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# Optical properties of ldpe films with different additives mixtures

Propiedades ópticas de ldpe cobertura com aditivos diferentes mixtures

Propiedades ópticas de películas pebd con diferentes mezclas de aditivos

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## Resumen

En este artículo se exponen los resultados del procesamiento de diferentes formulaciones de polietileno lineal de baja densidad (PEBD) mezclado con 5 tipos de aditivos diferentes, cuyo objetivo es analizar el efecto de los aditivos en las propiedades ópticas de películas de PEBD de protección de cultivo dirigida fundamentalmente para construcciones de invernaderos adecuados para el desempeño en medios tropicales. Los resultados de la transmisión de la región ultra violeta y visible muestran que la transmisión de luz de las película de

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referencia es mayor en la zona visible que en las películas fabricadas con mezclas de aditivos, debido al efecto difusivo de algunos elementos y a la acción sinérgica de los aditivos disminuyendo la transmisión de luz en la zona ultra violeta y visible.

**Palabras claves:** Polietileno lineal de baja densidad (PEBD), aditivos, propiedades ópticas, plasticultura.

## Resumo

Neste artigo são expostos os resultados do processamento de diferentes formulações de polietileno linear de baixa densidade (PEBD) misturado com 5 diferentes tipos de aditivos, que visa analisar o efeito de aditivos sobre as propriedades ópticas de filmes de PEBD dirigido proteção das culturas, principalmente para a construção de estufas adequadas para o desempenho em tropical. Os resultados da transmissão de ultra-violeta e mostram região visível que a transmissão de luz a partir da película de referência é maior no visível do que os filmes feitos com misturas de aditivos, devido aos elementos efeito difusivo e da ação sinérgica aditivos diminuir a transmissão de luz no ultravioleta e visível.

**Palavras chaves:** Polietileno linear de baixa densidade (LDPE), aditivos, propriedades ópticas, plasticultura.

## Abstract

This article presents the results of processing different formulations of linear low density polyethylene (LDPE) formulations, mixed it with five kind of different additives whose objective was analyzing the additives effects in the optical properties of LDPE films on greenhouse cover structure in protected cultivation for tropical environments. The results of ultra violet and visible region showed that the light transmission from the reference film was higher than additives films mixtures in the visible region, effect of some elements and synergistic action from additives contributing to decrease the light transmission in the ultra violet and visible region.

**Key words:** linear low density polyethylene (LDPE), additives, optical properties, plasticulture.

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## 1 Introduction

Plasticulture (the use of plastics in agriculture since the mid-twentieth century) was introduced primarily in developed countries, recently extended to developing countries, the use is particularly abundant in areas with limited

farmland as in Europe, Japan and Korea [[1]-[4]]. The increasing use of plastics in agriculture has enabled farmers to increase production and reduce dependence on weather conditions. Today, the use of plastics consumption generates less herbicides and pesticides, improved food security and more efficient use of water as a result, the use of plastics in agriculture is increasing worldwide, as a result of the agricultural transformation toward industrialization [[3]-[4]].

According to the International Committee of Plastics in Agriculture (CIPA) [[5]] there are about 500,000 hectares under greenhouse worldwide and 4.5 million hectares are using plastic as mulch. Therefore, it is estimated 2 to 3 million tons of plastic are used each year in agricultural applications, based on the report of JP Jouet [[6]], agriculture consumes 2.5% of world production of plastics (4 million tonnes in 2000) [[7]]. The conventional agricultural plastic films used today are made of polyethylene of low and high density, linear low density polyethylene (LDPE), poly (vinyl chloride), polybutylene or copolymers of ethylene and vinyl acetate [[8]-[9]].

The degradation of polymers used in agriculture is mainly due to radiation in the ultraviolet region [[10]-[11]] and recently has generated an evolution in the plastics additives applied in order to improve this degradation in severe environmental conditions, but additionally these do not wane the mechanical properties of plastics. Parallel to the growth of polyolefins industry has improved the additives performance especially in blocking the near infrared, antioxidants and the area of the light stabilizer, either new chemical structures or through the effects synergistic [[12]-[13]-[14]]. The trend of innovative additives is to maintain the properties of polymers and extend the shelf life. Thanks to new developments in the production of plastics, has been found that using low concentrations provide less degradation effects and increased mechanical properties [[15]-[16]].

Colombia has great agricultural potential but little industrialized, the reasons are varied, one of the most important is the lack of cultivation techniques, despite this they have planted about 4,500 hectares, thus developed the plasticulture technique mainly in flower industry . On the other hand, the traditional crops should be monitored to convert to productive element independent on geo-climatic conditions [[17]]. Also in areas close to major consumption centers are desert ,that are absolutely unproductive and leading to poverty of the inhabitants of the region. It is necessary to create mechanisms

that can enhance these sites and turn them into useful land[[19]].

In addition, the traditional farming changes depend on the new development on polymeric use in the greenhouses and new developments in polymeric materials production.

The purpose of this paper is to study several films protection alternatives on crops aimed to farmers and greenhouse builders. To validate this goals is necessary to understand the phenomena and variables that control the plants vegetative development, being the most important the radiologists and climate from viewpoint the polymers engineering. With this work we pretend to visualize the effect that the additives have in LDPE blow grade and the aging's film behavior of polyethylene TRI-CO-EXTRUCTION of low density in a harsh environment (temperatura, ultraviolet and sandstorm).

