



Understanding the Mechanical Properties of Polymer Blends in the Presence of Plasticizers and Other Additives

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Received: 15-12-2018; Revised: 20-01-2019; Accepted: 05-02-2019.

ABSTRACT

This work describes the evaluation of the fundamental mechanical properties of casted films of polymer blends containing plasticizer and other additives. The ultimate tensile properties of the films are depending on both type and concentration of plasticizer and other additives. The mechanical property data can be used to explain physicochemical interaction between polymer blends with plasticizer and additives.

Keywords: Polyvinyl Alcohol, PVA-PEG Graft Copolymer, HPMC, HPC, Mechanical Property, Tensile Strength, Young's Modulus.

INTRODUCTION

Polymers have been used in pharmaceutical formulations for several reasons including protection of the dosage form against environmental conditions and for hiding a bad taste, odor or appearance. The evaluation of mechanical properties of polymeric films for the development of film coating system, provides an essential information to verbalizing their performance in pharmaceutical dosage forms and it helps the pharmaceutical scientist to predict the stability and drug-release properties of film coated solid dosage forms.¹

The mechanical properties of the polymers determine its response to stresses and hence its resistance to rupture. The most commonly measured mechanical properties are elucidated in terms of glass transition temperature (T_g), tensile strength, toughness, Young's modulus, minimum film forming temperature (MFT), moisture effect and plasticizer performance. Ideally, increasing the tensile strength of the coating reduces the risk of cracking and reducing the elastic modulus decreases the potential of occurrence of bridging and cracking.²⁻⁶

Commercial film coating system does not consist of polymer alone but also contains other ingredients such as plasticizers, pigments and anti-adherents for a specific reason, either to assist processing or to improve performance and appearance. Addition of such other ingredients can affect the mechanical properties of the film coatings causing a decrease in their tensile strength and an increase in their modulus of elasticity thus affecting their performance in suit on the tablet surface.⁷ Plasticizers are added to reduce the brittleness, improve flow, and improve flexibility of polymeric chains.⁸⁻⁹ In addition, they will also increase toughness and strength of polymeric films, lower the glass transition temperature, decreasing internal stress and enhance the coalescence of the colloidal polymeric particles to form a uniform

homogenous film over the substrate.¹⁰ The mechanism of action for a plasticizer is for the plasticizer molecules to interpose themselves between the individual polymer strands thus breaking down polymer-polymer interactions. This action is facilitated as the polymer-plasticizer interaction which is stronger than the polymer-polymer interaction.¹¹⁻¹² Plasticizer must be able to diffuse into and interact with the polymer and have minimal tendency for migration or exudation from the polymer to be effective. Generally, the addition of plasticizer increases the ductility of the film, but this is often accompanied by a reduction in its tensile strength and modulus of elasticity. The addition of plasticizer, therefore, results in soft, tough film. Excessive addition of plasticizers may cause tablet tacking, plasticizer bleeding, color depletion or interaction with active ingredients and may significantly affect drug release.¹³⁻¹⁴

The addition of pigments into a coating formulation may improve the esthetic appearance of the final product.¹⁵ Pigments fall into three main categories; synthetic water-soluble organic dyes, insoluble aluminum and inorganic pigments. The influence of aluminum lakes and inorganic pigments on the properties of films is generally very different to that of plasticizers and significantly affecting the physical, mechanical, adhesive, and drug-release properties of the films.¹⁶⁻¹⁸ At a specific concentration, known as the critical pigment volume concentration (CPVC), the polymer present is insufficient to surround all the insoluble particles, and marked changes in the mechanical properties of the film will occur.¹⁹ The amount of insoluble filler incorporated in aqueous dispersion must be optimized without exceeding CPVC. Evidently, increase in concentration of pigment has shown the cellulosic films to become more brittle.²⁰

Water insoluble anti-adherents such as talc and glyceryl monostearate (GMS) are most commonly used in film coating formulations and they have been shown to



influence the mechanical and drug-release properties.²¹⁻²⁵ However, when water soluble additives such as lactose, sodium lauryl sulfate are also added in aqueous coating formulations, their inclusion resulted in a reduction of the tensile strength of all the films tested; indeed, some films became too brittle to test.²⁶ The effects of additives in coating formulations were dependent on the balance between their influence on the internal stress of film coating and the strength of the film-tablet interface.²⁷ Titanium dioxide, may be used in coatings to protect photosensitive drugs from exposure to light, thus improving product stability.²⁸ But, addition of titanium dioxide to polyvinyl alcohol also resulted in a decrease in tensile strength.²⁹

In this paper an attempt has been made to correlate the mechanical properties of casted films. The mechanical properties were observed for:

- (i) Polymer blends with plasticizer
- (ii) Polymer blends with plasticizer and additives

The results of these studies have generally been interpreted in terms of the physicochemical interaction between polymer blends with plasticizer and additives.

