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## INTRODUCTION

In the last forty years, the food packaging sector have knew a great development and the use of plastic material is growth thanks to many advantages that these materials can give. Plastic materials are light and resistant. There are many types of adapted polymers to confer the right properties and satisfy each needs. In last years, it is increasing the sector of flexible packaging that are a very fruitful solution to optimize volumes and weight in order to meet the important topic of reduction of environmental impact. Year by year, this kind of packaging followed the life style change. The eating habits are chanced and like consequence is changed also the way to buy food products and their packs. We can summarize this and we can say that there is less and less time to buying and cooking food products. We can think at always more women that work, more single people, more technology like internet, smartphone etc. that invade our time. Consequently, packaging was changed to satisfy these new needs. Today we can note in the super markets food packaging oriented to smaller dimension, mono-portions, user friendly and we can say that we ask at packaging to be “ALL IN ONE”. The “ALL IN ONE” concept is the possibility to obtain a pack with more and more characteristics inside. At the same time, TERMOPLAST was changed his products and technology and with years it passed from 3 layers film production to 5 and 9 layers technology to satisfy these important changes. This development is born to give at converters industry the possibility to simplify laminated structure, reduce impact environment or better functionality of food packaging. Termoplast have studied from many years new coextruded barrier films nine layers technology based and it has a big know how to processing many types of polymers like LLDPE, COPO PE-PP ,

PA, PET, EVOH, PP together in the same film structure to modulate final properties and to confer the right solutions for each packaging requirement. The advantage that nine layers technology shows respect to standard 5 and 7 layers technologies is the possibility to formulate the two added layers in appropriate way to confer specific properties respect to we can obtain with the standard barrier structures. For example, we can increase the water vapour barrier in order to obtain a super barrier film in confront of water and oxygen gases. We have called these new nine layers film, SUPER PF (super performance)

## METHODS AND ANALYSIS

To better understanding the advantages to use our new films SUPER PF, we compare different properties of this kind of barrier film with standard structures at five and seven layers with the same Total thickness (75 µm) and the same EVOH content (4%). In a seven and nine layers films, we use EVOH with a sandwich of PA (polyamide) with the same thickness . The three structure analyzed are resume below:

1. PE-EVOH 5 LAYERS STANDARD – PE/TIE/EVOH/TIE/PE
2. PE-PA-EVOH  
7 LAYERS STANDARD PE/TIE/PA/EVOH/PA/TIE/PE
3. PE-PA-EVOH  
9 LAYERS SUPER PF PE/NEW/TIE/PA/EVOH/PA/TIE/NEW/PE

The layers indicated like NEW are the two additional layers formulated with new types of polyethylene with high crystallinity. We tested all these film and compared the chemical , mechanical, sealing and barrier properties . The analytical instruments used in this work are Dynamometers, DSC, X-Ray, MOCON permeabilimeters, Hot tack tester, heat sealing tester.

## RESULTS

In order to check the increasing in crystallinity of new film SUPER PF, we show in the pictures fig.1 and Table 1, the X-Ray images for the three structures presented before. The table shows like the nine layers SUPER PF films we achieve an increase of total crystallinity of the film.

