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Changes in compatibility, tack and viscoelastic properties of ethylene n-butyl acrylate (EBA) copolymer-pentaerythritol rosin ester blend by adding microcrystalline wax, Fischer-Tropsch wax and mixture of waxes

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Abstract

Ethylene n-butyl acrylate copolymer (EBA) instead of ethylene vinyl acetate copolymer (EVA) can be used as the base polymer for hot melts. The lower polarity of EBA should affect differently the compatibility with the wax and the tackifier as compared to EVA. In this study the compatibility, tack and viscoelastic properties of EBA copolymer-pentaerythritol rosin ester blended with waxes of different nature (Fischer-Tropsch and microcrystalline) and in different amounts were studied.

An increase in compatibility of EBA-copolymer blend with microcrystalline wax was produced leading to increased tack and open time, and reduced viscosity. In contrast, the addition of Fischer-Tropsch wax decreased the compatibility and tack of the EBA-copolymer blend. The addition of a mixture of microcrystalline and Fischer-Tropsch wax caused a better balance in the rheological properties and thermal stability of the EBA-copolymer blends. Finally, an increase in the wax mixture content produced a complete removal of tack caused by dilution of the tackifier in the polymer blend rather than by differences in compatibility.

Keywords: A. Hot melt ; C. Thermal analysis ; D. Tack ; D. Viscoelasticity.

1. INTRODUCTION

Hot melt adhesives (HMAs) are physical blends of polymers, tackifiers and waxes which are applied in the molten state at high temperature for producing instant joints upon cooling. Ethylene vinyl acetate copolymers (EVA) are the polymer types most commonly employed in hot melts because of their excellent balance in mechanical properties and versatile performance, but they have limited performance at low temperature. Because of the glass transition temperature (T_g) of ethylene n-butyl acrylate copolymer (EBA) is about -50°C (T_g of EVA is around -30°C), the limited performance of HMA at low temperature can be overcome by using EBA instead of EVA. Furthermore, EBA has lower density, elongation-at-break and tensile strength, and is slightly less polar than EVA [1] due to the existence of a longer hydrocarbon chain pendant group (C4 vs C2) and of the acrylate group (Figure 1) instead of the acetate group; therefore, differences in compatibility of EBA with tackifiers and waxes with respect to that of EVA can be anticipated.

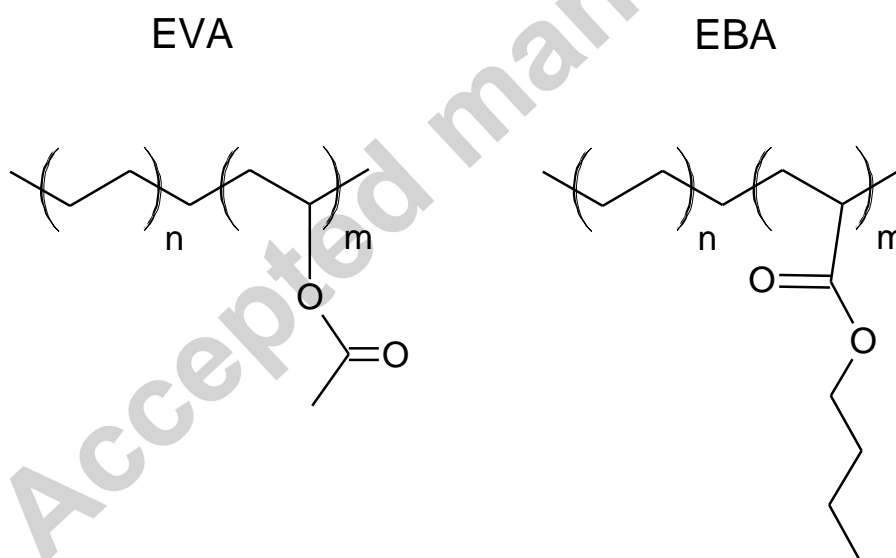


Figure 1. Chemical structure of EVA and EBA copolymers.

Waxes are added in EVA and EBA hot melt formulations for lowering viscosity and providing rapid setting and heat resistance [2]. Microcrystalline and Fisher-Tropsch waxes are the most commonly used in HMAs [2]. Microcrystalline (MC) waxes derived from petroleum contain, within their molecular structure,

important fractions of iso and cycloalkanes; as a consequence, microcrystalline waxes have low melting points and are flexible [3]. On the other hand, Fischer-Tropsch (FT) waxes are produced from gas synthesis, and show higher melting points and narrower molecular weight distribution than microcrystalline waxes [4].

The influence of adding wax on the compatibility, tack and viscoelastic properties of EBA-resin blends has not been sufficiently considered and most of the existing literature exists in patents. In the patent by Brady *et al.* [5] HMAs based on EBA, terpene phenolic tackifier and high melting synthetic wax intended for high speed, rapid automated cardboard case and carton sealing were proposed. These HMAs showed good adhesion to Kraft paper over a broad range of temperature (-18°C to 70°C) and excellent heat stability, having no variation in the viscosity values at 175°C for 72 hours. In contrast, similar EVA based formulations produced cloudy, poor flowing, and thermally less stable HMAs. Stauffer *et al.* [6] used EBA with low melt flow index, aliphatic or cycloaliphatic hydrocarbon resin and high melting synthetic wax, obtaining HMAs with low density. Liedermooy *et al.* [7] claimed that a mixture of EBA with melt index of at least 600, terpene phenolic resin and low melting point Fischer-Tropsch wax can be applied at relatively low temperature. In a later patent, Liedermooy *et al.* [8] proposed a combination of EBA with melt index of at least 850, rosin ester and microcrystalline or paraffin wax for producing HMAs that can be applied at relatively low temperature (170°C), having superior resistance to low temperature and good adhesion to difficult to bond substrates. Finally, Flanagan *et al.* [9] disclosed a HMA composition comprising EBA, tackifying resin, paraffin wax, and polyethylene wax for hard bound books characterized by its high flexibility.