## 2 Experimental development

The purpose of this stage is to analyze the effect of additives in each film. This pilot phase will be implemented in two levels:

1. Development of the additive concentrate and mixing process
2. Blown film made

### 2.1 Mixing Processor

For the development of this stage were processed 15 formulations of LDPE blended with five types of additives: for each three concentrations used (Table 2). To mix the additive in the polymer was made a premixed with an internal mixer rotor tangential plastic-corder equipped Brabender PLE331, creating a concentrate and achieving a good distribution and dispersion in the final product, then were ground and formed into pellets in the pelletizing section of the same team. To select the additives was carried out an optimization process using different formulations in accordance with the following parameters: absorption, stabilization, thermal, photoselection . Table 1 shows the additives and concentrations with which the films were produced as well as mixtures thereof according to the desired characteristics.

**Table 1:** LDPE formulations mixed with five different types of additives.

Name	Concentration% w	Designation	Description and effect	Supply
UV Stabilizer	0,7	E0, 7	Type HALS protects from ultraviolet light	Concentrate 20% w by Clariant
	1,25	E1, 25		
	1,5	E1, 5		
Kaolin IR Blocker	0,6	IR0, 6	Blocks of far infrared light (IR)	Concentrate 50% w by Clariant
	0,8	IR0, 8		
	1	IR1		
UV absorber	0,2	A0, 2	Benzotriazole type, which blocks ultraviolet light and prevent damage to plants	Clariant powder
	0,4	A0, 4		
	0,6	A0, 6		
RL smartlight 1000	0,6	S0, 6	It photosensitive, increases productivity in crops, absorbs UV and emits red	Ciba powder
	0,8	S0, 8		
	1	S1		
215 Iriodin	0,6	215 0.6	MIR is photosensitive blocks and prevents overheating without blocking the PAR	Merck powder
	0,8	215 0.8		
	1	215 1		

## 2.2 Blown Film

The first step in the blown film process is the study of the basic principles governing this type of process: the characteristics of the material to be blown, the temperature of different areas of the screw, screw speed, cooling film (flow and height), the bubble pressure, speed of calendaring and thickness of the die. The selection criteria were the processability of polymer materials, low cost and better mechanical properties. For these reasons the films were processed with linear low density polyethylene whose characteristics are shown in Table 2.

**Table 2:** Hanwha linear low density polyethylene blown film for 3304 level.

Melt index	1,1
Density $\frac{gr}{cm^3}$	0,923
Melting temperature °C	170-210
Blow-up Ratio	2:1-3:1
Optimal range of gage (mm)	0.015 to 0.1
Tensile strength MPa	13

In order to achieve additive compared with each other, the variables are kept constant in all films, and for this we use the computer Brabender Plastic-Corder PLE 331 with a screw 047 L / D 25:1 25  $\frac{3}{4}$  fillets inch single stage compression ratio of 4-1. Table 3 shows the condition of equipment in which they managed to stabilize the film.

**Table 3:** Terms of stabilization.

Temperature in the feed zone	160°C
Temperature in the transition zone	220°C
Temperature in the dispensing area	220°C
Temperature in the die	220°C
Pressure in the area of 7500 psi pump	39,90%
Maximum permissible torque	31%
Screw speed	60 rpm
Speed ironer	20 rpm
Residence of the material in the screw	2 minutes

It blew two types of films: the first with a single additive but varying the quantity and the second with a mixture of several additives. The results are explained below:

**2.2.1 First type of film** Difficulties arose in the process of obtaining the films due to moisture in the additive that creates a break in the film because the craters formed by water vapor which prevents the formation of the plastic bubble. In addition, problems in the mixture for the dispersion of the additive which produced clumps or clusters that do not break in the polyethylene, the distribution of the additive also did not occupy it everywhere in the film, the

characteristics obtained in the movies seen in Table 4.

**Table 4:** Films for additives in different concentrations.

Name	concentration% w	Denomination	Description and effect	Final appearance of the film	Difficulties in the film blowing
UV Stabilizer	0.7	E0.7	Type HALS protects from ultraviolet light	Good distribution and dispersion, elastic and with a red hue	None
	1.25	E1.25			
	1.5	E1.5			
Kaolin IR Blocker	0.6	IR0.6	Blocks of far infrared light (IR)	There are small particles of the additive	Having trouble dispersion which is solved with a mixed
	0.8	IR0.8			
	1	IR1			
UV absorber	0.2	A0.2	Benzotriazole type, which blocks ultraviolet light and prevent damage to plants	Good distribution and dispersion and with a green hue	None
	0.4	A0.4			
	0.6	A0.6			
RL smartlight 1000	0.6	S0.6	It photoselective, increases productivity in crops, absorbs UV and emits red	There are small particles of the additive with a red hue	Having trouble dispersion which is solved with a mixed
	0.8	S0.8			
	1	S1			
215 Iriodin	0.6	215 0.6	MIR is photoselective blocks and prevents overheating without blocking the PAR	Revealed small particles of the additive with a beaded red hue	Having trouble dispersion which is solved with a mixed
	0.8	215 0.8			
	1	215 1			
Red pigment	1	PR	It emits in the red photoselective 065 $\mu\text{m}$ which is the peak of photosynthesis	Good dispersion and a red hue	It has distribution problems which is solved with a mixed
Blue pigment	1	PA	It emits in the blue photoselective 045 $\mu\text{m}$	Good dispersion and a blue hue	It has distribution problems which is solved with a mixed

**2.2.2 Second type of film** The second type of film was developed with a mixture of various additives added in a single concentration, the characteristics of the films obtained are shown in Table 5. By adding each additive the transmission of light decreases, in this sense, the mixture was made more difficult EIR215 as the light transmission decreased significantly and the mixture of additives (stabilizer, kaolin and Iriodin) prevented stabilization blowing process, because it was necessary to reduce the concentration of kaolin from 8% to 5% and get this film. By contrast the mixture EIRA had the best processing, was composed of stabilizer, kaolin and UV absorber.

