

**Articles for**

**ORAL PRESENTATIONS**

**SESSION 2-4**

**Packaging - 1**

# Maintaining Quality of 'Douradão' Peaches for 28 days with LDPE Modified Atmosphere Packages

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Written for presentation at the  
2011 CIGR Section VI International Symposium on

Towards a Sustainable Food Chain  
Food Process, Bioprocessing and Food Quality Management

Nantes, France - April 18-20, 2011

**Abstract.** *'Douradão' peach is a perishable product and when cold stored is subject to chilling injury. The objective of the experiment was to evaluate the effect of modified atmosphere packaging (MAP) and cold storage on quality and storage life of these peaches. Fruits were packed in polypropylene (PP) trays and placed inside low density polyethylene (LDPE) bags (30, 50, 60, 75 µm thickness) with active modified atmosphere (10 kPa CO<sub>2</sub> + 1.5kPa O<sub>2</sub>, balance N<sub>2</sub>). The control was made with peaches held in nonwrapped PP trays. Fruits were kept at 1 ± 1 °C and 90 ± 5% relative humidity (RH) for 28 days and CO<sub>2</sub> and O<sub>2</sub> within packages was monitored every two days. After the storage period, samples were withdrawn from MAP and kept in air at 25 ± 1 °C and 90 ± 5% RH for ripening. On the day of removal from the cold storage and after the 4 days, peaches were evaluated for weight loss, decay incidence, flesh firmness, woolliness incidence, soluble solids content (SSC), titratable acidity (TA) and juice content. The results showed that MAP had influence on reducing weight loss and prevented postharvest decay. MAP of 1-2 kPa O<sub>2</sub> and 3-6 kPa CO<sub>2</sub> at 1 °C (from 50 and 60 µm LDPE films) were effective for keeping good quality of 'Douradão' peaches during 28 days of storage, the ripe fruits showed reduced incidence of woolliness, adequate juiciness and flesh firmness. Packages of 30 and 75 µm LDPE films were ineffective for reducing woolliness during cold storage. MAP fruit showed lower SSC and no relevant effect on TA. Control fruit did not present marketable conditions after 14 days of cold storage.*

**Keywords.** *Prunus persica*, LDPE, chilling injury, woolliness, storage life.

## Introduction

Peaches (*Prunus persica* L) ripen and deteriorate quickly at ambient temperature. Therefore, cold storage is used to slow down these processes and the decay development. However, chilling injury limits the storage life of peaches under low temperature for less than two weeks in regular atmosphere. Although the fruits have a good appearance when removed from cold storage, they fail to ripen satisfactorily and become dry and mealy or woolly in texture. Reports have related that the use of modified atmospheres (MA) with elevated CO<sub>2</sub> and reduced O<sub>2</sub> concentrations delay or prevent the onset of these chilling symptoms and the storage life of the fruit can be extended (Lurie & Crisosto, 2005). Modified atmosphere packaging (MAP) has been introduced as a less expensive alternative technology to the controlled atmosphere, but different results have been obtained depend on the cultivar and the final CO<sub>2</sub> and O<sub>2</sub> concentration attained at the steady-state (Zoffoli et al., 1997).

The 'Douradão' peach is one of the most important cultivar grown in São Paulo state, Brazil. These fruits have shown preference by consumers whom have mentioned it as having the best qualitative characteristics like sweet taste, intense cover color and big size, and by traders and their clients, mainly due to the higher prices tendency. However, nonripe fruits are subject to chilling injury when exposed to cold temperature, lower than 5 °C, for more than 14 days. Since this disorder is not externally visible, fruits are often marketed at this stage, which can lead to decreased consumer acceptance. The objective of this work was to evaluate the effect of MAP and cold storage on quality and storage life of 'Douradão' peaches.

## Materials and Methods

Peaches (*Prunus persica* L) 'Douradão' were harvested from a commercial orchard in Jarinu, São Paulo, southeast of Brazil under a sub-tropical climate, pre-selected and transported to the Postharvest Laboratory. Fruits were selected according to size and the skin background colour (green-yellow), at commercial maturity, and immediately pre-cooled to 5 °C. Before pre-cooling, 72 peaches were randomly sampled and held in air at 25 ± 1 °C and 90 ± 5% RH during 4 days for ripening. On the same day of harvest (3 trays) and on the 4<sup>th</sup> day of ripening (3 trays, each tray constituted a replicate), the peaches were evaluated for weight loss, decay incidence, flesh firmness, woolliness incidence, soluble solids content, titratable acidity and juice content.