The few studies in the existing literature analyzing the effect of adding tackifier and wax in HMAs based on EBA provided unclear conclusions. Wielinski *et al.* [1] studied the compatibility of EBA-wax binary blends by cloud point measurement using three EBAs with 35wt% of n-butyl acrylate co-monomer content but different melt indexes (40, 110 and 400 g/10min) and three waxes of different nature (paraffinic, microcrystalline and Fischer-Tropsch). They found that the compatibility did not depend on the melt flow index of the EBA but on the wax nature, and better compatibility was obtained with paraffinic wax,

followed by microcrystalline wax and Fischer-Tropsch wax. Simons *et al.* [10] analyzed the compatibility of binary and ternary blends of EBA/EVA blends, tackifiers of different nature and paraffinic wax, by using cloud point measurements and found that for incompatible tackifiers, the compatibility of the ternary blends depended on both the wax and the tackifier nature, whereas for relatively compatible tackifiers, the wax determined the compatibility. The influence of adding wax to EBA hot melt adhesives was also analyzed by Honiball *et al.* [11] who established that the wax structure, molecular mass, molecular mass distribution and crystallinity played a crucial role in the set time and properties at high temperature of the HMAs because of the compatibility with the wax.

In previous studies the compatibility of blends of polyethylene and EVA have been determined from cloud point and glass transition temperature obtained using differential scanning calorimetry (DSC) [12-14]. Although useful, these methods are not always sufficiently precise in assessing the compatibility mainly because the difficulty in defining precisely the glass transitions in HMAs from DSC thermograms [15]. Because the compatibility is strongly associated to the rheological and viscoelastic properties of blends of polyethylene and EVA, this criterion can be similarly applied to HMAs, and therefore in this study dynamic mechanical thermal analysis (DMTA) is proposed for studying the compatibility of EBA-tackifier blends with different waxes.

Therefore, the aim of this study is to analyze the influence of the wax nature and the mixture of waxes of different nature on the compatibility of a EBA-tackifier blend and its influence on the tack, rheological and viscoelastic properties.

2. EXPERIMENTAL

2.1. Materials

Ethylene n-butyl acrylate (EBA) copolymer containing 27wt% n-butyl acrylate (BA) (Alcudia PA27150, Repsol, Madrid, Spain) and pentaerythritol rosin ester (Lurefor 100, La Unión Resinera, Madrid, Spain) were used. Fischer-Tropsch wax - Sasolwax-H1 (Iberceras, Madrid, Spain) - and microcrystalline wax -

Ibercer 3080 (Iberceras, Madrid, Spain) - were blended with EBA and/or pentaerythritol rosin ester; 0.5wt% antioxidant (Irganox 1010, BASF, Kaisten, Switzerland) was added to all blends to avoid deterioration at high temperature during their preparation and characterization. The nomenclature and commercial names of the raw materials used in this study are given in Table 1 and some of their most relevant physico-chemical properties are included in Table 2.

Table 1. Nomenclature and commercial name of the raw materials used in this study.

Raw material	Nomenclature
EBA Alcudia PA27150	EBA
Lurefor 100	Tackifier
Sasolwax-H1	FT
Ibercer 3080	MC
Irganox 1010	Antiox.

Table 2. Some physico-chemical properties of the raw materials.

Property	EBA	Tackifier	FT	MC
Melt flow index (g/10 min)	150	-	-	-
Co-monomer content (wt%)	27	-	-	-
Melting point (°C)	76	-	96-100	75-85
Tg (DSC) (°C)	-50	57	-	-
Ring-ball softening point (°C)	100	99	-	-
Mettler softening point (°C)	133	112	113	85
Cloud Point (°C)	65	-	96	79

The ternary blends were prepared in a Pyrex glass beaker internally coated with aluminum foil placed on a hot plate. The hot plate was pre-heated at 90-120°C and the wax or wax mixture was added. Once the wax was melted, the temperature was increased to 130°C and then the tackifier and the antioxidant were added. Once a homogeneous mixture was obtained, EBA was added raising the temperature to 180°C allowing its melting, and afterwards, the Pyrex glass beaker was capped with three entrances glass plate which were connected to a nitrogen stream (to prevent oxidation), a thermometer (for controlling the temperature) and a stirrer connected to a Heidolph RZR-2000 stirring unit (Heidolph Instruments, Kelheim, Germany). The ternary blends

were stirred at 80 rpm and heated at 180°C for 1 hour; afterwards, the blends were allowed to cool to room temperature and removed from the glass beaker. The binary blends were prepared similarly to the ternary blends. The compositions of the binary and ternary EBA-based blends are given in Table 3.

Table 3. Compositions of the EBA-based blends.

Blend	Component (wt%)				
	EBA	Tackifier	FT	MC	Antiox.
BF	39.8	39.8	19.9	-	0.5
BM	39.8	39.8	-	19.9	0.5
BFM	39.8	39.8	12.1	7.8	0.5
BFM33	33.3	33.3	20.0	13.0	0.5
EBA/FT	76.2	-	23.3	-	0.5
EBA/MC	76.2	-	-	23.3	0.5
EBA/Resin	49.7	49.7	-	-	0.5

2.2. Experimental techniques

Brookfield viscosity. The viscosity of the blends and HMAs was measured in a Brookfield RD DV-I viscometer with Thermosel (Brookfield Engineering Laboratories Inc., Stoughton, MA 02072, USA) at 160 and 180°C by using a SC4-21 spindle. Viscosity was measured according ASTM D3236-88 by using 10g polymer blend and by varying the shear rate between 0.5 and 50 s⁻¹.