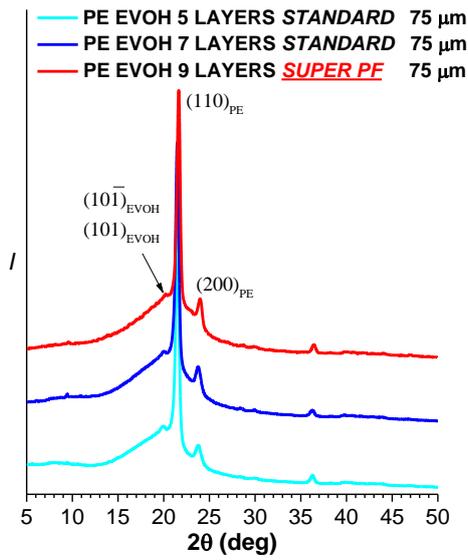
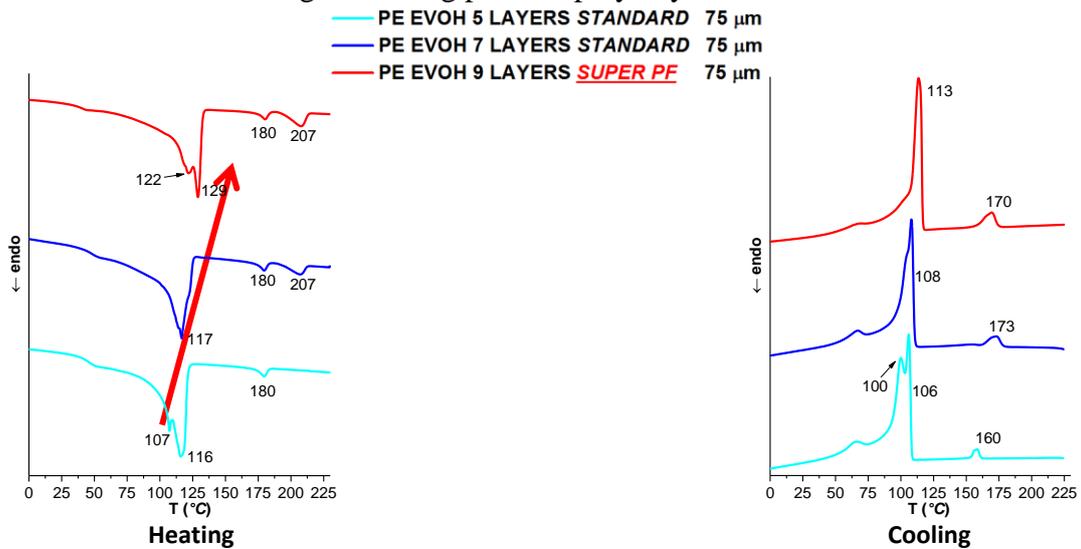


Fig.1 – X Ray Analysis

SAMPLE	Crystallinity grade (%)
PE EVOH STANDARD 5 LAYERS 75μm	42
PE EVOH STANDARD 7 LAYERS 75μm	45
PE EVOH 9 LAYERS SUPER PF 75 μm	50

Table 1

The DSC graphs (Fig.2) show the same structure and for the nine layers structure an increasing of melting point of polyethylene matrix.



An important aspect that we will see in the following pages is that the nine layers film shows an increasing of melting point and this is a very good results to obtain high mechanical properties and rigidity but it does not worsen sealing properties. In the graph below we show a comparison of mechanical properties for the three film. We can see that nine layers SUPER PF film have high mechanical properties respect to others and in particular this graph in fig.3 shows the essence of coextrusion in terms to combine more properties at the same time in the same structure. In fact the easy tear properties, express like the inverse of resistance to tear, shows in TD value a better easy tear for SUPER PF film in opposite to seven layers that in general confer , more mechanical properties respect to five layers but don't give the possibility to combine film with easy tear because the polyamide inside is resistance to tear. This is possible with the two added layers of nine layers structure than allow to overturns this result.