MATERIALS AND METHODS

The polymers and plasticizers were used in this study are Poly (vinyl alcohol) (PVA; Manufacturer: Nippon Gohsei (Gohsenol GL-05FS), Lot No.: 64M52T, Viscosity: 5.3 cP), Polyvinyl alcohol - Polyethylene glycol graft copolymer (PVA-PEG; Manufacturer: BASF (Kollicoat IR), Lot No.: 38230468E0, Viscosity: 120 cP), Hydroxypropyl cellulose (HPC; Manufacturer: Ashland Lot No.: 4673, Viscosity: 80 cP for 5% aqueous solution), Hydroxypropyl methylcellulose (HPMC 6cP; Manufacturer: DOW [Methocel E6 Premium LV], Lot No.: D011G4CL02, Viscosity: 5.9 cP for 2% aqueous solution), PEG 400 (Manufacturer: Clariant International, Lot No: DEG4401829), PEG 3350 (Manufacturer: Clariant International, Lot No: DEA4006020), Medium chain triglycerides (MCT; Manufacturer: IOI Oleochemical, Lot No: 141129-6), Triethyl citrate (TEC; Manufacturer: Vertellus, Lot No: 0000157958). Additives used in this study are titanium dioxide (TiO₂; Manufacturer: Brentag Specialties, Lot No: 0001161) and talc (Manufacturer: Luzenac, Lot No: S.180/18).

Plasticizers were selected in this study based on their solubility in water; PEG is soluble in water, TEC is slightly soluble in water whereas MCT is practically insoluble in water. The polymers selected in this study are water soluble, having different chemistry, hence, its interaction (physical) with plasticizers must be different in the presence of water insoluble additives (TiO₂ and Talc).

Preparation of polymer blends

- i) Polymer blends with plasticizer

Polymer blends were prepared by mixing in domestic blender (Robot coupe; R4 V.V; UK) at 90:10 ratio (PVA:

PVA-PEG; HPMC 6cP: PVA-PEG and PVA: HPC) followed by addition plasticizer (PEG 400, PEG 3350, TEC and MCT) at 10%, 15% and 20% (concentration with respect to total quantity of polymer). Separate polymer blends were prepared for each plasticizer and concentration level, therefore there are total 36 polymer blends.

- ii) Polymer blends with plasticizer and additives

Polymer blends were prepared by mixing in domestic blender (Robot coupe; R4 V.V; UK) at 90:10 ratio followed by addition of additives at different ratios (Polymer: diluent ratio; 20:80, 30:70, 40:60, 50:50, 60:40 ratio respectively) and plasticizer. PEG 3350 was used as a plasticizer at different concentration level with respect to polymer blends to additives ratio as given in below Table 1. All polymer blends have similar quantity of PEG 3350 with respect to total quantity of polymers.

Film casting and evaluation of mechanical properties

For “polymer blends with plasticizer”, the solution of polymer blends was prepared in purified water at 20% solids (PVA: PVA-PEG) and 15% solids (HPMC 6cP: PVA-PEG and PVA: HPC). In case of “polymer blends with plasticizer and additives” the solution of all polymer blends was prepared in purified water at 20% solids. Films of these solutions were casted at an approximate thickness of 100 μ on glass plates with the help of a film casting knife. Casted films were allowed to dry overnight at room conditions (~ 22°C ±2°C, 50% RH ± 2% RH). The films were cut into pieces of uniform shape (75 mm x 10 mm) with the help of Dogbone cutter (RR/HCP, Ray-Ran Test Equipment, UK). Tensile strength of these casted film pieces was determined using Tensile strength tester (5942, Instron, UK) equipped with Bluehill 3 software. A total of 10 films under each combination were evaluated for its mechanical properties.

