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Ait-Oubahou A.

in

Gerasopoulos D. (ed.).
Post-harvest losses of perishable horticultural products in the Mediterranean region

Chania : CIHEAM
Cahiers Options Méditerranéennes; n. 42

1999
pages 103-113

MODIFIED ATMOSPHERE PACKAGING OF TOMATO FRUIT

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Abstract

Weight loss, decay and rapid deterioration are often the major factors that determine the storage and marketability duration of fruit and vegetables. These factors depend among others on fruit quality and physiological stage and the atmosphere surrounding the fruit. Tomato fruit kept within sealed packages resulted in an atmosphere with high carbon dioxide and low oxygen content. These conditions retained flesh firmness, low acidity and soluble solids concentration and delayed fruit lycopene development. This paper reports on modeling for optimizing a modified atmosphere package and the effect of achieved conditions on fruit characteristics and attributes.

1. INTRODUCTION

Since the work of Kidd and West (1932), many researchers demonstrated the benefits of modifying the atmosphere of the storage unit. Controlled atmosphere (CA)and Modified Atmosphere Packing (MAP) have been extensively studied for different commodities. Several researchers reported the benefits of MAP on keeping fruit quality and extending shelf-life (Henig, 1975; Daun and Gilbert, 1975; Hobson, 1981, Geeson *et al.*, Cameron *et al.*, 1989; Ait-Oubahou *et al.*, 1990). Despite the advantages of this technique, several draw backs still limit the wide use of the technique and need to be solved. When fruit respiration does not match film permeability characteristics, adverse concentration of CO_2 and very low concentrations of O_2 will build up and fruit fermentation will follow. These conditions are often responsible for the off flavors and rotting of the fruit inside the package unit. The objective of this work is to report on modeling of MAP for tomato fruit. The method followed herein was adopted with modifications from Cameron *et al.*, (1989) and Ait-Oubahou *et al.* (1990) for experiments conducted on different horticultural commodities in order to ameliorate chilling injury occurring during exposure to low temperature during storage and subsequent transfer to relatively warm temperature. Only results of green pepper and eggplant fruits are presented and commented herein.

2. MATERIALS AND METHODS

Tomato fruit of long shelf-life Daniella hybrid, were obtained from a commercial farm in the area of Agadir located less than 2km south of the Institute. Fruits were harvested early in the morning and transported to the laboratory for different experiments. Fruits were sorted, washed, disinfected with chorine, rewashed and separated into three lots composed of mature green, turning and red color. Fruits are packed on the same day of harvest in low density polyethylene firm (LDPE) of 44.4 ìm thick. Six different weights of fruits ranging from 140 to 640 $\pm$ 5 grams were packed in 800 cm^2 area and stored at $20\pm2°$ C. Each treatment is composed of 18 sealed packs and 12 perforated bags as controls. Six packs form each treatment were used to evaluate storage duration, while 4 packs from each treatment were sampled at weekly for internal and external quality attributes.

Analysis of MAP atmospheres

The concentration of carbon dioxide and oxygen within the packed units were measured by withdrawing daily 2 x 1 ml of the gas in the headspace of the packages by inserting a hypodermic needle with 1 ml volume plastic syringe through a silicone rubber fixed onto 1 cm^2 electric black tape on the plastic bag. The samples were injected into a Gas Chromatograph (Carle series 100) for analysis. Gas sampling was made daily until the steady state was reached.

Fruit quality assessment

Each week, samples were removed from the packaged units and analyzed. Fruit color was determined by a Minolta Chromameter 200 CR-200 and the "a" value of the Hunter L, a, b coordinates was recorded at four different parts of the fruits on its equatorial zone. Fruit flesh firmness was assessed using a motorized penetrometer fitted with a 2 mm diameter probe. The reading were recorded on kg force. Other analysis include weight loss (%), acidity, soluble solids concentration and percent of decay. The storage duration was determined for each treatment.

Data analysis

Results of weekly measurements of quality were analysed following analysis of variance and separation of means was performed using Newman and Keuls method at 5% level.

3. RESULTS AND DISCUSSION

The steady state was reached between 4 to 9 days depending on each treatment Concentrations of carbon dioxide and oxygen within the package depend on weight and fruit physiological stage of each treatment (Fig. 1). These concentrations vary from 1.7 to 4.9 and 10.2 to 2.3 KPa respectively for the Co_2 and O_2 with little variations between different fruit stages. Theoretical curves for O_2 and CO_2 were developed for each stage as shown in Fig. 2. The best fit curve for O_2 concentration within the package at steady state for different fruit weights has the following equation form:

$Y = a * \exp(b*X) + c$ **Equ. 1**

Where: Y = Oxygen concentration (Kpa) and a, b and c are arbitrary constants and their values are given in table 1. X = fruit weight (kg)

Table 1. Values of different constants of equation 1 for different fruit

Fruit stage	a	B	c
Mature green	12.03	-3.67	2.15
Turning	13.24	-3.87	2.17
Red	11.45	-2.91	2.29

Based on Fick's Law, the flux of O2 that goes through the film barrier can be calculated as follows:

J_{O2} (Film) + P_{O2}*A/T)*$[O_2]_{atm}$ - $[O_2]_{pkg}$) **Equ. 2**

Where: J_{O2} = Flux of oxygen through the film ($mmol.hr^{-1}$)

PO2 = Permeability coefficient of O2 (mmol.kPa-1.hr-1.cm-1)

A = Package area (cm2), T - Film thickness (cm)

[O2]atm = Oxygen partial pressure in the atmosphere (kPa)

[O2]pkg = Oxygen partial pressure in the package (kPa)

PO2 and PCO2 = *exp(-b/T+273)

T = Film thickness (cm)

At steady state and if we assume that the oxygen uptake represents the amount of the oxygen that passes through the fruit skin and that the resistance of the skin to oxygen is not a major barrier, fruit respiration rate can be then expressed in the following manner:

$$RR_{O2} = \frac{\{Po2*A}{T} \{[O_2]_{atm} - [O_2]_{pkg})\} / W$$ Equ. 3

Where RR_{O2} = Fruit respiration rate ($mmol.kg^{-1}$.hr-1) and

W = Fruit weight (kg).