**Table 5:** Films of mixtures of additives.

Designation	Content							Final appearance of the film	Difficulties in the film blowing
	E %w	IR% w	A% w	S% w	215% w	PR *% w	PA *% w		
EIR	1.25	8						Fuzzy	None
EIRA	1.25	8	0.4					Fuzzy	None
EIRS	1.25	8		1				Red diffused	distribution problems
EIR215	1.25	5			1			Fuzzy pearl	dispersion and moisture problems
EIRPR	1.25	8				1		Fuzzy pink	distribution problems
EIRPA	1.25	8					1	Blue Fuzzy	distribution problems

\* PR = red pigment, PA = blue pigment

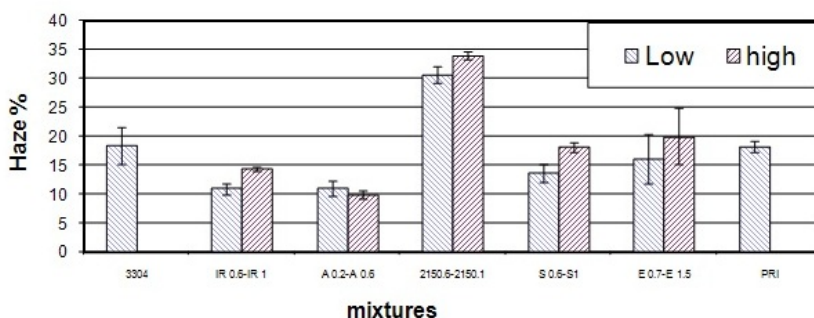
### 2.3 Evaluation of optical properties

To evaluate the optical properties are worked according to ASTM D 1003 [[19]], the team Cary 50 Conc UV-Visible Spectrophotometese, the range of 200nm to 1000nm measuring equipment in the ultra violet and visible.For this evaluation, cut rectangular pieces of film 1 cm by 4 cm and placed in the cavity of the team entry shows the percentage of light transmission in the previous range.Haze measurement was performed according to ASTM D 1003, using the computer model Hazemeter Gardner HG1204 with rotating dial, digital photoelectric unit PG5500 and Gardner digital photometric unit, between the sphere and the light emitting chips are placed square film (2in x 2in) and the computer measures the percentage of diffuse light.

## 3 Results

### 3.1 Haze measurements

The haze results for the first type of film are shown in Figure 1 where it is clear that the additive that affects the diffused light is the Iriodin. Moreover the other additives do not haze increase with respect the film without any additives.

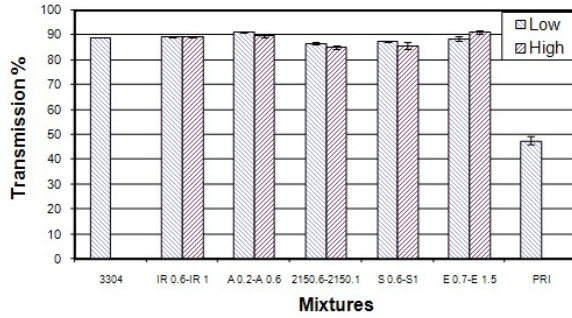


**Figure 1:** Haze of the films depending on the concentration

The light diffuse transmission results for the first type of films are shown in Figure 2, it shows little variation by changing the concentration and the

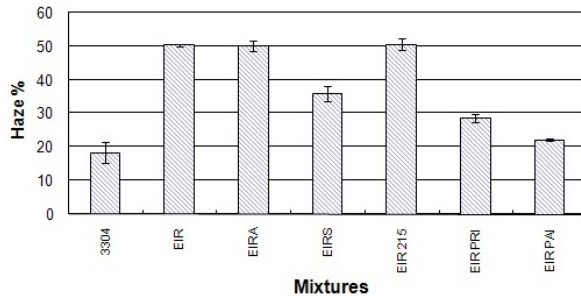


only additive that reduces transmission of light is the red pigment significantly reducing by half.

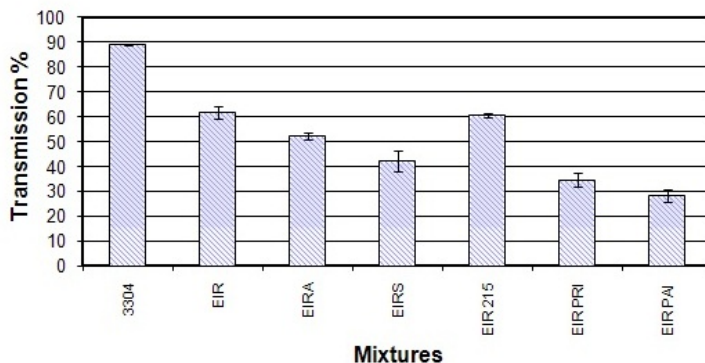


**Figure 2:** Transmission of the films depending on the concentration

The haze results of the second type of films are shown in Figure 3. Here you can see that the film are mixed diffusive about the lm without additive. And the films most affected are those with EIR, such as EIRs, EIRPR, EIRP. The diffusive effect is formed by the IR kaolin due to high concentrations (8%). The results of light transmission of the second type of films are shown in Figure 4. In this we see that additive films is not 3304, have a high light transmission with respect additive films, because when compared to the EIR, the same transmission Iriodin is probably because of the concentration of kaolin (5%). The UV absorber decreased slightly transmission and the Smart decreased much more, but the bad behaved had the red and the blue pigments, the worse being blue.