Rheological properties. The rheological properties of the blends and HMAs were measured in a Bohlin CS-50 plate-plate rheometer (Bohlin Instruments Ltd., Gloucestershire, UK), using an upper plate of 20 mm diameter, a temperature range between 200 and 30°C, a cooling rate of 5°C/min, an oscillation frequency of 1 Hz and 0.005% strain.

Tack measurement. The tack of the blends and HMAs were measured in a Texture Analyzer TA.XT2i (Stable Microsystems, Surrey, UK) by using modified probe tack test. Tack was measured between 30 and 200°C using a stainless steel flat cylindrical probe of 3 mm diameter. Samples were prepared by heating at 180°C 2g of sample over a stainless steel plate (7x7x0.01 cm) and pressing

at 1 kg/cm² for 10 seconds in a hot-plate press, followed by cooling to room temperature. Homogeneous films of 1mm thick were obtained.

Softening point. For assessing the compatibility of the blends and HMAs [16], the softening points were measured in a Mettler Toledo FP900 Thermosystem calorimeter (Schwerzenbach Mettler Toledo GmbH, Germany) using an FP83 dropping point cell. Samples were prepared according ASTM D3104 using a cup-shaped sample holder of 6.35 mm diameter.

Cloud point. For assessing the compatibility of the blends and HMAs, the cloud point was also determined by heating about 1g of sample to 120°C and immersing the bulb of an ASTM 2C thermometer. The temperature at which the molten adhesive started to become cloudy was taken as the cloud point.

Dynamic mechanical thermal analysis (DMTA). The viscoelastic properties and compatibility of the blends and HMAs were measured in a TA Q800 dynamic mechanical thermal analyzer (TA Instruments, Lukens Drive, New Castle, UK) by using two points bending geometry (single cantilever). The amplitude of deformation was 64 microns and the temperature was varied from -80°C to 90°C using a heating rate of 5°C/min. 2.5g of sample was heated at 130°C on a rectangular aluminum mould (7.2x2.7x0.1 cm). After cooling, a film about 0.1cm thick was obtained which was removed from the aluminum mould and cut into pieces (3.5x1.3 cm) for DMTA analysis.

3. RESULTS AND DISCUSSION

3.1. Addition of wax of different nature and mixture of waxes in EBA-tackifier blends

Figure 2 shows the variation of the Brookfield viscosity at 160°C as a function of shear rate for the mixtures of EBA copolymer-pentaerythritol rosin ester blend and microcrystalline wax only (BM), Fischer-Tropsch wax only (BF), and mixture of microcrystalline and Fischer-Tropsch wax (BFM). The highest viscosity

corresponds to the blend with MC wax (BM) followed by the one with FT wax (BF). Shear thinning appears in both BM and BF blends, more markedly in BM, indicating the existence of physical interactions between the components which are weakened by increasing the shear rate. Molecular weight, molecular weight distribution, branching and crosslinking affect the viscosity of the polymer blends. FT wax has a linear structure, narrower molecular weight distribution and lower molecular weight than MC wax, which is highly branched, thus contributing to lowering the viscosity in the MC blend [17]. Surprisingly, the viscosity of the EBA-tackifier blend with the mixture of microcrystalline and FT waxes (BFM) is lower than for BM and BF (they contain one wax only), and shear thinning is almost absent, indicating a change in the miscibility between the components of the blend when two waxes of different nature are added.

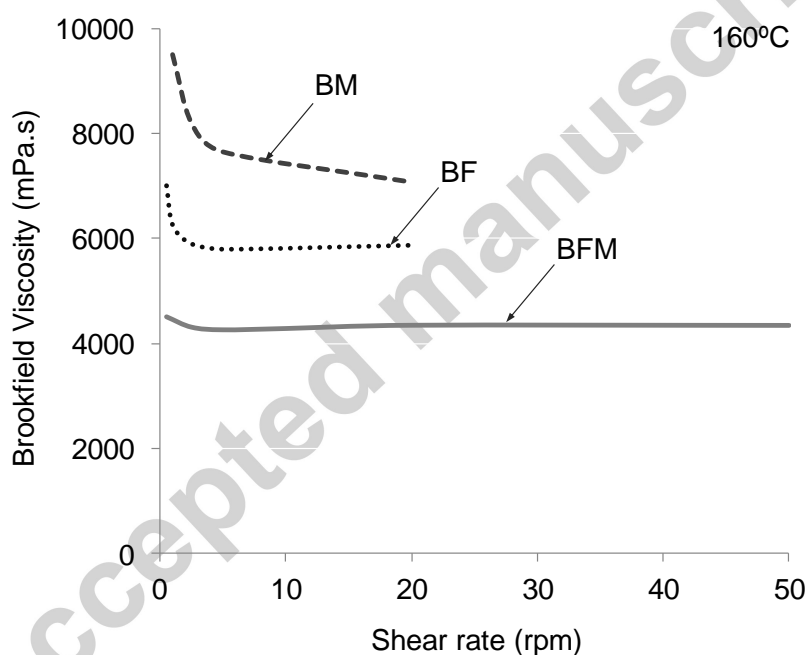


Figure 2. Variation of the Brookfield viscosity at 160°C of the ternary blends as a function of the shear rate.