The experiment was carried out in an entirely randomized design where fruits were distributed into five lots, one was held in nonwrapped PP trays (control) kept in air and the others were placed in similar PP trays, inserted in bags of low density polyethylene (LDPE) film where gas mixture of 10 kPa CO<sub>2</sub> + 1.5 kPa O<sub>2</sub> (balance N<sub>2</sub>) was injected and packages were sealed.

(T<sub>1</sub>) **Control**: nonwrapped PP trays;

(T<sub>2</sub>) **MA30**: LDPE film of 30 µm thickness, with CO<sub>2</sub> permeability rate at standard temperature and pressure (CO<sub>2</sub> PR) of 22,021 mL m<sup>-2</sup> d<sup>-1</sup> and O<sub>2</sub> permeability rate at standard temperature and pressure (O<sub>2</sub> PR) of 6,012 mL m<sup>-2</sup> d<sup>-1</sup>. The water vapor permeability rate (WVPR) at 38 °C and 90% RH was 14.1 g water m<sup>-2</sup> d<sup>-1</sup>.

(T<sub>3</sub>) **MA50**: LDPE film of 50 µm thickness, with CO<sub>2</sub> PR of 11,562 mL m<sup>-2</sup> d<sup>-1</sup> and O<sub>2</sub> PR of 2,986 mL m<sup>-2</sup> d<sup>-1</sup>. The WVPR was 6.6 g water m<sup>-2</sup> d<sup>-1</sup>.

(T<sub>4</sub>) **MA60**: LDPE film of 60 µm thickness, with CO<sub>2</sub> PR of 9,577 mL m<sup>-2</sup> d<sup>-1</sup> and O<sub>2</sub> PR of 2,872 mL m<sup>-2</sup> d<sup>-1</sup>. The WVPR was 5.9 g water m<sup>-2</sup> d<sup>-1</sup>.

(T<sub>5</sub>) **MA75**: LDPE film of 75 µm thickness, with CO<sub>2</sub> PR of 7,425 mL m<sup>-2</sup> d<sup>-1</sup> and O<sub>2</sub> PR of 1,705 mL m<sup>-2</sup> d<sup>-1</sup>. The WVPR was 4.1 g water m<sup>-2</sup> d<sup>-1</sup>.

All treatments were stored during 28 days at  $1 \pm 1$  °C and relative humidity (RH) of  $90 \pm 5\%$ . After 14, 21 and 28 days, fruits were taken from cold storage, the LDPE films removed and subsequently the trays were held in air at  $25 \pm 1$  °C and  $90 \pm 5\%$  RH during 4 days for ripening. Quality parameters were determined on the same day of removal and on the 4<sup>th</sup> day of ripening, as mentioned to the fruits at harvest. Three replicates per treatment were obtained to each assayed period.

Changes in O<sub>2</sub> and CO<sub>2</sub> inside the packages were monitored every two days during cold storage using a gas analyzer. (PBI Dansensor) provided with a paramagnetic sensor for oxygen analyzer and an infrared sensor for carbon dioxide. Weight loss was expressed as percentage of initial mass weight. The decay incidence (DI) was determined visually (adapted from Bassetto, 2006) in the fruits surface. The woolliness incidence (WI) was determined visually in both sides of a cut fruit (adapted from Fernández-Trujillo et al., 1998). The flesh firmness was measured on two opposite sides of each fruit using a TAXT-2 Texture Analyser, at room temperature, equipped with a 8 mm tip diameter plunger, operating with the following conditions: 5.0 mm s<sup>-1</sup> pre-test speed, 1.0 mm s<sup>-1</sup> test speed, 5.0 mm s<sup>-1</sup> post-test speed, 9 mm depth and 25% strain (ASAE, 2000). On each day of evaluation, segments from each fruit were homogenized to determination of soluble solids content (SSC) and titratable acidity (TA). Also, the amount of extractable juice was determined using a refrigerate centrifuge (Santana, Benedetti, Sigrist & Sarantopoulos, 2010).

An ANOVA for each attribute was performed using the F test and the treatment means were compared by the Tukey multiple range test at  $p \leq 0.05$ , using the SAS statistical package (SAS, 2003). The values at harvest and after each storage period were compared to find significant differences among treatments.