**Figure 3:** Haze of the films with mixtures of additives

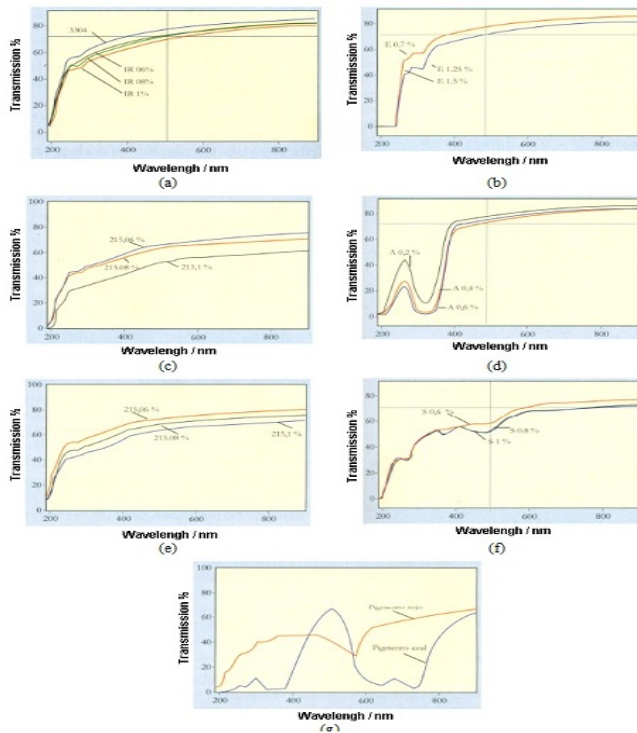


**Figure 4:** Transmission of the films with mixtures of additives

## 3.2 Transmission Ultraviolet Visible (UV-VIS)

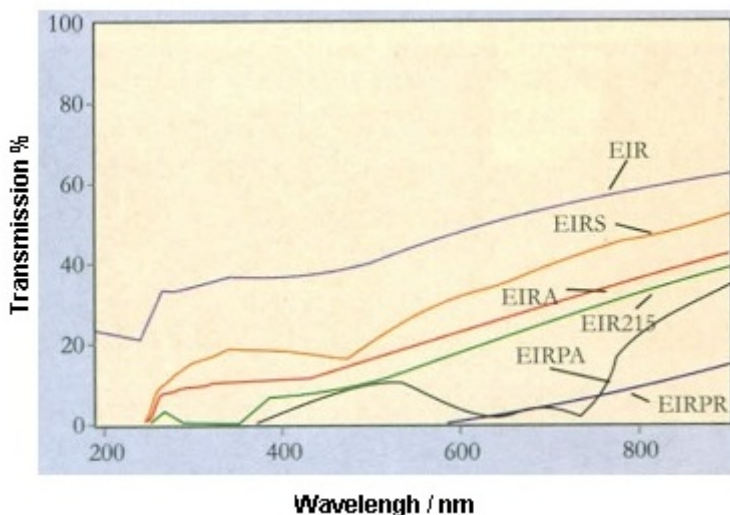
**3.2.1 First type of film** The results of transmission in the ultraviolet to the visible range 200-900 nm for the first type of film are shown by the additive in the following order: 3304 with kaolin (IR), stabilizer (E), absorption (A), Smart (S ) Iridin 215, pigment red, pigment blue movies. The results of the transmission of polyethylene without additives (3304) and three concentrations of kaolin to block the IR are shown in Figure 5a, there is observed that with increasing transmission additive concentration decreases. The movie stabilizer and three concentrations are shown in Figure 5b, this shows that the transmission is in the area of 300 nm, then decreases to 250 nm, below this range there is no transmission, as well as concentrations 1.25% and 1.5% did not show variations, with absorber and three concentrations is shown Figure 5c, this is seen in the area near 400 nm, there is a drop in the absorption of 300nm to 350 nm, then let between 300nm and 250nm, the effect of ultraviolet light absorption does not change significantly in concentrations of 0.4% to 0.6% obtained similar results with these concentrations. The transfer of the film with Smart and three concentrations are shown in Figure 5d, the which shows a reduction in transmission at 600 nm and another at 250 nm, shows that the concentrations of 0.8% and 1% are very similar in the transmission of light. Figure 5e shows the movie with three concentrations Iridin 215 and in this we see that the light transmission has a slight decrease by increasing

the concentration of 0.6% to 0.8% of Iriodin, however, with increasing concentration 1% light transmission decreases broadly. Figure 5f shows that the compound Iriodin 205, allows more light passed at the same concentrations, however, its main application is as a shadow in architectural structures and greenhouses. The film with red and blue pigment are shown in Figure 5g red absorbs below 600 nm and emits in the 450nm blue and the other lengths generate low transmittance. By comparing the UV-VIS transmission of mixtures will be appreciated the stabilizer at a rate of 0.7 and 0.2% absorbed, than the transmission of polyethylene without additives, other additives reduce UV transmission of SIV in different proportions.



**Figure 5:** Transmission of UV VIS: a) Kaolin and 3304; b) three concentrations of stabilizer, c) three concentrations of Iriodin 215; d) three concentrations of absorbing e) three concentrations of Iriodin 205 f) three concentrations of Smart, g) films with red and blue pigments.