Figure 3a shows the variation of the storage modulus of the ternary blends containing the different waxes. At high temperature the storage modulus is low and by decreasing the temperature a sudden increase in storage modulus is produced due to the solidification of the blends; once the blend is fully solidified,

the storage modulus is high (above 10^6 Pa). BM blend shows the lowest storage moduli values at all temperatures among all ternary blends and the important increase in storage modulus is produced near 80°C ; this increase is found at higher temperature in BF and BFM blends likely due to the lower melting point of the MC wax with respect to FT wax. On the other hand, BF blend shows higher storage moduli values than BM blends throughout the temperature range because of the linear structure of the FT wax which should favour the creation of physical interactions with the ethylene domains of EBA. The BFM blend containing a mixture of waxes shows the highest storage modulus and the highest loss modulus at high temperature (Figure 3b) with respect to the ternary blends made with MC or FT wax only, an unexpected behavior which shows the existence of synergy between the mixture of waxes and the rest of the components of the formulation in the molten state. Furthermore, the sudden increase in storage modulus in BFM is produced at a temperature closer to that of the BF blend although the increase is less sudden.

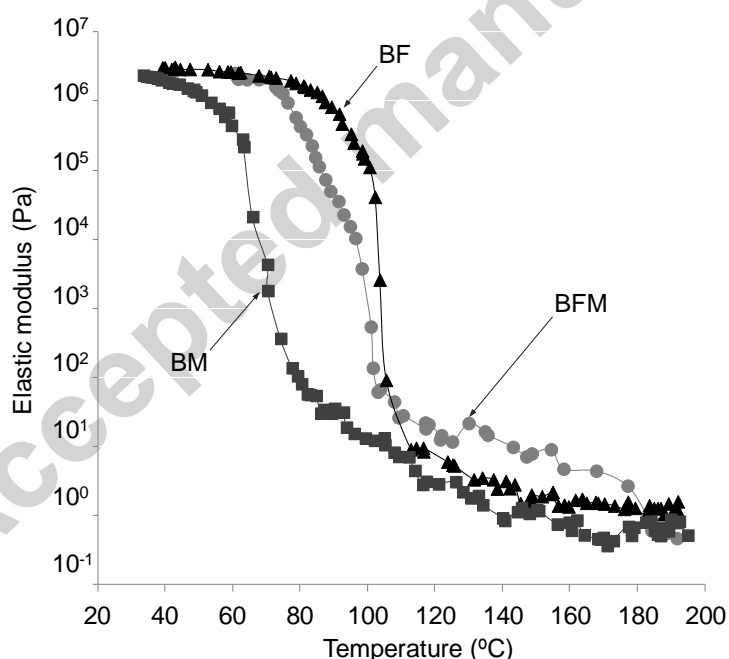


Figure 3a. Variation of the elastic modulus (G') of the ternary blends as a function of the temperature. Plate-plate rheometry.

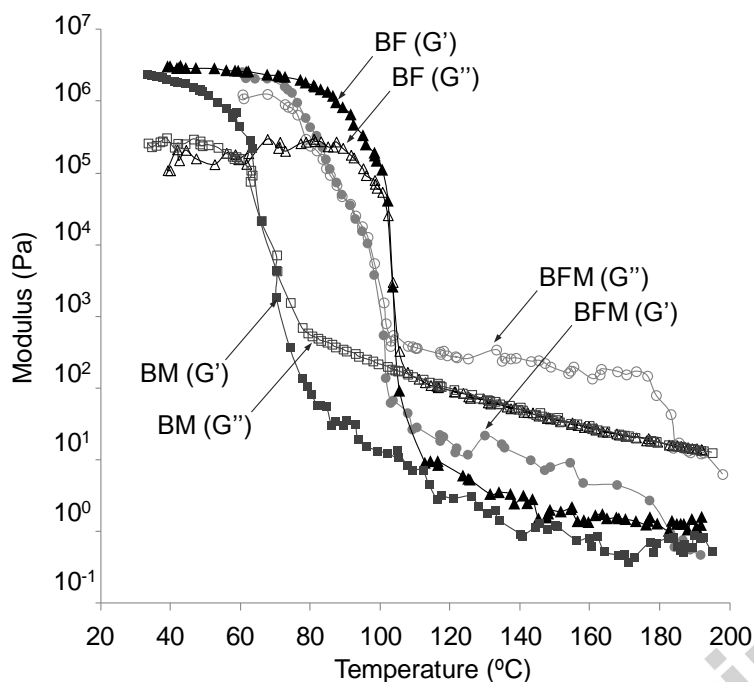


Figure 3b. Variation of the storage (G') and loss (G'') modulus of the ternary blends as a function of the temperature. Closed symbols: Storage modulus; Open symbols: Loss modulus. Plate-plate rheology experiments.

All ternary blends show a cross-over between the storage and loss modulus (Figure 3b). In practice, this cross-over zone (ΔG_c) defines the region in which the ternary blend can be used as a HMA (particularly the set time) and, in order to withstand the stresses in the adhesive joints during formation, it is desirable that an increase in modulus in a shorter temperature range (ΔT_c) be produced. On the other hand, the temperature at the cross-over between the storage and loss modulus correlates well with the open time of the HMA, i.e. the time after applying HMA during which it can flow and wet-out the substrate on which it is applied [18]. Table 4 shows that the cross-over temperature (T_c) is higher in BF blend, followed by BFM, resulting in a shorter open time for BF. The modulus at the cross-over is higher in the ternary blend containing the mixture of waxes. On the other hand, the ternary blend with the mixture of waxes shows the highest ΔG_c range too, although it is produced over a greater temperature interval than for the other blends (Table 4). The crystallinity of the waxes and the temperature at which crystallization sets, which is a function of the melting point of the wax, dominates the rheological behavior of the blends. MC wax is highly branched, preventing the formation of large crystals, and has a lower melting

point than FT wax, and therefore the addition of MC shifts the cross-over modulus to a lower temperature which is produced in a shorter moduli range. However, the addition of the FT wax causes a slight increase in the temperature at the cross-over of the EBA-resin blend than by using the mixture of waxes, and the modulus increment in the cross-over region is produced faster. On the other hand, the differences between the storage and loss modulus at low temperature are more important in the ternary blends containing one wax only than in the blend with a mixture of waxes, indicating a synergistic behaviour between the two waxes.