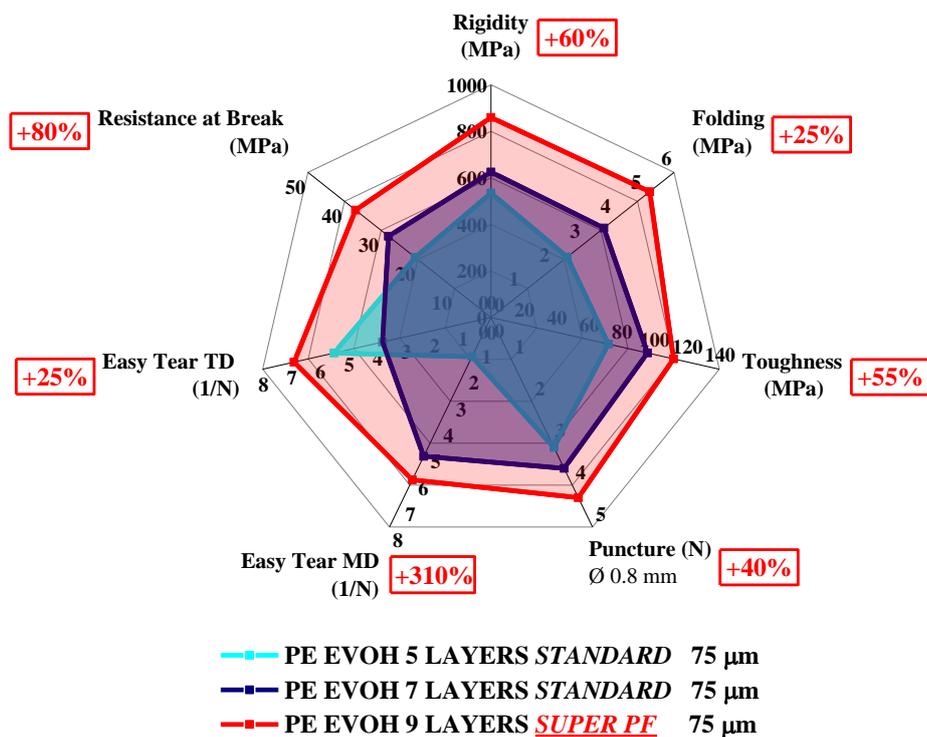


Fig.3 – Comparison of mechanical properties

In food packaging applications a very important aspect are the sealing properties where we can discern the hot seal properties that are named HOT TACK (fig. 4) and where we measure the seal resistance when the sealing is still hot, with a very short cooling time (dwell time) of 0,5 sec. The standard HEAT SEAL curve (fig. 5) measures seal resistance when this is enough cool (cooling time > 2 min.) .

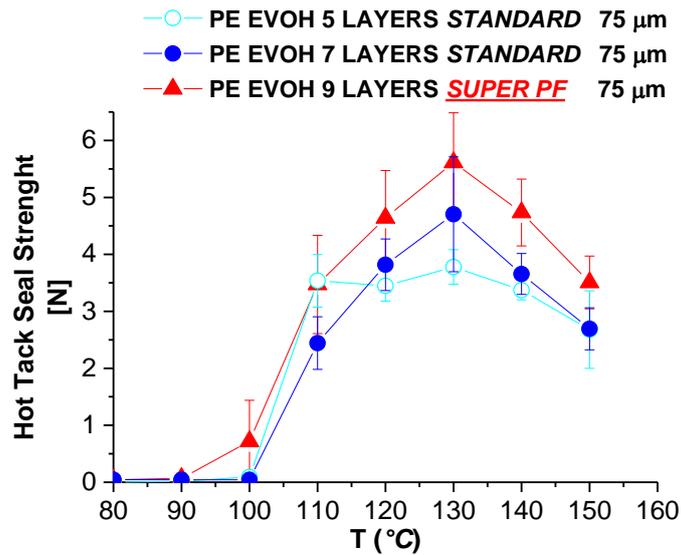


Fig. 4 – Hot-Tack Curves

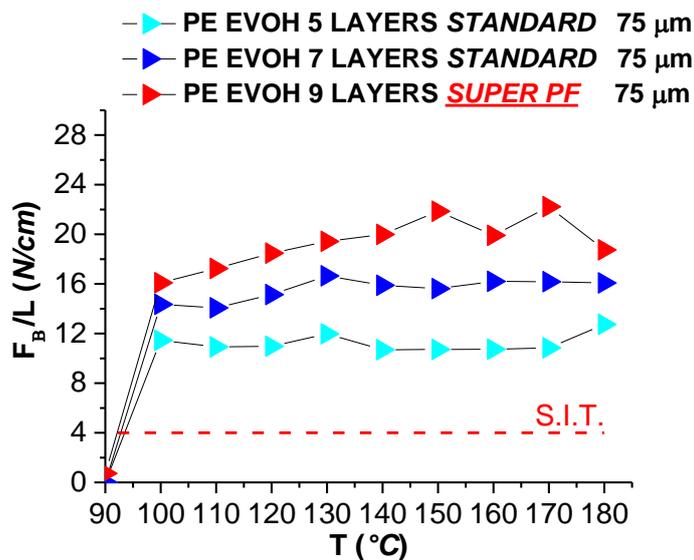


Fig. 5 – Heat Seal Curves

The two graph above, show that SUPER PF film have the same range of sealing temperature though higher melting point of polyethylene. This is possible thanks to the perfect design of each layer. However the increase of melting point have the advantage to confer at film more resistance to temperature and this is important in flexible food packaging to avoid micro-holes in the sealing zone. The image below (fig.6) show a picture of behavior of the three film at seal temperature of 180°C without any support added to the polyethylene film.