## Results and discussion

Significant differences in the atmosphere composition among treatments were detected during the cold storage period (Fig.1). An increased in O<sub>2</sub> (more than 1000%) and a decrease in CO<sub>2</sub> level (about 99%) for the treatment MA30 were found and an atmosphere similar to the air within the packages was obtained. No significant differences were detected in O<sub>2</sub> level in the MA50 treatment and the O<sub>2</sub> concentration was maintained at 2 kPa. Although a decrease in CO<sub>2</sub> level (about 65%) within these packages was verified, the CO<sub>2</sub> partial pressure was maintained at 4-3 kPa until the end of cold storage. A decrease in O<sub>2</sub> (about 33%) and CO<sub>2</sub> (about 40%) levels within 60 µm LDPE packages were verified. Both package systems (MA50 and MA60) attended to the recommended level for MAP peaches mentioned by Kader (1997) and they were adequate to pack 'Douradão' peaches. Significant differences were detected in O<sub>2</sub> level at MA75 treatment since the first day of cold storage. The O<sub>2</sub> partial pressure reached very low levels (decrease about 47%). Probably, the O<sub>2</sub> consumption by fruit respiration and the low O<sub>2</sub> package permeability for this application, caused the danger anoxia in the fruit, once 1% O<sub>2</sub> is the minimum safe concentration recommended at low temperatures. An increase in CO<sub>2</sub> concentration (about 20%) was verified, exceeding the recommended level for peaches MAP mentioned by Kader (1997).

The fruits within the Control treatment showed 8.2% weight loss after 28 days cold storage while those peaches packed in LDPE films reached around 0.20% (Table 1) and no differences among MAP treatments were detected.

MAP had positive influence on decay prevention of peaches. Fruits from Control and MA30 decayed after 28 days cold storage plus ripening, reaching more than 16 and 13% rotten fruits, respectively, while others MAP treatments reached about 2% (data not shown). The fruits from MA75 treatment were also affected, reaching 6% rotten fruit due fermentation.

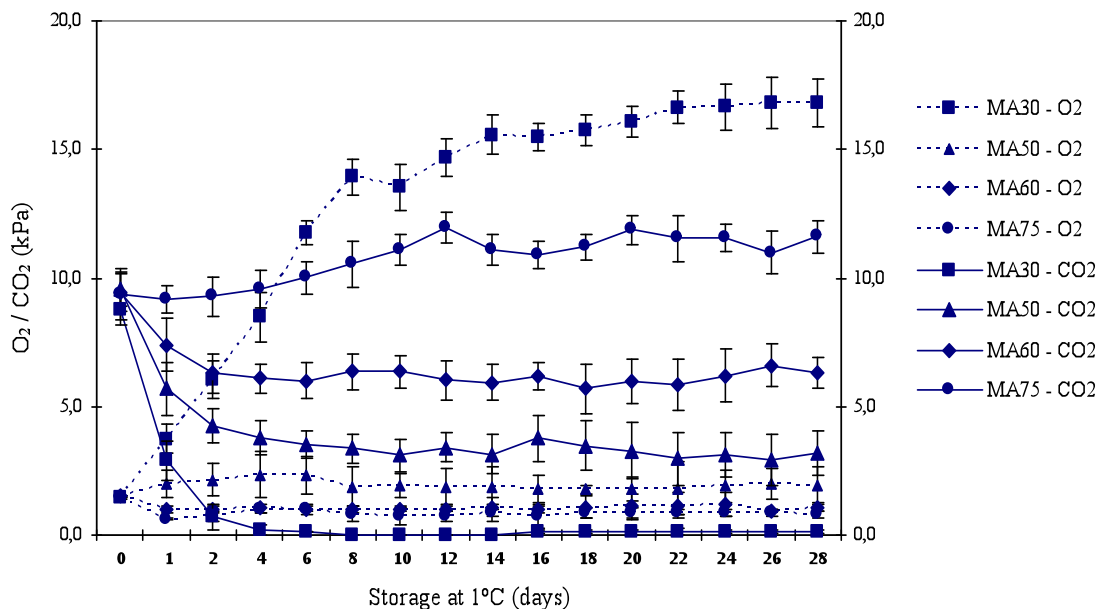


Figure 1. Changes in O<sub>2</sub> (A) and CO<sub>2</sub> (B) partial pressure inside MAP of 'Douradão' peaches and control, stored at 1 ± 1 °C during 28 days. Standard deviation represented by the vertical bar (n=4).

The maintenance of fruit in packages with higher CO<sub>2</sub> concentrations delayed the rising of SSC which increased slightly along the cold storage period. Peaches from Control reached higher levels compared to MAP ones (Table 1). This possibly means that after 28 days cold storage, MAP delayed fruit ripening. After 4 days ripening, a significant increase in SSC was detected under all treatments, with higher increase in fruits from Control. The SSC from MA30, MA50 and MA60 were similar to that fruits evaluated immediately after harvest. Slight or no changes in TA along the cold storage was verified for all treatments.

MAP had great influence on flesh firmness after 28 days cold storage. The softening rate of fruits from Control was proportional to the increase in storage time and weight loss while the peaches packed in LDPE kept higher firmness values and no difference among these treatments were detected. Firmness of the fruits from MA30, MA50 and MA60 treatments were quite similar to that after harvest (Table 1). After ripening, a decrease in flesh firmness was detected for all treatments, with the most significant decrease for the Control.