**3.2.2 Second type of film** The results of the UV-VIS transmission in mixed films are shown in Figure 6 where it is seen that the addition of additives reduces transmission of light. The results are discussed in descending order in transmission: the movie EIR, there is a reduction of transmission that comes from the high percentage of kaolin (8%), by adding other additives decreases the transmission. With a lower transmission is the EIRS, this film has the best performance against the transmission of light having three additives. Subsequently the film is EIR215 despite having a lower percentage of kaolin than the others, the results in light transmission are not representative, so if the content of kaolin increases light transmission decrease. Running EIRA mix, this is the movie that contains a smaller amount of absorption, however does not favor the synergistic action. Then there are two pigments whose light transmission is more complicated than the others: the EIRPA and EIRPR. The mixture EIRPA, and the transmission of wavelengths is equal to the EIRPR, EIRPA however allows some transmission of other wavelengths. The red EIRPR has stabilizer 1.25% 8% kaolin and red pigment is less than 1% transmission, however the wavelengths it emits 0.650 nm are used for plant growth. In general the transmission in the red for all films is approximately: EIR 50%, 40% EIRs, EIR215 30% EIRA25%, 10% EIRPR and EIRP.

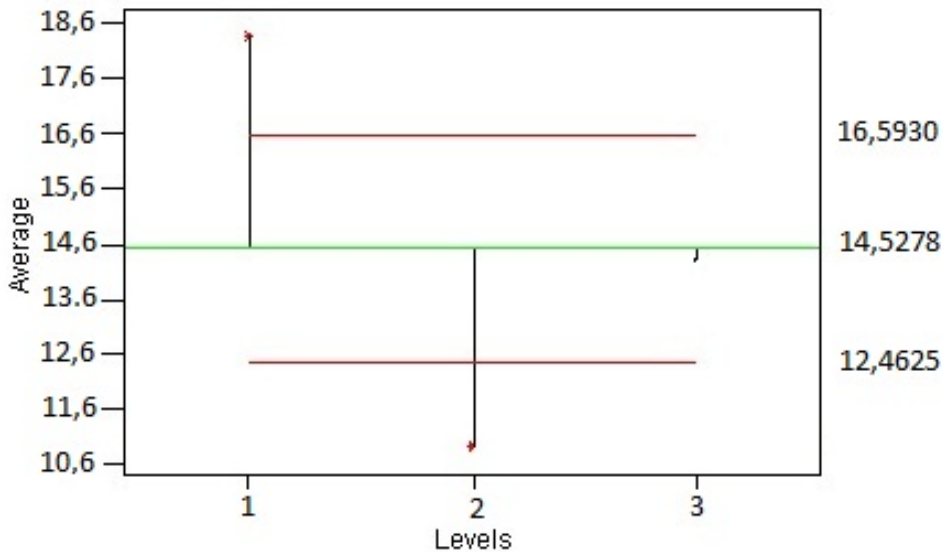


**Figure 6:** Transmission of UV VIS transmission in mixed films

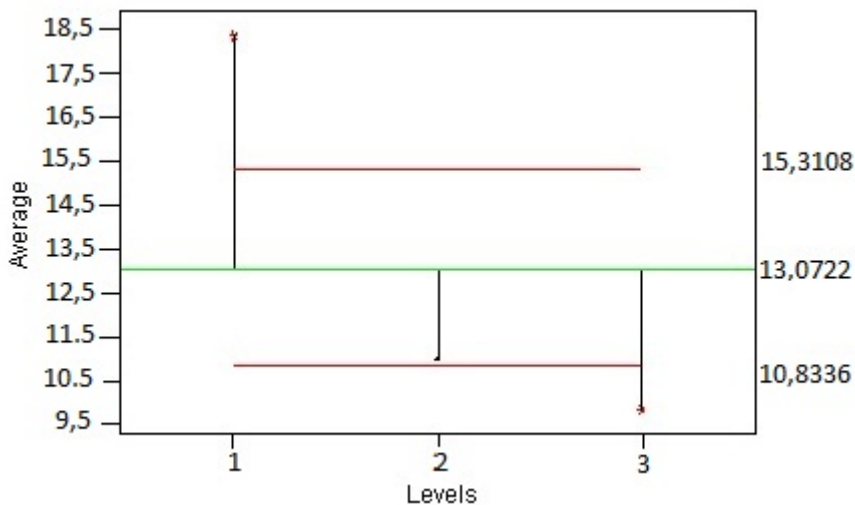
## 4 Analysis of results:

### 4.1 Analysis of Haze

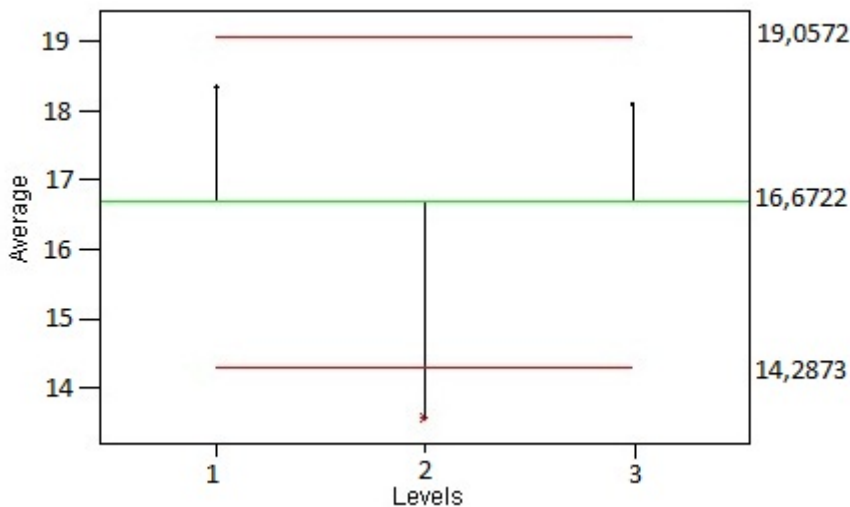
The results of analysis of variance in Haze for the first type of film is as follows: the additive E (UV stabilizer) did not modify the Haze compared with the polymer without the additive. IR additives, A, S (Kaolin, UV absorber and SMAST) decreased Haze, as shown in figures 7, 8 and 9 respectively. The additive 215 (Iridin 215) Haze increased as shown in Figure 10. The results of analysis of variance (ANOVA) on Haze for the second type of film are shown in Figure 11, this one the first films on the left are diffusive, this effect is caused by the content of kaolin in its components. The EIRs (3 in Figure 11) has the least the first 4 Haze EIR, and EIR215 EIRA. The effect on the EIR215 Haze (4 in Figure 11) is equal to the EIR (1 in Figure 11), taking into account that the three separate components of the former are more Haze than the separate components of the second (see Iridin 215 with numbers 16 and 17 of the figure).