RESULTS AND DISCUSSION

- i) Polymer blends with plasticizer

It has been reported that the selection of plasticizers in coating formulation has distinct effect on the mechanical properties of the polymeric films in aqueous dispersion.³⁰ In present study showed that, both type of plasticizer and its concentration have an impact on result of mechanical properties (modulus of elasticity, tensile strength) of casted films. The modulus of elasticity is a measure of the stiffness and rigidity of the film. The tensile strength data of different polymer blends with respective concentration of plasticizers are presented in below Table 2, 3 and 4. In case of PEG 400 as a plasticizer, all polymer blend PVA: PVA-PEG, HPMC 6cP: PVAPEG and PVA: HPC at 90:10 ratio showed gradual decrease in Young's Modulus, tensile stress at max load as the concentration of plasticizer increases in the blend, whereas extension at break increases as the concentration of plasticizer increases in polymer blend. In the similar line, there was significant difference in Young's modulus value and extension at break in PEG 400 plasticized polymers blends as



compared to that of polymer blends formulated without plasticizer. This increased extension at break caused by addition of plasticizer was explained by the increase in chain mobility in the presence of plasticizer. Increasing plasticizer content led to an increase in percent elongation and a reduction in strength.³¹⁻³³ The above finding indicates that, the introduction of PEG 400 as a plasticizer to the polymer blends promoted increase in viscoelastic behavior of the polymers which resulted in films were more soft and tough. A soft and tough film will possess a low tensile strength but much greater elongation and a higher area under the curve (toughness).³⁴

However, opposite scenario was observed with PEG 3350 plasticized films. The polymers blends showed gradual increase in Young's modulus and decrease in extension at break. There was increase in extension at break when the plasticizer was included in the film at the 10% and 15% level. No further increase was found in the extension as the plasticizer increased from 15% to 20%. Similarly, Young's modulus decreases at 10% plasticizer level and further there was slight increase in Young's modulus at 15% plasticizer level. Although, there was significant difference in Young's modulus value and extension at break for the PEG 3350 plasticized polymers bends as compared to that non-plasticized polymer blend. This is mainly due to the plasticizing efficiency of polyethylene glycols decreases with increasing molecular weight. The high-molecular-weight solid PEG additives exhibited

phase separation.¹¹ Similar effects were reported by Aulton with the inclusion of PEGs. Plasticization efficiency increased with decreasing PEG molecular weight and possibly due to the greater number of plasticizer molecule available to interact with the polymer.³⁵ Rowe reported decrease in elasticity of polymeric film with increasing molecular weight grade of PEG, this was mainly attributed to decrease in mole fraction of the hydroxyl groups.³⁶

In case of MCT and TEC as a plasticizer polymer blend PVA: PVA-PEG, HPMC 6cP: PVAPEG showed decrease in Young's modulus and increase in extension at break as compared to that of polymer blends formulated without plasticizer. However, in case of polymer blends PVA: HPC showed leaching of plasticizers (for both MCT and TEC) from the polymeric films as well as some kind of phase separation of polymers were also observed. The leaching was quite rapid from the casted films and increased with increasing level plasticizers. Although casted films of polymer blends (PVA: HPC; 90:10) with inclusion of plasticizers (MCT and TEC) at 10%, 15% and 20% concentration were successfully formulated, however, stain of liquid plasticizer (MCT and TEC) as well as separation of polymers were visually observed on the surface of casted films indicating that, these plasticizers are not compatible for this polymer blends. Bodmeier and Paeratakul reported the leaching of water soluble plasticizers (TEC) from polymeric films prepared by casting and drying of plasticized Aquacoat dispersion.³⁷

Table 1: The selection of polymer blend and respective ingredients.

Polymer blend	Name of Ingredients	Polymer blend to Additives ratio				
		20:80	30:70	40:60	50:50	60:40
		T1	T2	T3	T4	T5
Quantities (%)						
PVA: PVA-PEG (ratio 90:10)	PVA	18	27	36	45	54
	PVAPG	2	3	4	5	6
	PEG 3350	5	7.5	10	12.5	15
	TiO2	45	37.5	30	22.5	15
	Talc	30	25	20	15	10
	Total (%)	100	100	100	100	100
HPMC 6cP: PVA-PEG (ratio 90:10)	HPMC 6cP	T6	T7	T8	T9	T10
		18	27	36	45	54
	PVAPG	2	3	4	5	6
	PEG 3350	5	7.5	10	12.5	15
	TiO2	45	37.5	30	22.5	15
	Talc	30	25	20	15	10
Total (%)	100	100	100	100	100	
PVA: HPC (ratio 90:10)	PVA	T11	T12	T13	T14	T15
		18	27	36	45	54
	HPC	2	3	4	5	6
	PEG 3350	5	7.5	10	12.5	15
	TiO2	45	37.5	30	22.5	15
	Talc	30	25	20	15	10
Total (%)	100	100	100	100	100	

Table 2: Tensile strength properties of PVA: PVA-PEG blends with inclusion of different plasticizers.