Just after removing from cold storage, the fruits from Control, MA30 and MA75 presented lower juice content while peaches from MA50 and MA60 reached higher ones. The values from these two treatments were similar to that evaluated after harvest (Table 1).

Woolliness was affected by the MAP treatments. The Control treatment presented more than 40% woolly fruits after 14 days of cold storage and 65% woolly fruits after 28 d. This fact alone makes the storage strategy economically unfeasible. The use of MAP reduced the occurrence of woolliness; fruits from MA50 and MA60 were little affected, reaching only 6% woolly fruits after 28 days of cold storage. The fruit from MA30 and MA75 reached, respectively, 54% and 37% woolly fruits after the same storage period (Table 1).

## Conclusions

MAP had influence on reducing weight loss and prevented postharvest decay; fruit from MAP showed lower SSC and no relevant effect on TA. MAP of 1-2 kPa O<sub>2</sub> and 3-6 kPa CO<sub>2</sub> at 1 °C, obtained with 50 and 60µm LDPE films, were effective for keeping good quality of 'Douradão' peaches during 28 days of cold storage.

The ripe fruits showed reduced incidence of woolliness, adequate juiciness and flesh firmness. Packages of 30 and 75µm LDPE films were ineffective for reducing woolliness during cold storage. Control fruit did not present marketable conditions after 14 days of cold storage.

## Acknowledgements

This research received financial support from the São Paulo Research Foundation – FAPESP, Brazil. The authors thank Air Liquide Brazil for its contribution by granting gas cylinders to this research.

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## Appendix

**TABLE 1** - Weight loss, soluble solids content and titratable acidity of 'Douradão' peaches after harvest and under MAP after cold storage (CS) at  $1 \pm 1$  °C during 14, 21 and 28 days, plus 4 days ripening in air at  $25 \pm 1$  °C.

Treatments	Weight loss (%)		Soluble solids content (°Brix)		Titratable acidity (g malic acid 100 g <sup>-1</sup> sample)	
After harvest	-	+ 4 d ripening 4.41 <sup>x</sup> ± 0.35 <sup>y</sup> AB	9.87 ± 1.29 b	+ 4 d ripening 12.22 ± 1.27 AB	0.27 ± 0.04 a	+ 4 d ripening 0.26 ± 0.02 AB
Treatments	After 28 d CS	+ 4 d ripening	After 28 d CS	+ 4 d ripening	After 28 d CS	+ 4 d ripening
Control	8.20 ± 1.24 a	6.97 ± 0.39 A	11.61 ± 0.71 a	13.36 ± 0.83 A	0.27 ± 0.04 a	0.26 ± 0.02 AB
MA30	0.19 ± 0.06 b	6.77 ± 0.50 A	10.56 ± 0.72 ab	13.14 ± 1.04AB	0.29 ± 0.07 a	0.26 ± 0.04 AB
MA50	0.27 ± 0.10 b	5.51 ± 0.33 B	9.95 ± 0.93 b	11.93 ± 0.89 B	0.27 ± 0.06 a	0.22 ± 0.03 C
MA60	0.14 ± 0.09 b	5.45 ± 0.58 B	9.89 ± 0.78 b	12.13 ± 0.92AB	0.27 ± 0.05 a	0.23 ± 0.03 BC
MA75	0.22 ± 0.08 b	5.33 ± 0.77 B	9.52 ± 0.43 b	10.33 ± 0.93C	0.31 ± 0.04 a	0.29 ± 0.04 A

Treatments	Flesh firmness (N)		Juice content (%)		Woolliness incidence (%)	
After harvest		+ 4 d ripening 5.39 ± 2.12 A. b	69.03 ± 3.16 a	+ 4 d ripening 70.54 ± 2.40 A	0.0 ± 0.0 d	+ 4 d ripening 0.0 ± 0.0 D
Treatments	After 28 d CS	+ 4 d ripening	After 28 d CS	+ 4 d ripening	After 28 d CS	+ 4 d ripening
Control	32.88 ± 9.05 c	3.63 ± 0.92 B	49.86 ± 2.27c	50.92 ± 3.82 C	64.58 ± 3.61 a	91.67 ± 3.61 A
MA30	45.21 ± 9.84 ab	3.99 ± 0.81 AB	50.14 ± 2.58 c	52.45 ± 1.59 BC	54.17 ± 5.55 ab	64.58 ± 3.61 B
MA50	49.68 ± 7.79 ab	5.11 ± 0.32 A	66.88 ± 2.0 ab	68.60 ± 1.71 A	6.25 ± 0.0 c	6.25 ± 0.0 C
MA60	49.93 ± 3.96 ab	5.16 ± 0.43 A	65.42 ± 1.66 b	67.89 ± 1.27 A	6.25 ± 0.0 c	6.25 ± 0.0 C
MA75	40.44 ± 8.69 bc	4.54 ± 1.09AB	52.92 ± 2.84 c	54.70 ± 1.60 B	37.50 ± 4.83 b	54.17 ± 9.55 B