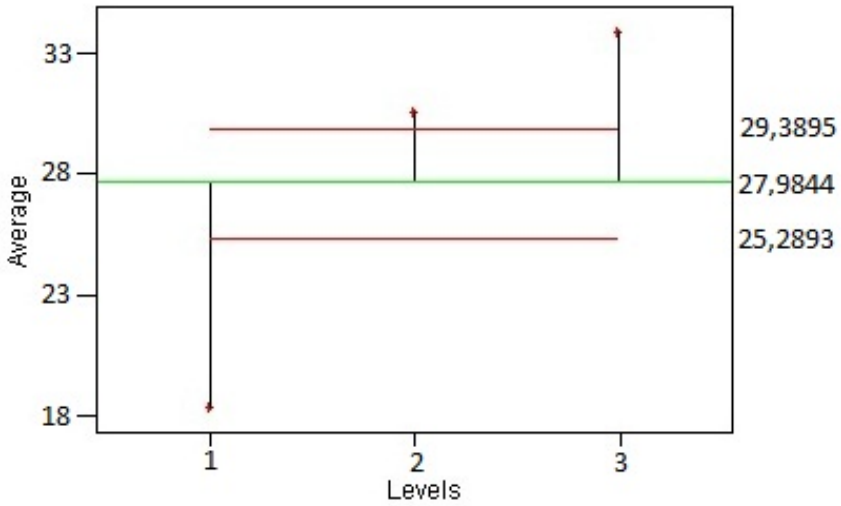
**Figure 7:** Analysis of the means of Haze for kaolin (IR)



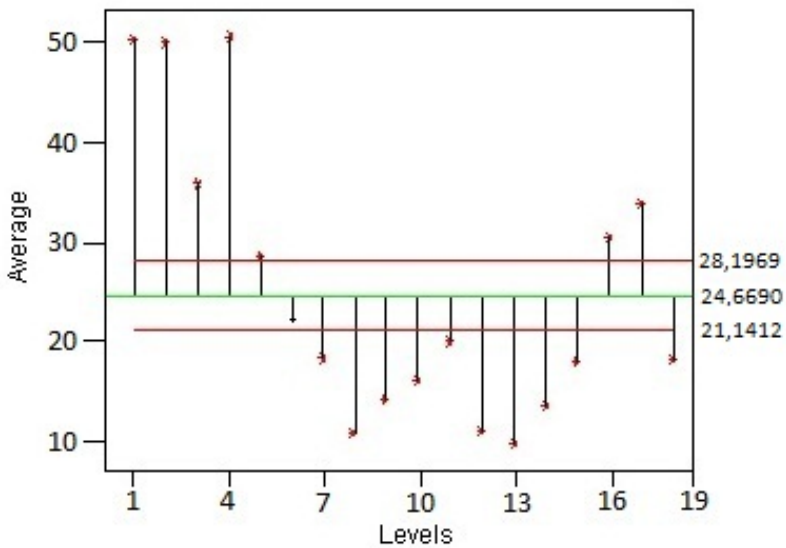
**Figure 8:** Analysis of the means of Haze for the UV absorber



**Figure 9:** Analysis of the means of Haze for the Smart



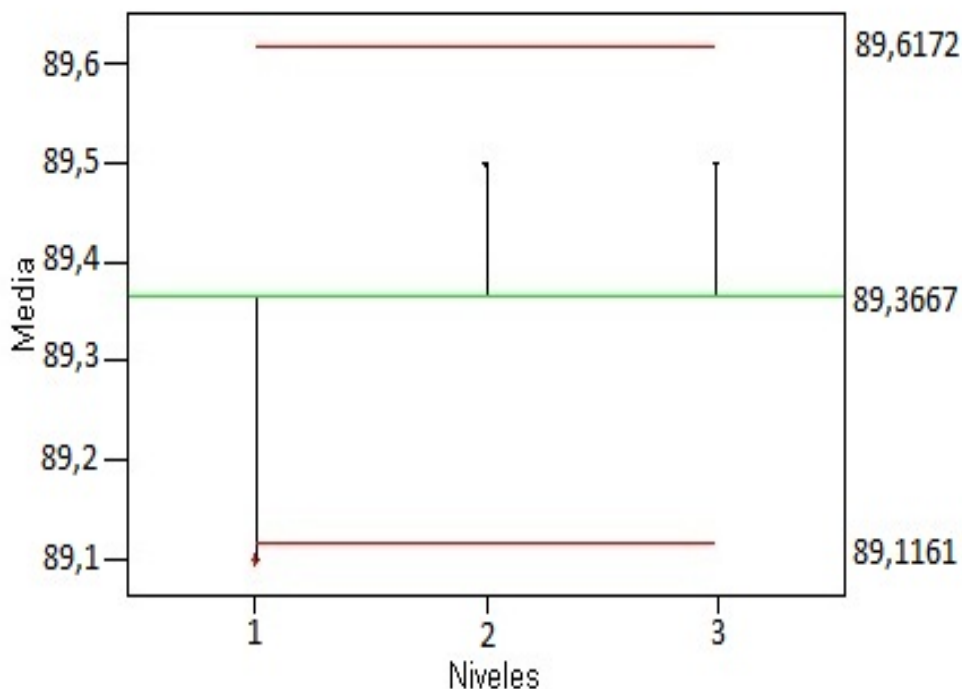
**Figure 10:** Analysis of mean Iriodin Haze for the 215