Blend Details		Young's Modulus (MPa)	Tensile stress at maximum load (MPa)	Tensile strain at break (%)	Toughness (Tensile/modulus)	Extension at break (mm)	
Polymer blend	Plasticizer concentration						
PVA: PVA-PEG (90:10); 20% w/w Solids	*0%	1304.02 ± 144.52	25.79 ± 1.85	107.47 ± 16.79	0.02002 ± 0.00	59.20 ± 9.23	
	PEG 400	10%	116.99 ± 32.48	20.65 ± 6.31	1.21 ± 0.28	0.18 ± 0.05	93.19 ± 21.32
		15%	88.84 ± 16.91	16.57 ± 3.41	1.61 ± 0.39	0.19 ± 0.04	123.493 ± 30.26
		20%	85.31 ± 10.68	18.02 ± 2.68	1.99 ± 0.37	0.21 ± 0.04	152.18 ± 28.09
	PEG 3350	10%	113.66 ± 25.91	13.55 ± 1.69	0.92 ± 0.10	0.12 ± 0.02	69.54 ± 7.86
		15%	203.39 ± 68.86	18.89 ± 6.97	1.25 ± 0.38	0.10 ± 0.04	94.68 ± 28.84
		20%	156.56 ± 41.40	10.12 ± 0.74	0.84 ± 0.16	0.07 ± 0.02	63.53 ± 12.30
	MCT	10%	89.79 ± 28.48	14.29 ± 4.92	1.20 ± 0.26	0.16 ± 0.05	91.60 ± 19.59
		15%	152.82 ± 93.05	15.78 ± 5.28	1.38 ± 0.55	0.14 ± 0.09	104.93 ± 41.95
		20%	149.17 ± 83.95	15.10 ± 2.50	1.27 ± 0.37	0.14 ± 0.08	96.91 ± 28.50
	TEC	10%	399.98 ± 153.69	13.34 ± 4.05	0.61 ± 0.56	0.04 ± 0.03	46.44 ± 11.79
		15%	168.83 ± 70.80	12.67 ± 5.58	0.97 ± 0.31	0.10 ± 0.07	74.27 ± 23.30
20%		219.19 ± 93.55	16.38 ± 2.86	1.21 ± 0.28	0.09 ± 0.05	92.25 ± 21.38	

Table 3: Tensile strength properties of HPMC 6cP: PVA-PEG blends with inclusion of different plasticizers.

Blend Details		Young's Modulus (MPa)	Tensile stress at maximum load (MPa)	Tensile strain at break (%)	Toughness (Tensile/modulus)	Extension at break (mm)	
Polymer blend	Plasticizer concentration						
HPMC 6cP: PVA-PEG (90:10); 15% w/w Solids	0%	2079.99 ± 319.05	27.18 ± 4.40	6.32 ± 1.46	0.01308 ± 0.00	3.48 ± 0.81	
	PEG 400	10%	1118.27 ± 174.35	14.79 ± 2.33	0.027 ± 0.01	0.013 ± 0.00	2.03 ± 0.39
		15%	1260.53 ± 157.22	14.16 ± 2.17	0.024 ± 0.00	0.011 ± 0.00	1.782 ± 0.34
		20%	1072.34 ± 157.77	14.19 ± 2.27	0.045 ± 0.02	0.013 ± 0.00	3.371 ± 1.17
	PEG 3350	10%	1681.18 ± 51.32	20.83 ± 0.87	0.04 ± 0.01	0.01 ± 0.00	2.93 ± 0.72
		15%	1546.04 ± 123.84	18.20 ± 1.36	0.03 ± 0.01	0.01 ± 0.00	2.34 ± 0.56
		20%	1547.67 ± 126.06	19.78 ± 2.25	0.04 ± 0.01	0.01 ± 0.00	2.73 ± 0.66
	MCT	10%	1334.16 ± 107.78	15.61 ± 1.96	0.03 ± 0.01	0.01 ± 0.00	1.90 ± 0.52
		15%	1128.88 ± 180.04	14.68 ± 2.97	0.02 ± 0.01	0.01 ± 0.00	1.88 ± 0.58
		20%	964.36 ± 62.54	10.75 ± 1.34	0.02 ± 0.00	0.01 ± 0.00	1.22 ± 0.21
	TEC	10%	939.67 ± 178.41	11.14 ± 2.84	0.02 ± 0.01	0.01 ± 0.00	1.68 ± 0.44
		15%	1028.54 ± 207.33	11.97 ± 3.94	0.03 ± 0.01	0.01 ± 0.00	2.061 ± 0.49
20%		695.13 ± 72.19	8.43 ± 1.00	0.04 ± 0.01	0.01 ± 0.00	2.75 ± 0.53	