<sup>x</sup>Average and <sup>y</sup>Standard deviation

Small letters compare significant differences between values at harvest and after cold storage under different treatments according to Tukey test ( $p \leq 0.05$ ), for each storage period.

Capital letters compare significant differences between values at ripening after harvest and ripening after cold storage under different treatments according to Tukey test ( $p \leq 0.05$ ), for each storage period.

# Physico-chemical Properties of Tragacanth Gum-based Films

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Written for presentation at the  
2011 CIGR Section VI International Symposium on

Towards a Sustainable Food Chain  
Food Process, Bioprocessing and Food Quality Management

Nantes, France - April 18-20, 2011

**Abstract.** *Emulsion coatings were formulated and films were developed using tragacanth gum as the basic structural component. Preliminary experiments were carried out to determine the proper concentration of tragacanth gum, lipid and plasticizers in the film. The effects of tragacanth gum, oil and glycerol concentration on water vapor permeability (WVP), mechanical properties and opacity (OP) of the films were evaluated using the response surface methodology. WVP increased by tragacanth and glycerol concentration and was decreased by oil concentration. Increasing the amount of tragacanth gum and decreasing the glycerol and oil concentration increased tensile strength (TS) while elongation at break (EB) increased by increasing both tragacanth and glycerol concentration and decreased by increasing oil concentration. Oil was the most influential factor that affected opacity, which increased with increasing oil concentration. Models developed for WVP, EB, TS and OP had high coefficient of multiple determination ( $R^2$ ) values (0.983, 0.952, 0.824, 0.94) respectively.*

**Keywords.** Tragacanth; Barrier - mechanical properties; Opacity; Response surface methodology

## Introduction

Edible films and coatings, which are defined as thin layers of edible material applied to the surface of a food surface as a coating, or placed (preformed) between food components. (Krochta and De Mulder-Johnstone, 1997). Edible coatings can function as barriers to water vapor, gases, and other solutes and also as carriers of many functional ingredients (Lin and Zhao, 2007). Tragacanth gum is the exudates of the plant genus *Astragalus*. The structure of tragacanth gum is highly complex. This gum gives the highest viscosity of all plant hydrocolloids and produces viscous colloidal sols which have a texture similar to that of a soft gel (Zahedi, and Vedadi, 1991). The objectives of this study were to gain a better understanding of relationships between film-forming constituents and film properties, and to analyze the effects of tragacanth gum, glycerol and oil concentration on barrier, mechanical and optical properties of the films using response surface methodology.

## Materials and Methods

In the beginning different concentrations of tragacanth and three types of plasticizers were tested to determine the best gum concentration and type of plasticizer. After rehydrating tragacanth gum in distilled water for 18 h at 20°C, glycerol (kimia drug, Tehran, Iran) was added to the tragacanth solution and thoroughly mixed with magnetic stirring. Then, oil and 30% (lipid dry weight basis) lecithin (Serva, New York, USA) were added and emulsified using a homogenizer (PowerGen 700, Fisher Scientific, Pittsburg, PA). 2.2. Preparation of Tragacanth gum films. Films were cast by spreading emulsions on smooth polyethylene plates. Emulsions were allowed to dry for approximately 18 h at 25°C and 40% relative humidity (RH). Air bubbles in the solutions were removed by placing the plates under vacuum. All films used for the experiments were equilibrated at 53% RH, using a saturated solution of magnesium nitrate (Merck) at 25°C for 72 h before being tested. Film thickness was measured and verified at several positions with a digital micrometer (Mitutoyo Corp., Morton Grove, IL) before the experiments. Film thickness was 0.05 mm after drying.

The ASTM Standard Method E 96–80 (ASTM 1987) was used to determine water vapor transmission by sealing glass cups with the film. Tensile test measurements were evaluated on samples of films using a Dynamic Mechanical Analyser (Sms. Surey.UK, TA X2i Instruments) with a film testing fixture. Film opacity (OP) was determined using a modified standard procedure (BSI 1968).