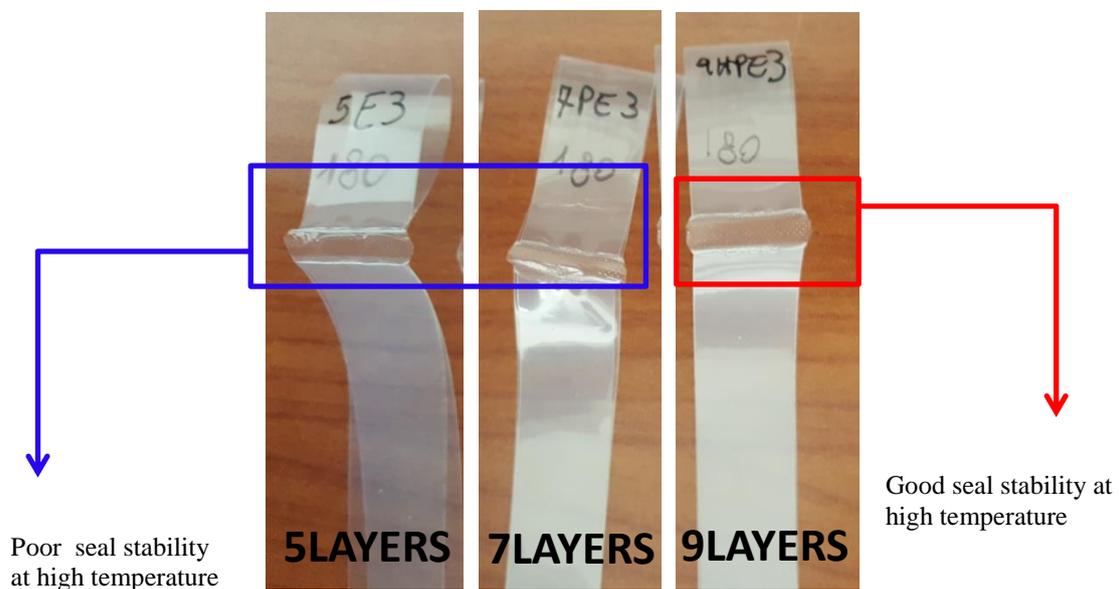


Fig.6 – Pictures of films after sealing at 180°C

Concern permeability to gases, our aim was to obtain a film with a good oxygen barrier like EVOH based film and at the same time with good water vapour barrier. In the next graph, fig.7, we have the comparison of WVTR (water vapour transmission) for all the samples.

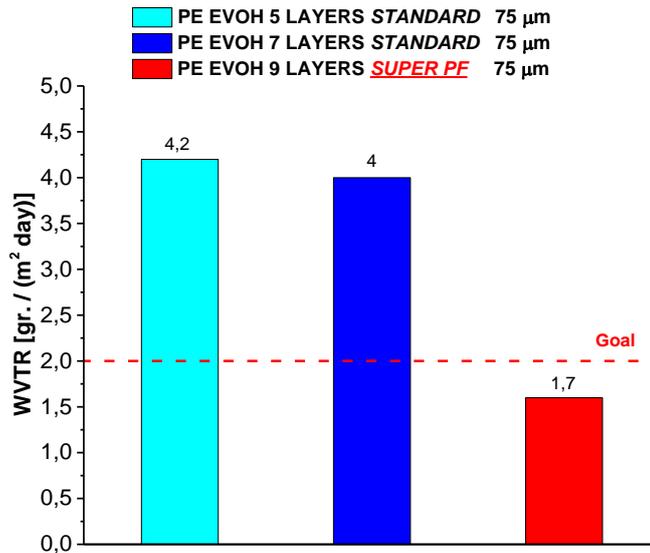


Fig. 7 – Water vapour transmission (WVTR)

The presence of layers that confer at film a good water vapour barrier give us also the possibility to investigate about the property of the film to protect EVOH layers from humidity because EVOH polymer is very sensitive to water and over 65% of relative humidity, his barrier falls like showed in the fig. 8 below.