Table 4. Some results obtained from the plate-plate rheometry experiments of the ternary blends.

Ternary blend	T_c (°C)	G_c (kPa)	ΔT_c (°C)	ΔG_c (Pa)
BF	104	3	36	1990
BM	66	22	31	1542
BFM	91	37	40	2060

Tack in HMA is imparted by the tackifier and its value depends strongly on the miscibility with the other components in the formulation [2]. Figure 4 confirms that the nature of the wax modifies the tack of the EBA-resin blend. The highest tack corresponds to BM although it is produced at a lower temperature than in the other ternary blends and, furthermore, the tack is maintained over a relatively short temperature interval (Table 5). When FT wax is added to the EBA-resin blend, the tack is relatively small and is produced above 70°C only. On the other hand, in BFM, the tack is high and the temperature interval upon which high tack is maintained is greater.

The value of tack of the HMAs is controlled by the compatibility between their components. In this study the compatibility of the ternary blends was assessed by softening point, cloud point and DMTA measurements.

The compatibility of the EBA-resin-wax blend is largely controlled by the degree of crystallinity of the wax and the temperature at which its crystallization sets [9]. The crystallization of the wax depends on its melting point which is higher for the FT wax (96-100°C) than for the MC wax (75-85°C). Therefore, it can be anticipated that the softening point should be higher for BF and lower for BM,

while the EBA-resin blend with the mixture of waxes presents an intermediate softening point (Table 6). Similarly, the cloud point values show that the higher compatibility, i.e. lower cloud point, corresponds to BM followed by BFM (Table 6), and therefore the most incompatible blend is BF. These results are in agreement with the plate-plate rheological experiments and the variation in tack as the most incompatible ternary blend BF shows the lowest tack and this ternary blend also shows the lowest temperature and modulus at the cross-over between the storage and loss modulus (Table 4).

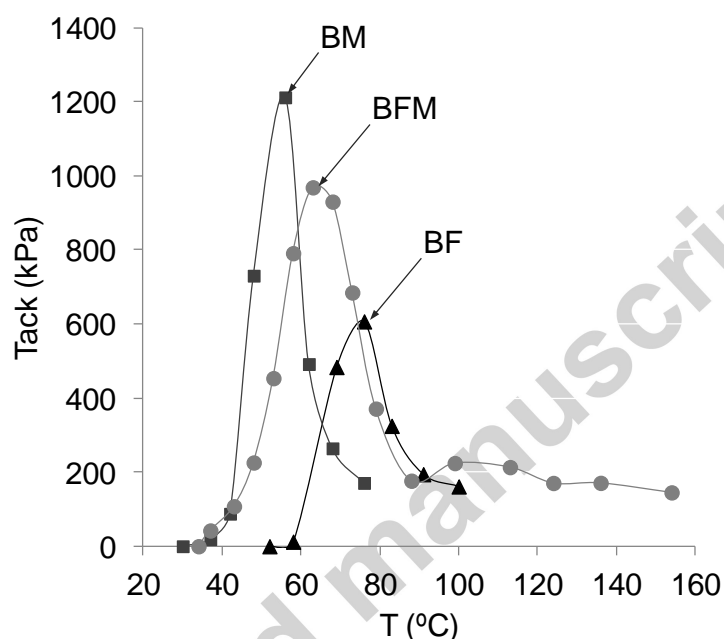


Figure 4. Variation of tack as a function of the temperature for the ternary blends.

Table 5. Temperature and maximum value of tack of the ternary blends.

Ternary blend	Tack (kPa)	$T_{\max \text{ tack}}$ (°C)
BF	607	76
BM	1212	56
BFM	969	63

Table 6. Softening point and cloud point values of the raw materials and ternary blends.

Raw material/Blend	Softening point (°C)	Cloud point (°C)
EBA	133	65
Tackifier	112	-
FT	113	96
MC	85	78
BF	115	94
BM	86	75

The compatibility of the ternary blends was also studied by DMTA. Most polymer blends show one α -transition at high temperature (due to cooperative molecular movement) and one β -relaxation at low temperature (due to the movement of short chain segments) [12-14]. If the components in a polymer blend are miscible, one single structural relaxation should appear. On the contrary, immiscible blends show separate phases corresponding to separate structural relaxations. Furthermore, the closer are the relaxations of each phase to the relaxations of the pure components, the lower is the compatibility of the blend. Figure 5a shows the variation of tan delta as a function of temperature for several binary blends, i.e. EBA-tackifier, EBA-FT and EBA-MC. EBA copolymer is highly compatible with pentaerythritol rosin ester as only one relaxation is found. The compatibility of EBA copolymer with the MC and FT waxes is lower than for the tackifier as two relaxations appear; further, the FT wax is more incompatible than MC with EBA copolymer (Table 7). On the other hand, the tan delta value is related to the degree of interaction between the components in a polymer blend, i.e. the lower the tan delta value, the higher the interaction between the components, and therefore, lower tan δ value indicates better cohesion but less flexibility in the polymer blend [19]. Thus, the lowest values of tan delta ($=G''/G'$) corresponds to EBA-FT, indicating higher cohesion than in the other binary blends. The higher cohesion can be related to the linear structure of the FT wax which is also related to its high melting point. As the tackifier (pentaerythritol rosin ester) is compatible with the EBA copolymer, the compatibility of the EBA-resin-wax blend should be determined by the nature of the wax. Figure 5b and Table 7 shows that the ternary blend with MC wax is the most compatible, followed by the ternary blend with the mixture of waxes; the ternary blend with FT wax is the most incompatible. This trend is in agreement with the one shown by the cloud points. Furthermore, the tan delta values in BF and BFM blends are very similar and lower than for the BM.

