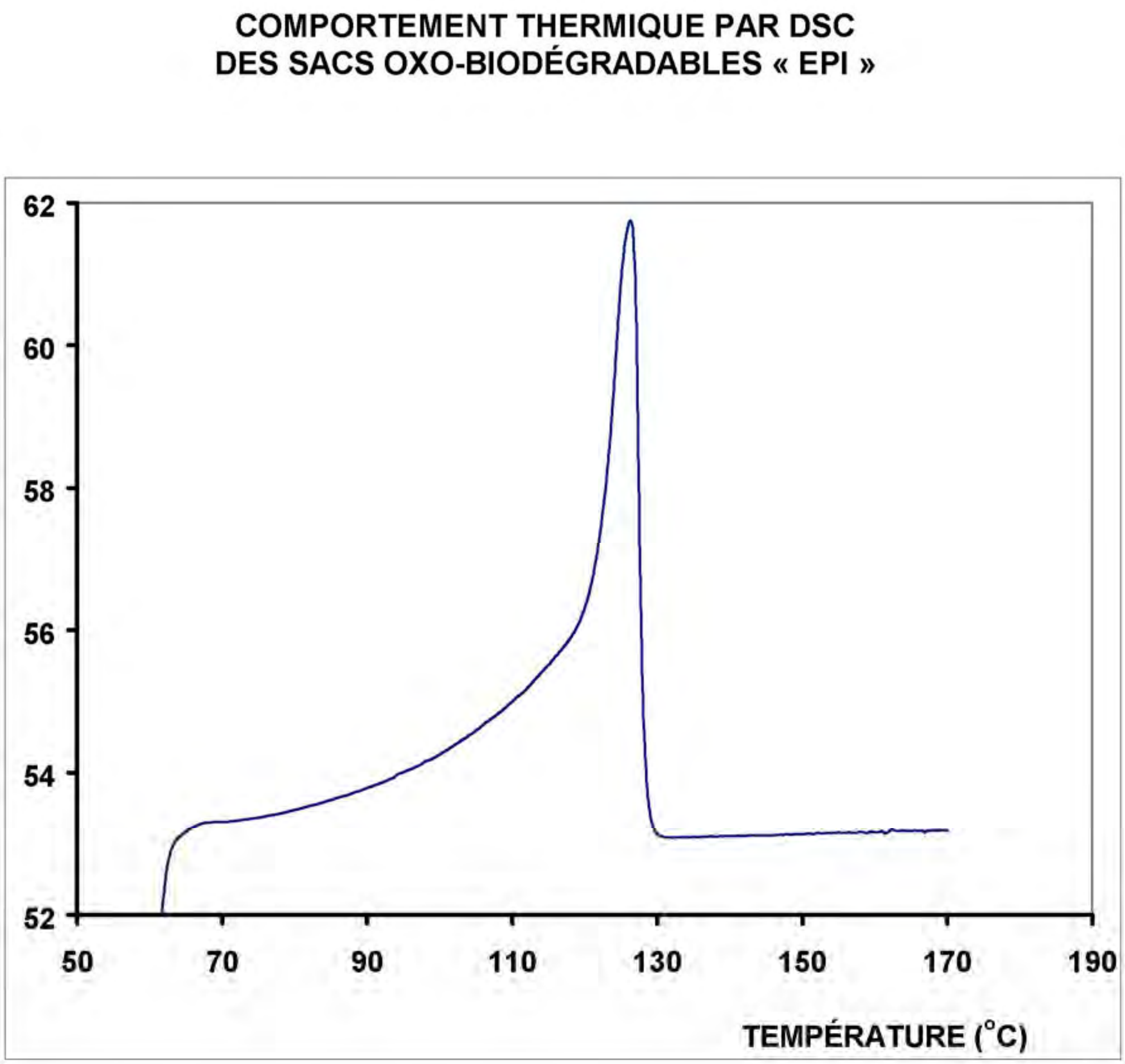


Thermal Behaviour by DSC of Conventional Bags

COMPORTEMENT THERMIQUE PAR DSC
DES SACS OXO-BIODÉGRADABLES « Néo-Sac »