### 2.6. Experimental Design

A reduced, three-level, response surface factorial design was used to evaluate each main effect, as well as the interaction effects. The three independent variables (factors) were tragacanth gum concentration (T), glycerol concentration (G) and oil concentration (O) of film-forming emulsion. Data were analyzed to fit the following equation to each dependant variable (Y):

$$Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_{12}X_1X_2 + b_{13}X_1X_3 + b_{23}X_2X_3 + b_{11}X_1^2 + b_{22}X_2^2 + b_{33}X_3^2 + b_{123}X_1X_2X_3 \quad (1)$$

where  $b_n$  are constant regression coefficients and  $X_1$ ,  $X_2$ , and  $X_3$  are coded independent variables. The analyses of variance and regression coefficient calculation were carried out using Microsoft Excel. SAS software (1999) was used to perform stepwise procedure to simplify the models. Three dimensional surface plots were generated from obtained models by Sigma Plot (2001).

## 3. Results and Discussion

Results showed that 0.5-2% (w/w) gum can produce proper films, more than 2% (w/w) resulted in very thick solution that plating technique was too difficult, and less than 0.5% w/w gum produced very thin and brittle films. The best plasticizer for the tragacanth gum film-forming solution was glycerol.

### 3.1. Model Development

Equation (1) was fitted to the experimental data. Four equations were obtained and tested for adequacy and fitness by ANOVA. The models developed for WVP, EB, TS and OP yielded high  $R^2$  values and significant F values.

$$WVP = 14.38 \cdot 10^{-11} + 2.8 \cdot T + 7.68 \cdot G - 1.45 \cdot O + 0.988 \cdot T^2 + 1.99 \cdot G^2 + 2.19 \cdot O^2 \quad (2)$$

$$TS = 2.64 + 1.35 \cdot T - 0.399 \cdot G - 0.481 \cdot O + 0.624 \cdot T^2 \quad (3)$$

$$EB = 4.13 + 0.610 \cdot T + 1.42G - 0.237 \cdot O + 0.176 \cdot T^2 + 0.255G^2 \quad (4)$$

$$OP = 286 + 49.46T - 6.44G - 6.80O - 16.6T^2 \quad (5)$$

### 3.2. WVP

Statistical analysis showed that the WVP of tragacanth-based films was influenced by linear effects of tragacanth, glycerol and oil concentration, and quadratic effects of tragacanth, glycerol and oil. The WVP increased with tragacanth and glycerol contents (Fig 1a). This is in agreement with the experiments performed by [Gontard, Weller and Testin \(1993\)](#) with wheat gluten films; [Yang and Paulson \(2000\)](#) with gellan film; [Mali and Grossmann \(2004\)](#) with yam starch films and [Maftoonazad, Ramaswamy and Marcotte \(2007\)](#) with pectin films, all indicating an increase in WVP with an increasing plasticizer concentration. Generally, water vapor transmission through a hydrophilic film depends on both diffusivity and solubility of water molecules in the film matrix ([Gontard and Guilbert, 1994](#)). Inclusion of glycerol molecules between the polymer chains causes an increase in the inter chain spacing, promoting water vapor diffusivity through the film and hence enhancing the water vapor transmission. ([Lieberman and Gilbert 1973](#)).

As shown in Fig 1b, increasing the oil concentration up to 35% (tragacanth gum dry weight basis) decreased the WVP; however, by increasing the amount of lipid more than 35% (tragacanth gum weight basis), WVP was positively influenced. At the very high concentration of lipid the WVP again decreased. At higher concentrations, the lipids could result in larger globules during the drying stage of film making and contribute to disruption of the continuous structure of films, and consequently contributing to higher WVP ([Kamper and Fennema, 1984](#)). At the very high concentration of lipid WVP decreased (Fig 1c). It seems that the film has changed to a bilayer film. It means that one layer of lipid is formed on the surface of the film.

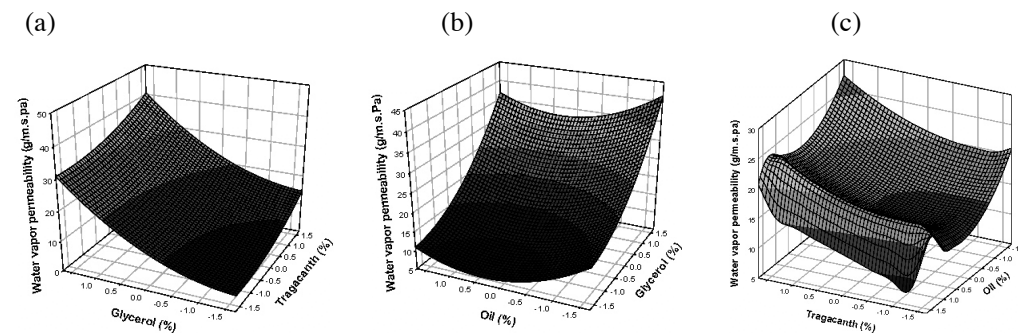


Fig. 1. Water vapor permeability: (a) effects of glycerol and tragacanth gum concentration; (b) effects of oil and glycerol concentration and (c) effects of oil and tragacanth gum concentration