According to Tables 5 and 7 the cohesion is lower and the tack is higher when the compatibility of the blend increases. Therefore, the tack of the blends seems to be more sensitive to the dilution of the tackifier in the blend than to its cohesive strength. The compatibility increases and the cross-over modulus

shifts to lower temperature when the softening point of the blend decreases. Since the softening point of the blends depends mainly on the softening point and the crystallinity of the wax, it can be concluded that in the compatible EBA-resin blend, the addition of a high crystalline wax (i.e. Fischer-Tropsch wax) decreases more the compatibility than by adding a low crystalline wax (microcrystalline wax), and, at the same time, the open time is also reduced.

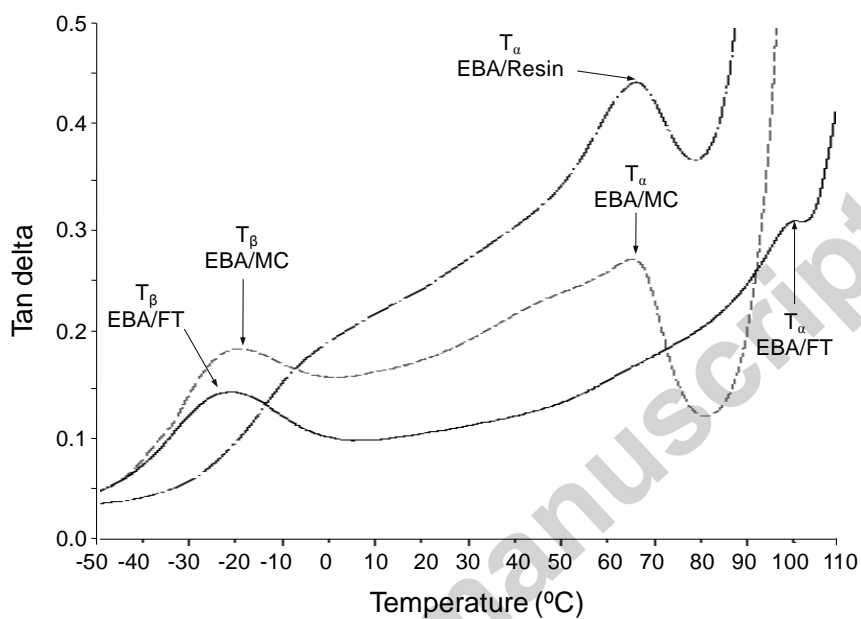


Figure 5a. Variation of tan delta as function of the temperature for the binary blends. DMTA experiments.

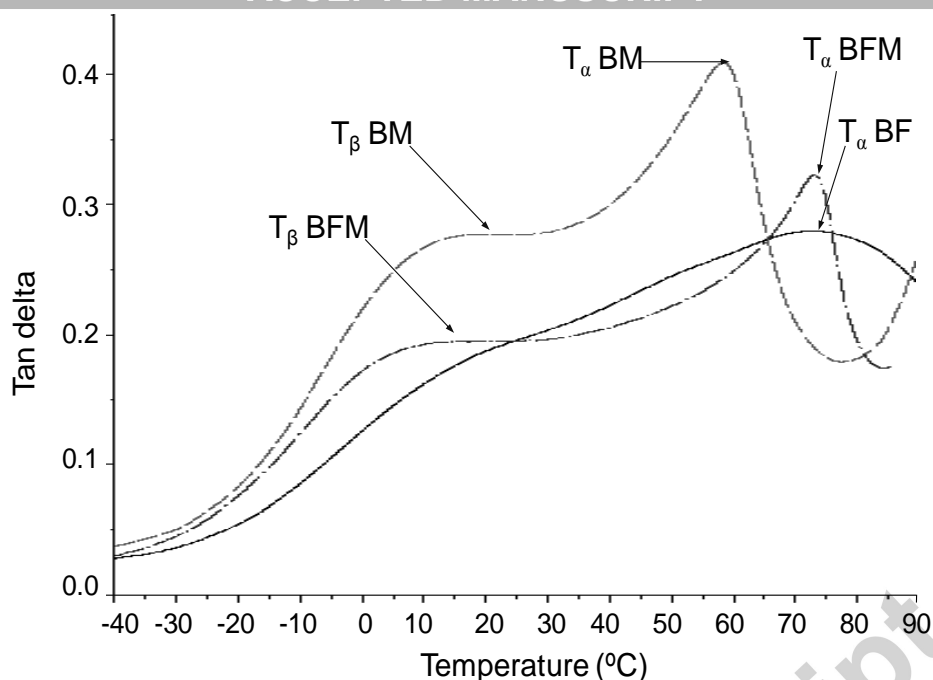


Figure 5b. Variation of tan delta as function of the temperature for the ternary blends. DMTA experiments.

Table 7. Temperature and maximum tan delta values of the binary and ternary blends. DMTA experiments.