Table 4: Tensile strength properties of PVA: HPC blends with inclusion of different plasticizers.

Blend Details		Young's Modulus (MPa)	Tensile stress at maximum load (MPa)	Tensile strain at break (%)	Toughness (Tensile/modulus)	Extension at break (mm)	
Polymer blend	Plasticizer concentration						
PVA: HPC (90:10); 15% w/w Solids	*0%	1905.15 ± 313.40	23.77 ± 1.44	29.38 ± 13.89	0.01271 ± 0.00	16.22 ± 7.67	
	PEG 400	10%	164.05 ± 29.87	18.01 ± 3.23	0.70 ± 0.18	0.11 ± 0.02	53.48 ± 13.63
		15%	101.73 ± 20.89	13.23 ± 4.20	0.76 ± 0.24	0.13 ± 0.02	58.43 ± 18.17
		20%	127.67 ± 48.15	11.85 ± 4.09	0.44 ± 0.20	0.09 ± 0.02	34.04 ± 15.61
	PEG 3350	10%	169.85 ± 47.74	12.74 ± 3.40	0.69 ± 0.19	0.08 ± 0.02	52.25 ± 14.24
		15%	233.90 ± 46.96	9.66 ± 1.46	0.44 ± 0.10	0.04 ± 0.01	33.59 ± 7.56
		20%	433.65 ± 37.87	7.62 ± 2.11	0.26 ± 0.09	0.02 ± 0.01	19.61 ± 6.83
	MCT	10%	Film properties unable to determine due to visual leaching of added plasticizer (MCT and TEC) at all concentration level from the casted films				
		15%					
		20%					
	TEC	10%					
		15%					
20%							

*Reproduced from Ref 38.



ii) Polymer blends with plasticizer and additives

The modulus of elasticity in general practice was found to increase when pigments were added to the polymer systems.^{27,39-40} Present study showed that, additives at all concentration levels have an impact on result of mechanical properties (modulus of elasticity, tensile strength) of casted films of polymer blends. Although all polymer blends contain similar concentration of plasticizer (PEG 3350) with respect to total concentration of polymer). Tensile strength data presented in Table 5. All polymer blends showed gradual increase in Young's modulus and decrease in extension at break as the concentration of additives in the casted film increases. The tensile strength properties data of different polymer blends with respective concentration of additives are represented in below Table 2. Among all polymers blend, PVA: PVA-PEG (90:10) and PVA: HPC (90:10) showed comparatively higher extension at break as compared to that observed with HPMC: PVA-PEG (90:10) at all concentration level of additives. Also, literature survey indicates that, PVA crystallinity was depressed in the

presence of the additives⁴¹ which may have further impact on mechanical properties of polymer blends. Casted film of polymer blend HPMC 6CP: PVA-PEG (90:10) and PVA: HPC (90:10) showed harder and brittle at 20:80 ratio of polymers: additives, hence, mechanical properties of this ratio was not determined, however, in case of PVA: PVA-PEG (90:10) ratio showed comparatively less brittleness at 20:80 ratio of polymers: additives. Hard and brittle films exhibit a high tensile strength and Young's modulus with little elongation. The presence of brittleness in casted film at high concentration of additives may be due to these insoluble additives (titanium dioxide and talc) acting as stress concentrations, thereby promoting the initiation of cracks in the film and/or the presence of interactions between the additives and the polymer.⁴² Ideally these water insoluble additives are defects in the film⁴³, which enhances film failure and therefore decrease in elongation. Further this brittleness as well as Young's Modulus of casted film decreases in all polymer blends as the concentration of additives decreases.

Table 5: Tensile strength properties of different polymer blends with varying concentration of additives.