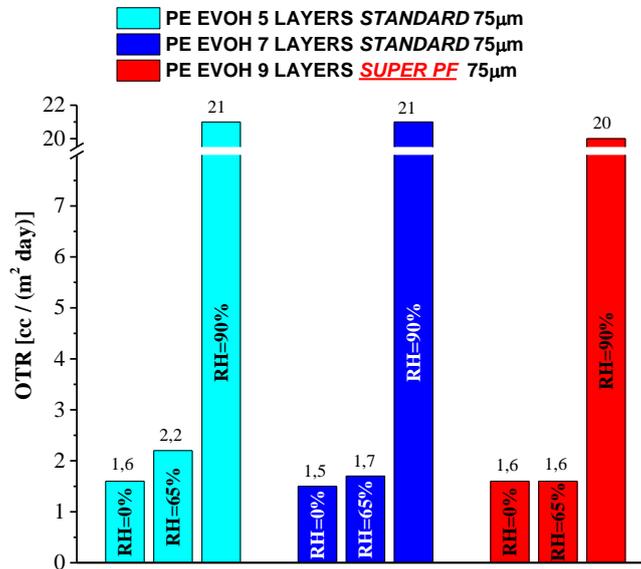


Fig. 8 – Oxygen barrier at different R.H. (relative humidity) conditions

We can say that the equilibrium values of oxygen barrier for all types of films show the same behavior at different R.H. and in particular, with drastic condition 90% R.H. The difference for these structures is the time to reach the equilibrium value. In fact, SUPER PF film shows a slower trend respect to others structures due at better capacity of the film to preserve EVOH from humidity . The graph (fig. 9) below show this kind of behavior.

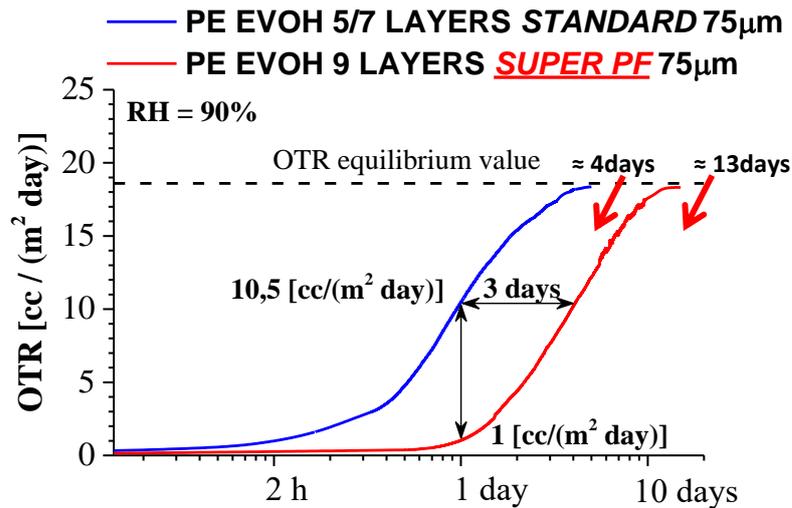


Fig. 9 – OTR versus time

## CONCLUSIONS

In conclusion, this study shows the possibility to obtain, thanks to the new nine layers technology, a new polyethylene based film with enhanced mechanical and barrier properties with more resistance at temperature. This permit to give at market that develop new food packaging a new possibility to change standard thickness in many applications reducing it up to 25% the total thickness of film to meet a reducing environmental impact. At the same time this kind of film could be suitable to give at Converter industry the possibility to simplify laminated structure (for exemple, triplex to duplex ) and in some case substitute Aluminium foil used in food packaging to confer barrier and machinability at packaging.