### 3.3. Mechanical Properties

In general, an edible film must withstand the normal stresses encountered during its application, subsequent shipping and handling of the food, to maintain its integrity and also barrier properties (Gontard, Guilbert and Cuq, 1992). TS is a measure of integrity and heavy-duty use potential of films, and EB is a quantitative representative of the film's ability to stretch (Gennadios, Weller and Testin, 1993). A wide range of magnitude: TS ranged from 0.65 to 7.15 MPa and EB between 1.99 to 7.8%. The TS of tragacanth-based films was influenced by the linear effects of tragacanth ( $P < 0.01$ ), glycerol and oil concentration ( $P < 0.05$ ), and quadratic effects of tragacanth. Tragacanth films exhibited an increase in TS by increasing tragacanth concentration (Fig 2a and 2b). The response surface tends to indicate that high tragacanth concentration induces the formation of a resistant film with a high TS. The most resistant films could be expected to be formed at high tragacanth concentration (2g/100 mL). As seen in Fig. 3a, this point is at the most upper part of the surface plot. In fact by increasing the amount of glycerol, the TS of the film decreased. The weakest films came at the lower amounts of tragacanth (0.63 g/100 mL) and higher amounts of glycerol (67% tragacanth dry weight basis). As a result, direct interactions between the molecular chains are reduced, and the chain segmental mobility is increased, causing the mechanical strength of the films to decrease (Yang and Paulson, 2000). The same results were observed by Yang and Paulson (2000) for gellan films plasticized by glycerol, Gontard et al. (1993) for wheat gluten films and Maftoonazad et al. (2007) for pectin films plasticized by sorbitol.

Figure 2c shows the effect of oil concentration on the film's TS. Increasing the amount of lipid in the film structure decreases the film's TS. Debeaufort and Voilley (1995) showed that the smaller the lipid globule diameters and that the higher their homogeneous distribution within the methylcellulose matrix were, the higher the TS and percentage of elongation were.

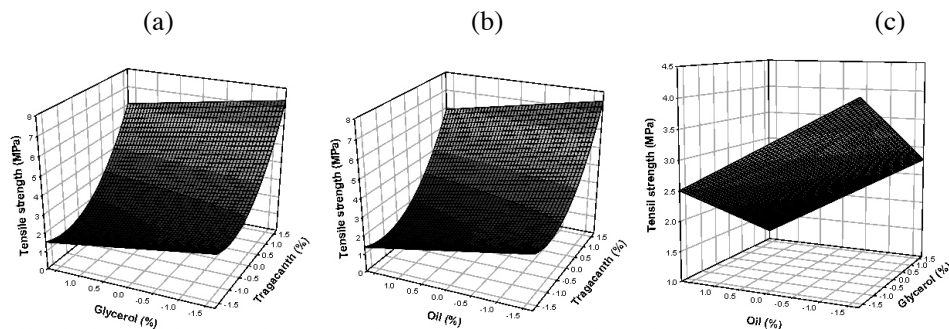


Fig. 2. Tensile Strength: (a) effect of glycerol and tragacanth gum concentration; (b) effect of oil and tragacanth gum concentration and (c) effect of oil and glycerol concentration

The EB of tragacanth-based films was influenced by the linear effects of tragacanth ( $P < 0.01$ ), glycerol ( $P < 0.01$ ) and oil ( $P < 0.05$ ) concentration and the quadratic effects of tragacanth and glycerol.

Tragacanth films exhibited an increase in EB with increasing tragacanth concentration (Fig 3a and 3b). Increasing the amount of glycerol molecule also increased the EB (Fig 3c). It could thus be expected the most stretchable films to be formed at the largest concentration of glycerol (67% based on tragacanth dry weight basis). The lowest EB was observed at the lowest

concentration of glycerol used (23% based on tragacanth dry weight basis). In addition, as mentioned before, increasing the amount of plasticizer decreases the film resistance.