Blend	T_{β} (°C)	$\text{Tan } \delta_{\beta}$	T_{α} (°C)	$\text{Tan } \delta_{\alpha}$
BF	-	-	73	0.28
BM	19	0.28	59	0.41
BFM	14	0.19	73	0.32
EBA/MC	-19	0.18	66	0.27
EBA/FT	-23	0.14	99	0.31
EBA/Resin	-	-	66	0.44

3.2. Addition of different amount of mixture of Fischer-Tropsch and microcrystalline waxes to EBA-tackifier blend

The influence of the amount of the mixture of FT and MC (FT+MC) waxes added to the EBA-tackifier blend was studied. According to Figure 6, an increase in the amount of FT+MC waxes from 19.9wt% (BFM) to 33.3wt% (BFM33) reduces the viscosity of the HMAs at 160 and 180°C, as expected. Shear thinning is observed at 160°C only and it is more marked when the amount of FT+MC waxes in the HMA increases.

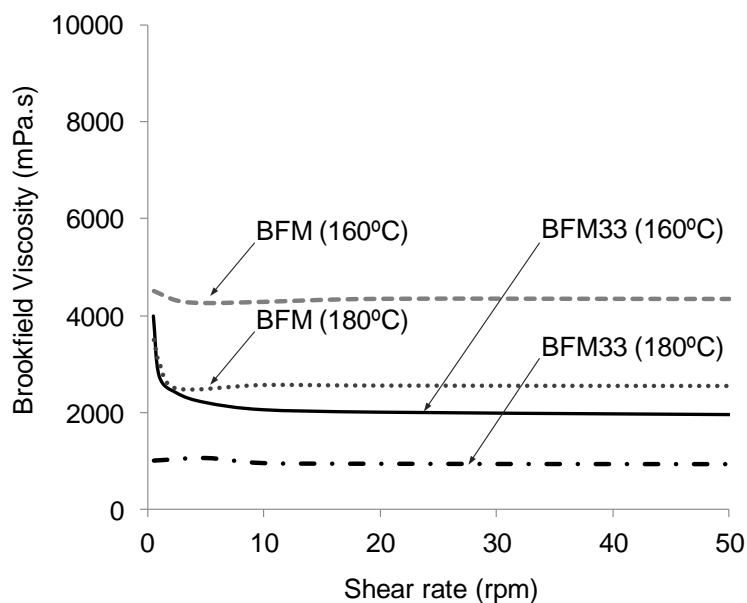


Figure 6. Brookfield viscosity at 160°C and 180°C of the EBA-tackifier blend with different amount of FT+MC waxes as a function of the shear rate.

The increase in the amount of FT+MC waxes should increase the crystalline fraction of the EBA-tackifier blend because the content of FT wax in the formulation is higher. Therefore, it can be anticipated that the cross-over of the storage and loss modulus in BFM33 should shift to higher temperature and the increase of the modulus should occur over a shorter temperature interval (Figure 7 and Table 8). The difference between the storage and loss modulus at low temperature increases by increasing the content of FT+MC waxes in the EBA-tackifier blend. On the other hand, the different rheological behavior of the HMAs containing different amounts of FT+MC waxes can be related to the higher content in FT wax and, therefore, to differences in compatibility.

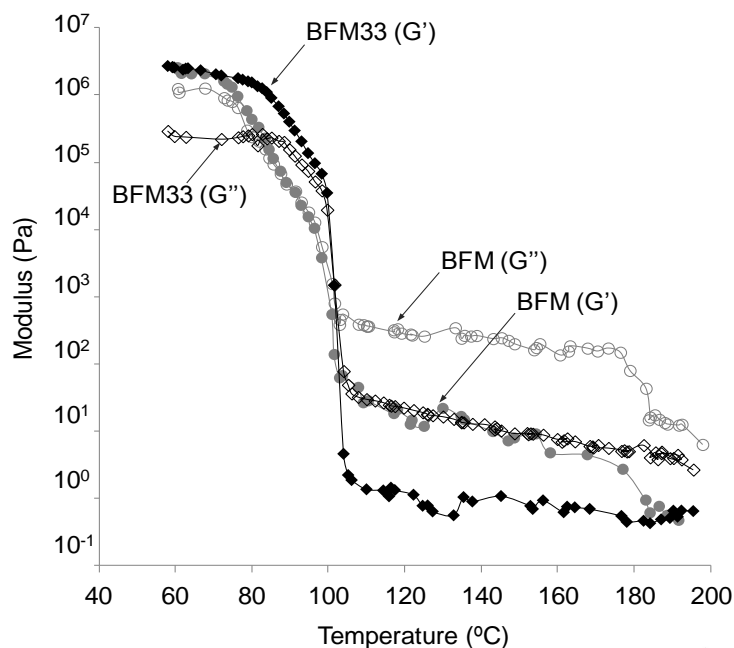


Figure 7. Variation of the storage (G') and loss (G'') modulus of the EBA-tackifier blend with different amount of FT+MC waxes as a function of the temperature. Plate-plate rheometry experiment.

Table 8. Some results obtained from the plate-plate rheometry experiments of the EBA-tackifier blend with different amount of FT+MC waxes.

Ternary blend	T_c (°C)	G_c (kPa)	ΔT_c (°C)	$\Delta G'_c$ (Pa)
BFM33	102	1	25	1540
BFM	91	37	40	2060

Figure 8 shows the variation of tack as a function of temperature for BFM and BFM33. The increase in the amount of FT+MC waxes reduces drastically the tack of the HMA because of the increase in the FT wax content in the mixture which may be due to differences in compatibility.