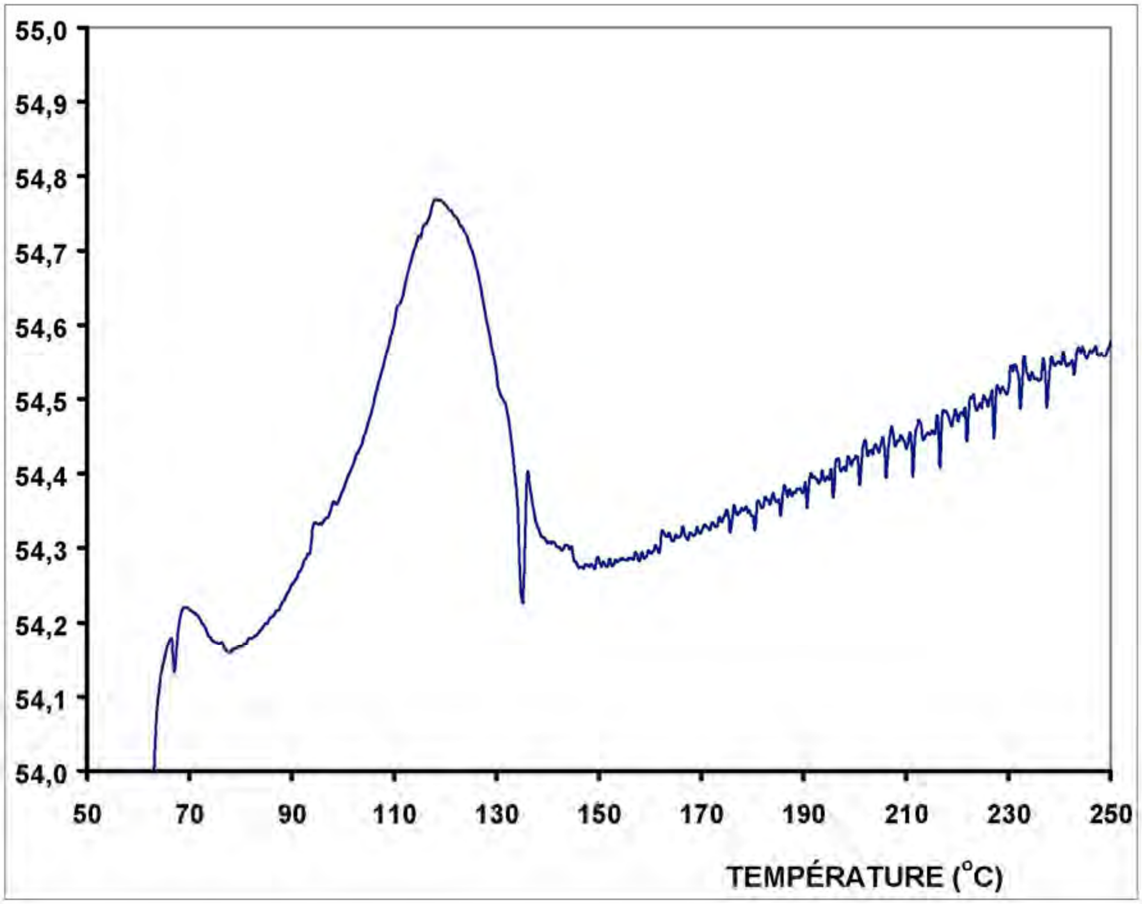


Thermal Behavior by DSC of "Neo-sac" Oxo-biodegradable Bags

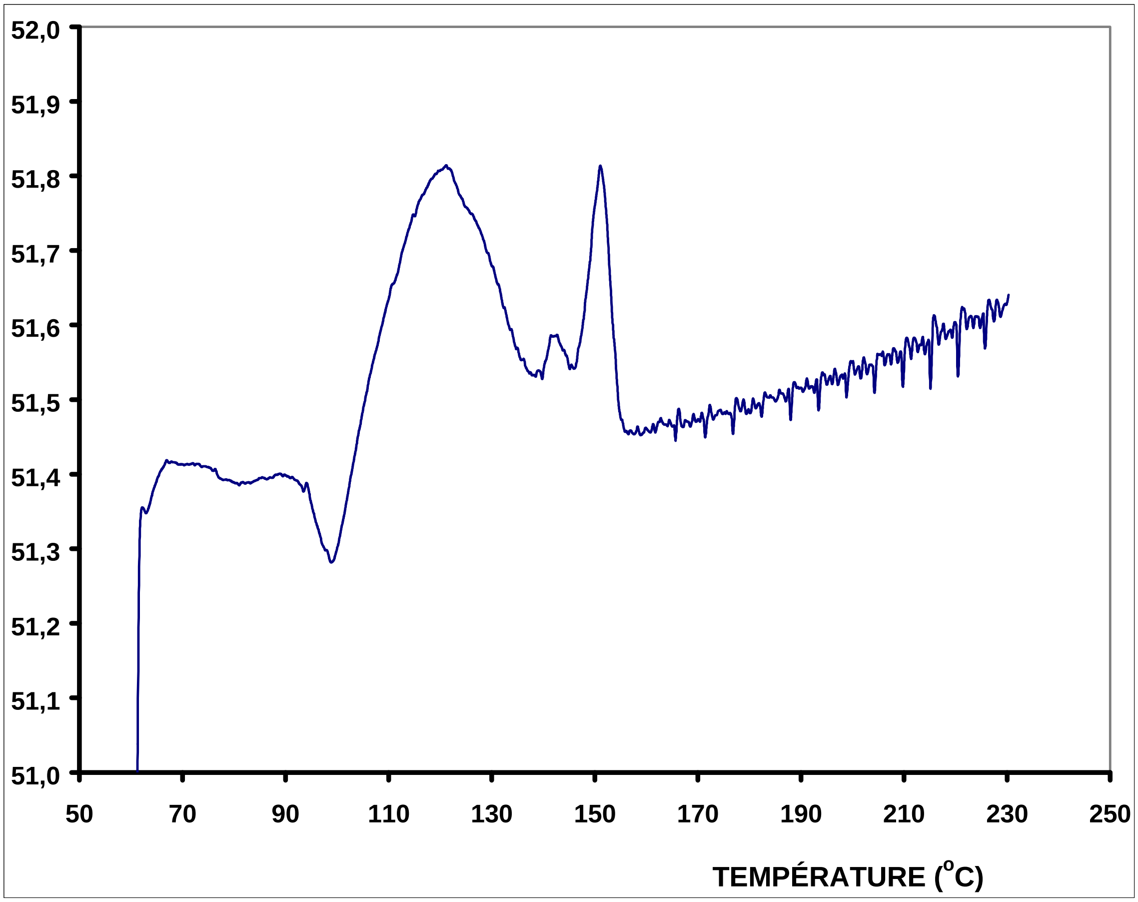


Thermal Behaviour by DSC of “EPI” Oxo-biodegradable Bags

COMPORTEMENT THERMIQUE PAR DSC
DES SACS HYDRO-BIODÉGRADABLES « Eco-Film »



Thermal Behaviour by DSC of "Eco Film" Hydro-biodegradable Bags



Thermal Behaviour by DSC of “BioBag” Hydro-biodegradable Bags