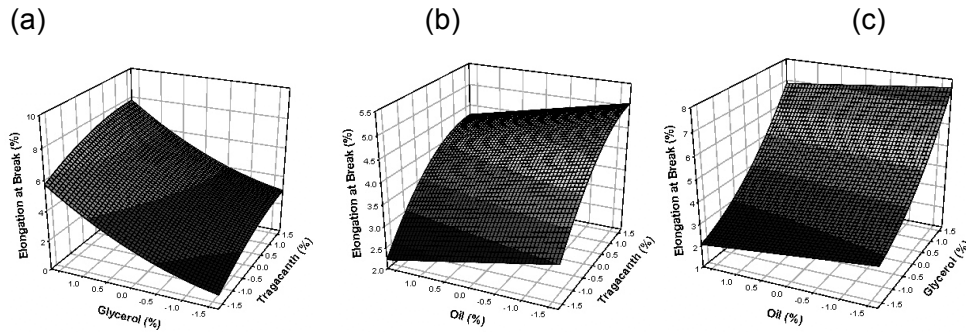


Fig. 3. Elongation at Break: (a) effect of glycerol and tragacanth gum concentration; (b) effect of oil and tragacanth gum concentration and (c) effect of oil and glycerol concentration

### 3.4. Opacity

To have a transparent film, the opacity of the film should be low in relative value. The most important factor with respect to film opacity is the oil concentration. The linear effect of oil, the quadratic effect of glycerol and oil and the interaction of tragacanth, glycerol and oil were found to be significant. It could be expected that the most transparent film to be formed is at the lowest oil concentration (23% based on tragacanth gum dry weight basis) (Fig. 5).

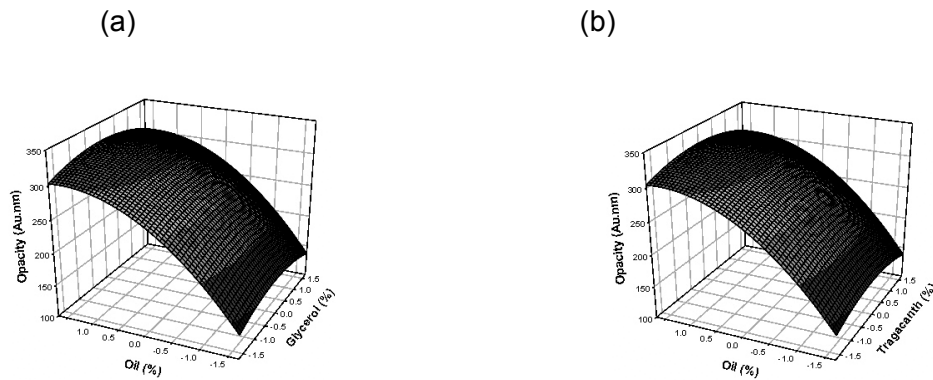


Fig. 5. Opacity: (a) effect of glycerol and tragacanth gum concentration and (b) effect of oil and tragacanth gum concentration

## 4. Conclusion

Film components had a marked influence on film properties. Tragacanth gum and glycerol concentration had significant effects on WVP and mechanical properties. Oil concentration influenced WVP, mechanical properties and opacity significantly. The use of response surface methodology was effective for the study of complex film-forming conditions and the effect of different variables.

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## Potential Applications of Biodegradable Films Prepared with Fish Proteins and Essential Oils to Preserve Food Products

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### Abstract.

*The essential oils of garlic, origanum, citronella, coriander, clove, thyme and tarragon have been referred as having potential application as antioxidant and antibacterials agents against the growth of pathogenic and spoilage bacteria in food products. However, the application of these essential oils directly on food products to increase their shelf-life has a negative impact on sensory attributes (principally on odour).*

*In recent years, packaging research has focused on biodegradable films as substitutes of synthetic plastics. Fish proteins have been successfully used for the preparation of biodegradable films, and can be used as carriers of substances (e.g. essential oils) with bioactive properties (antibacterial and antioxidant activity) as a form of active packaging.*

*In this context, the aim of this work was to characterize different attributes of biodegradable films prepared with fish proteins and incorporated with essential oils. The fish proteins were recovered by alkaline solubilization from Cape hake by-products suitably handled and preserved and films were prepared by alkaline solubilization of proteins in order to obtain films with 4 mg of protein per cm<sup>2</sup> and 1 µL of essential oil per cm<sup>2</sup>. Films antibacterial and antioxidant activities were evaluated, as well as their mechanical, physical and optical properties.*

*Films incorporated with essential oils reduced the activity of seven foodborne pathogenic and spoilage bacteria, revealed antioxidant activity (e.g. radical scavenging activity and ferric reducing power) and a considerable decrease of the essential oils odour was obtained. The addition of essential oils into films affected mechanical, physical and optical properties (e.g. decreased the puncture force, elongation at break and water vapour permeability) compared with films without essential oils.*

*In conclusion, fish protein based films incorporated with substances with bioactive properties have a very good potential application to ensure the safety of food products and to increase their shelf-life.*

**Keywords.** Essential oils, antibacterial activity, antioxidant activity, biodegradable films, fish proteins based films.