Blend Details			Young's Modulus (MPa)	Tensile stress at maximum load (MPa)	Tensile strain at break (%)	Toughness (Tensile/modulus)	Extension at break (mm)
Polymer ratio	Polymers: additives ratio						
PVA: PVA-PEG (90:10)	20:80	T1	7067.6 ± 1780.66	15.697 ± 2.66	0.005 ± 0.001	0.002 ± 0.0	0.355 ± 0.080
	30:70	T2	3914.7 ± 677.7	15.375 ± 2.27	0.008 ± 0.003	0.003 ± 0.0	0.707 ± 0.133
	40:60	T3	3352.9 ± 946.9	10.697 ± 2.90	0.011 ± 0.002	0.003 ± 0.00	0.847 ± 0.140
	50:50	T4	1316.5 ± 212.7	10.962 ± 0.011	0.011 ± 0.005	0.006 ± 0.00	2.402 ± 2.370
	60:40	T5	1030.8 ± 112.1	5.777 ± 0.85	0.056 ± 0.016	0.005 ± 0.00	4.228 ± 1.220
	100:0	*	156.6 ± 41.40	10.120 ± 0.74	0.840 ± 0.16	0.070 ± 0.02	63.530 ± 12.30
HPMC 6CP: PVA-PEG (90:10)	20:80	T6	Film is brittle, unable to determine film properties				
	30:70	T7	6051.3 ± 366.58	10.872 ± 1.83	0.002 ± 0.001	0.002 ± 0.00	0.212 ± 0.04
	40:60	T8	5053.9 ± 440.6	14.801 ± 3.33	0.005 ± 0.002	0.002 ± 0.00	0.445 ± 0.17
	50:50	T9	3018.9 ± 282.7	19.134 ± 1.83	0.009 ± 0.001	0.006 ± 0.00	0.719 ± 0.09
	60:40	T10	2070.8 ± 458.60	10.131 ± 1.02	0.024 ± 0.006	0.005 ± 0.00	1.805 ± 0.50
	100:0	*	1547.7 ± 126.06	19.780 ± 2.25	0.040 ± 0.01	0.010 ± 0.00	2.730 ± 0.66
PVA: HPC (90:10)	20:80	T11	Film is brittle, unable to determine film properties				
	30:70	T12	8618.3 ± 735.8	14.601 ± 1.78	0.003 ± 0.001	0.001 ± 0.00	0.287 ± 0.07
	40:60	T13	4402.5 ± 442.7	12.141 ± 0.91	0.008 ± 0.001	0.004 ± 0.00	0.618 ± 0.15
	50:50	T14	2079.6 ± 396.9	8.503 ± 1.21	0.020 ± 0.006	0.004 ± 0.00	1.551 ± 0.51
	60:40	T15	1166.1 ± 94.94	6.599 ± 0.67	0.054 ± 0.014	0.005 ± 0.00	4.064 ± 1.09
	100:0	*	433.7 ± 37.87	7.620 ± 2.11	0.260 ± 0.09	0.020 ± 0.01	19.610 ± 6.83

*data from polymer blends with plasticizer

The increased Young's modulus may be related to the increased stiffness and brittleness of hybrid composite films by the addition additives in polymer blend. This may be brought about in two ways; first, the mobility of polymer phase may be physically hindered by the presence of the additives particles (this is a hydrodynamic effect). Second, additives-polymer interaction (a

reinforcing effect) could stiffen the molecular chains of portions of the polymer matrix at the additives -polymer interface thus reducing segmental mobility. Thus, decrease in extension at break caused by addition of additives can be further explained by the decrease in chain mobility of polymers in the presence of high concentration of additives. Additives therefore, reduce



intermolecular bonding between polymer molecules and affect the properties of the film (decreasing polymer mobility as well as its elongation). Here elongation has been considered as a measure of the deformation capacity, i.e. the ability to deform under stress, of a film.

From the tensile strength data (from Table 5), minimum concentration of additives (less than 70%) in polymer blend is recommended, in order to produce continuous film (reduces the brittleness of casted film). Ideally increasing the tensile strength of the coating reduces the risk of cracking and reducing the elastic modulus decreases the potential of occurrence of bridging.