**Figure 11:** Analysis of the means of Haze for mixed films as well as concentrations

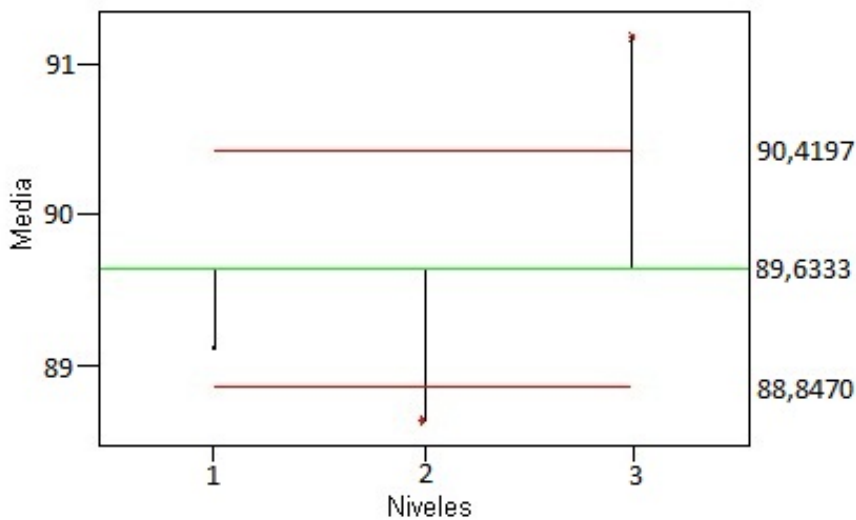
## 4.2 Analysis of Transmission

ANOVA analysis for the transmission of light is shown in Figures 12-17. For the first type of films are shown in Figure 15 that the kaolin, in concentrations of 0.6 and 0.8%, up a bit light transmission, this is because the small crystals allow yet more disorder in the film, the same applies to the UV stabilizer and UV absorber, the figures 13 and 14 show this effect. Figures 15 and 16 show how smart and reduce the transmission Iriodin 215. Figure 17 shows the light transmission for films whose numbers correspond mixed 1 to 6, they see that the light transmission is lower than in the movies that have only one additive (8 to 18). It is noteworthy that in the first six movies, has Iriodin (EIR215) of the number 4, does not increase the transmission with respect to a (EIR), kaolin is at a concentration of 5% while EIR215 the EIR is 8%.