The compatibility of the EBA-tackifier blend with different amounts of FT+MC waxes measured by the softening and cloud point is slightly lower by increasing the amount of FT+MC waxes (Table 9), indicating that the reduction in tack is not strongly affected by the compatibility of the blend but to the dilution of the tackifier when 33.3wt% of the mixture of waxes is added. Similarly, the variation of tan delta as a function of temperature (Figure 9) indicates that the temperature of the two maxima in tan delta are displaced slightly to higher temperatures and the tan delta values decrease by increasing the amount of FT+MC waxes, indicating slight differences in compatibility. Relatively similar

cohesive strength of the blends with different amounts of FT+MC waxes is obtained, supporting the important influence of the dilution of the tackifier on the tack of the HMA.

Table 9. Softening point and cloud point of the EBA-tackifier blend with different amount of FT+MC waxes.

Ternary blend	Softening point (°C)	Cloud point (°C)
BFM33	111	93
BFM	108	89

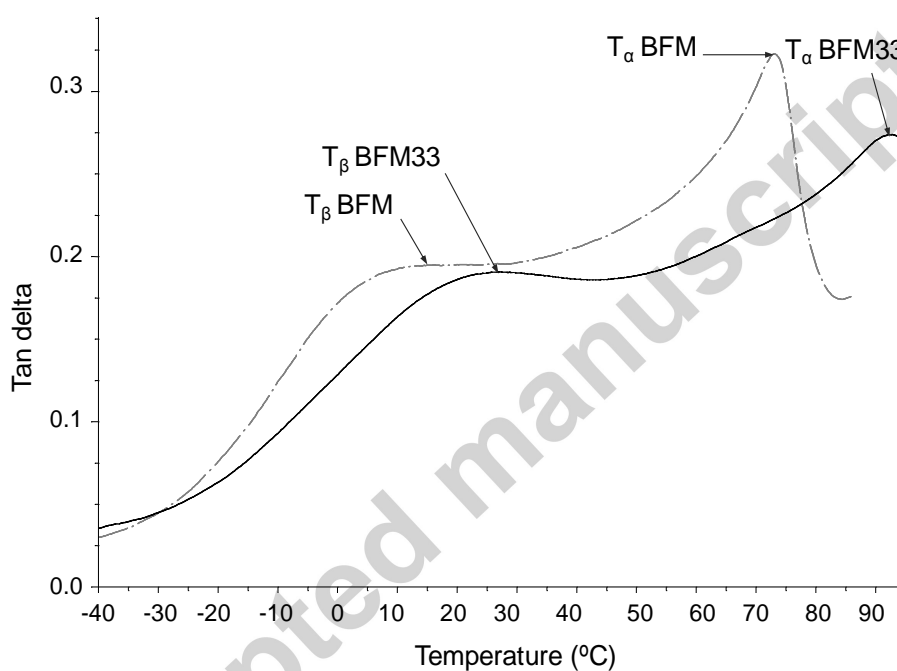


Figure 8. Variation of tan delta as a function of the temperature for the EBA-tackifier blend with different amount of FT+MC waxes. DTMA experiments.

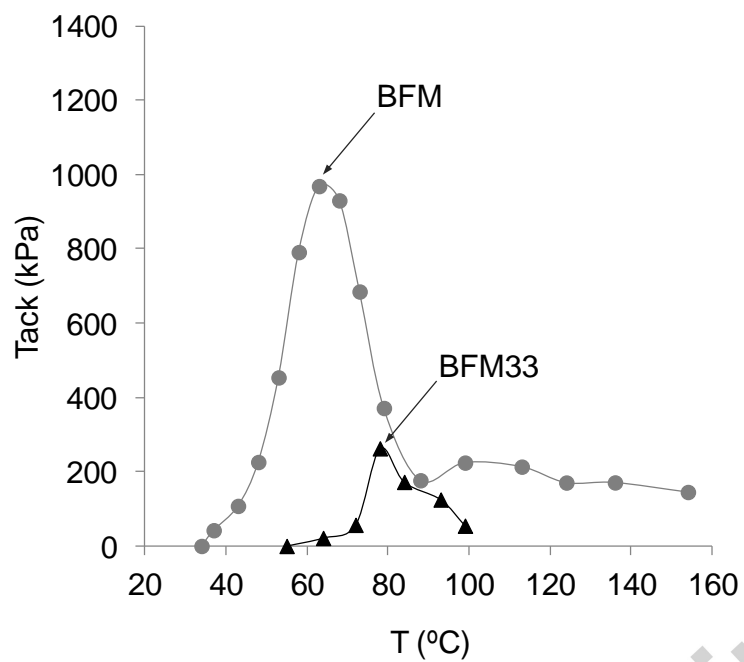


Figure 9. Variation of tack as a function of the temperature for the EBA-tackifier blend with different amount of FT+MC waxes.

4. CONCLUSIONS

The influence of the compatibility on the properties of EBA-tackifier-wax blends depended on the wax content. For a content of 33.3wt% of MC and FT wax mixture, the properties of the ternary blends depended more on the extent of dilution of the tackifier than on the compatibility. In the EBA-tackifier-wax blends with 19.9wt% wax, their properties and compatibility were determined by the nature of the wax and the addition of single or mixtures of waxes. The ternary blend was more compatible, more flexible and showed higher tack when microcrystalline wax was added, but it had lower cohesion and higher viscosity at 160°C. In contrast, by adding Fischer-Tropsch wax the compatibility, tack and flexibility of the ternary blend decreased. The addition of microcrystalline and Fischer-Tropsch mixture caused unexpected behavior in the ternary blends because lower viscosity, higher storage modulus and higher loss modulus at high temperature were found; furthermore, higher tack was maintained over a broader temperature interval. Finally, the usefulness of DMTA for determining the compatibility of binary and ternary blends of EBA has been shown.

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