Polymers with high additive capacity can be defined as those that can incorporate very high levels of insoluble

additives while still retaining their functional characteristics. A more well-defined concept, in this regard, is the CPVC (critical pigment volume concentration)^{19,44-45}. According to this theory, below the CPVC, the polymer is able to completely bind and surround the additives particles, forming a dense and continuous film, however, above the CPVC, there is incomplete binding of pigment particles by the polymer, resulting in the formation of voids within the film.⁴⁶⁻⁴⁷ In present study, continuous film formed with polymer blends having less than 70% of additives. Figure 1 showed graphical presentation of polymers: additives concentration (%) vs Young's Modulus (mPa) vs Extension at break (mm).

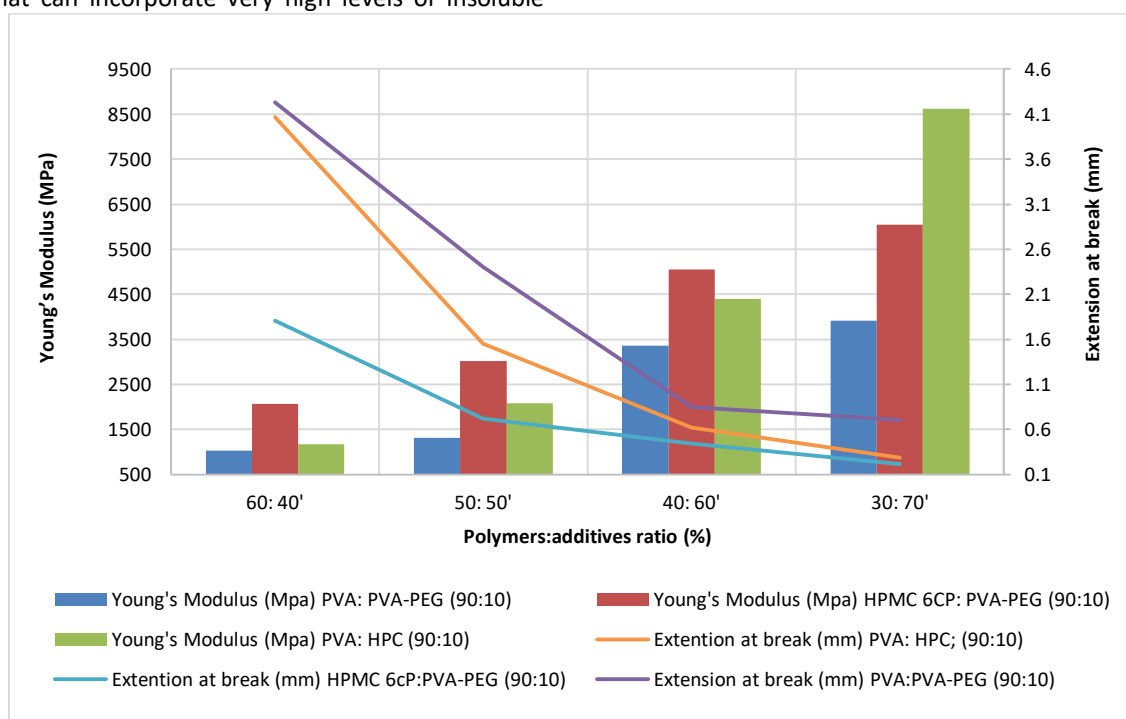


Figure 1: Graph of Polymers: additives concentration (%) vs Young's Modulus (mPa) vs Extension at break (mm)

CONCLUSION

The mechanical properties of films prepared from aqueous dispersion of polymer blends with inclusion of different types of plasticizers and water insoluble additives (different concentration levels) provide valuable information to predict the best ratio of polymer blends with plasticizers and additives that can be used in the development of coating formulation.

The presences of plasticizers in polymer blends have a significant impact on reduction of modulus of elasticity of polymer. This is required to reduce the brittle properties and to achieve effective coatings on different formulations (pellets, tablets) without the formation of cracks and defects. Thus, plasticizers are essential ingredients for most polymers of pharmaceutical interest. Choice of plasticizer and its concentration play an important role in changing the physical properties of polymer to render it more useful in performing its function as a film-coating material.

In contrast, addition of additives (titanium dioxide and talc) in polymer blend resulted in reduction in tensile strain, extension at break and toughness while the Young's modulus increased. High concentration of additives will provide hard and brittle film indicating high tensile strength and Young's modulus with little elongation. Low concentration (below critical level) of additives, polymeric films become soft and tough which possess lower tensile strength and higher elongation.

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Source of Support: Nil, Conflict of Interest: None.