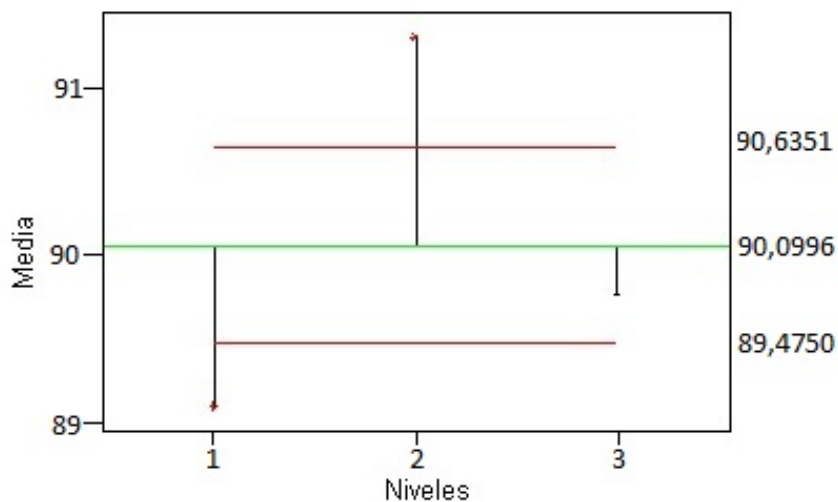


**Figure 12:** Analysis of the means of transmission for the kaolin (IR)





**Figure 13:** Analysis of the means of transmission for UV stabilizer (E)



**Figure 14:** Analysis of the means of transmission for the UV absorber (A)

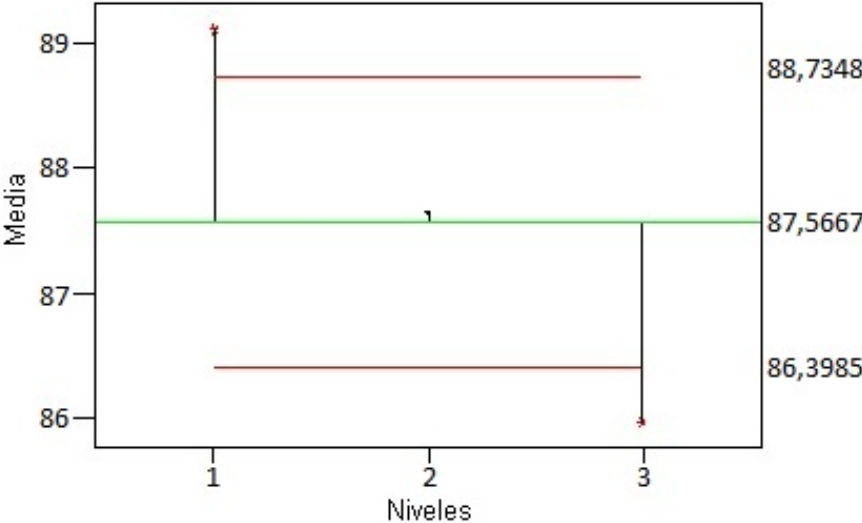


Figure 15: Analysis of the means of transmission for the Smart

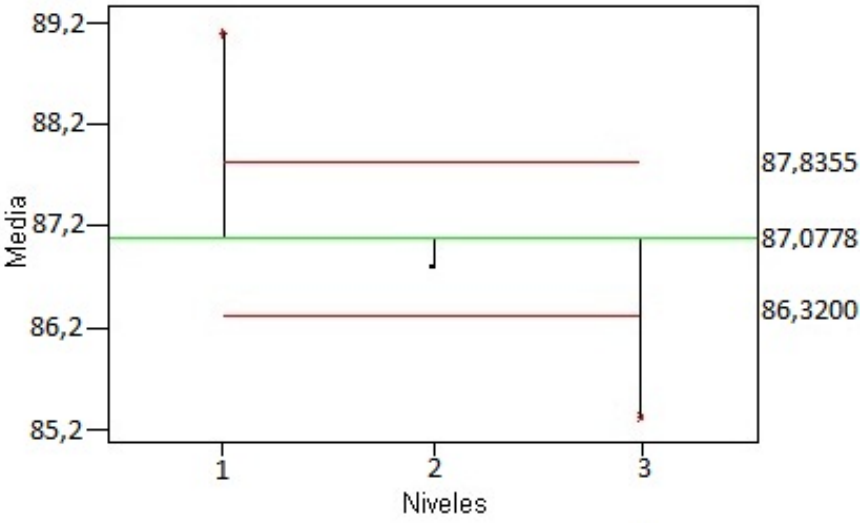
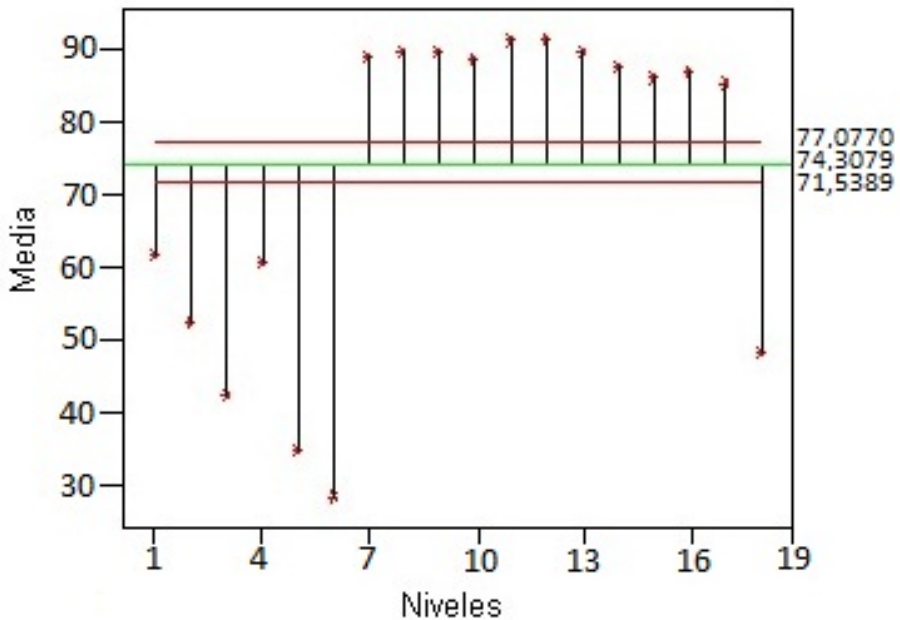


Figure 16: Analysis of the means of transmission for the 215 Iriodin



**Figure 17:** Analysis of the average transmittance for mixed films as well as concentrations

### 4.3 Analysis of Transmission UV VIS

The transmission of the first type of film in the range of UV to Visible (200-900 nm) did not significantly decrease the transmission of light in the PAR region (400-700 nm). Iridin additives 205 and 215 are the least likely to transmit light PAR as shown in Figures 5.23 and 5.24 of Chapter III. UV stabilizer additives and UV absorber block light in the UV area of 200-400 nm. Transmits only the red pigment in the range of 650-700 nm where the plants just use the full activation of photosynthesis. By mixing additives decreases the transmission and the synergy of elements behavior makes them differently, because some decrease further transmission to others. It is important to see that the red pigment additives and blue are the lowest PAR light transmission are, however, the red pigment crop growth than in the blue, this is because the plant uses for photosynthesis length red wave.

## 5 Conclusions

Processing techniques were developed for pilot production of film with different formulations and protocols for efficient mixing. Within the set of formulations developed for the process of obtaining LDPE films with different mixtures of additives suitable for performance in tropical environments. We obtained a wide range of innovative alternatives for many essential applications in agriculture: plastic cold and retention of near-and half IR. Mixed films were diffusive compared to film without additive. Also, the more diffusive films were those containing EIR, because to diffusive effect is composed by the IR kaolin because to high concentrations. The light transmission on mixes films without 3304 additive had a high transmission light with respect to films with this additive. Besides the UV absorber decreased in a minimum proportion, the transmission and Smart it decreased in a higher proportion as red and blue pigments. The UV VIS transmission results in mixed films it showed to adding additives the light transmission decreasing.

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