The respiration rage can also be characterized by the carbon dioxide production and modeling approach for MAP is similar. In this study, we report only on oxygen concentration approach.

Using oxygen values obtained within packages at steady state for different treatments, respiration rates are calculated for each fruit stage and the best fit curve form is given by Equ. 3.

RR_{O2} = a * (1-Exp(-b * X) **c **Equ. 4**

The values of constants a, b and c are given in Table 2.

Table 2. Values of constants a, b and c of equation 3 describing the respiration rate of different fruit stages.

Physiological stage	a	b	c
Mature green	5.08	0.01	1.05
Turning	0.93	0.07	1.18
Red	1.42	0.06	1.56

After substitution of respiration rate and rearrangement of equation 3, film characteristics and fruit weight will be obtained for desired oxygen concentration at steady state. For different fruit weights to be packed for desired oxygen levels at equilibrium, film characteristics is determined as follows:

$$\frac{P_{O2} * A}{T} = \frac{a * (1 - \exp(-b*[O_2]_{emb}))}{[O_2]air - [O_2]_{emb}} \qquad \textbf{Equ. 5}$$

This relationship is used to generate data of film characteristics according to different fruit weights within the package. The results of this method are illustrated in Fig. 3. The same approach is used to generate data of fruit weights for different film characteristics and for different oxygen concentrations as shown in Fig. 4

Figures 3 and 4 permit a prediction of a given O_2 concentration at steady state, film thickness, surface area and oxygen permeability coefficient of the film. For instance, if we wish to package 1.2 kg of red tomato and under 5 to 7% O_2 at steady state, Fig. 3 indicates that the film characteristics to be used in order to attain these conditions should vary from 0.015 and 0.026. Similarly, if the P_{O2}*A/T is known, fruit weight can be obtained from fig. 4 for any desired oxygen levels within the package.

Fruit quality assessment

Table 3 shows the fruit color changes as illustrated by the "a" value of the Minolta chromameter.

From this table it is clear that increasing fruit weight within the package tended to delay the color changes. Fruits remain much greener than the control or within the bags with low fruit weights. This fact is very relevant when the fruits are packaged at mature green stage. The delay in lycopene development is caused by the gaseous conditions (high CO_2 and low O_2) developped in the package. Film packaged fruit in 4 to 6% O_2 had a better external color and no shriveling was apparent as in the control. However, bags with high fruit weight packed at mature green stage show fruits with yellow color after long term storage at warm temperature. Meanwhile, bags with fruit weights varying from 0.1 to 0.4 kg developed a full red color.

It appears from Fig. 5 that fruits kept in perforated bags or in bags with low fruit weight show the highest weight loss during the storage period. While the control lost during storage at 20° C more than 17%, MAP fruits of different physiological stages at the same period show less than 2% of weight loss.

Table 3 effect of plastic film and storage duration on external color changes for tomato fruit.

Fruit stage	Fruit weight (kg)	Storage during (days)			
		7	14	21	28
Green	Control	21.5	25,79	29.53	-
	0.1	13.3	23.78	24.09	26.6
	0.2	-0.03	18.43	23.97	25.3
	0.3	-3.75	3.65	21.7	24.1
	0.4	-5.39	-1.42	12.8	18.0
	0.5	-7.18	-5.0	-3.7	17.01
	0.6	-8.6	-5.2	0.06	12.0
Turning	Control	25.67	29.98	-	--
	0.1	20.3	4.1	26.8	27.21
	0.2	18.51	23.69	24.0	26.14
	0.3	13.10	21.3	23.73	25.41
	0.4	10.43	13.25	20.9	22.73
	0.5	-0.02	7.31	19.7	20.98
	0.6	-0.03	4.32	12.7	20.31
Red	Control	29.32	35.62	-	-
	0.1	24.32	25.6	27.3	29.19
	0.2	23.9	24.8	26.13	26.69
	0.3	23.79	24.12	25.622	26.32
	0.4	23.63	24.06	25.0	25.17
	0.5	23.61	23.9	22.7	21.8
	0.6	23.59	22.48	22.14	21.67

Fruit ripening was delayed when fruit are packaged in MAP. Table 4 indicates that concentrations of oxygen between 3 and 6% obtained with weights of 0.34 to 0.64 kg show high juice content, low acidity and low soluble solids concentration. Flesh firmness is also retained with 0.4 kg weight in the bag (Fig. 6). Retardation of ripening of tomato by gas modification was repeatedly reported by several workers on CA or MA studies (Hobson, 1981; Geeson *et al*, 1985, Cameron *et al*, 1989).

Table 4: Internal quality[x] of red tomato fruit as influenced by modified atmosphere packaging conditions during storage at 20°C.

Weight (kg)	Oxygen (%)	pH	Juice content (%)	Acidity (%)	Soluble solids (%)
At harvest		3.12	43.8	0.63	4.95
0.1	12.97	4.43b	46.7a	0.42a	5.28b
0.2	9.39	4.34ab	49.3a	0.43b	5.17ab
0.3	6.28	4.32a	49.6a	0.44bc	5.13ab
0.4	5.61	4.31a	50.3a	0.45	5.08a
0.5	4.44	4.30a	49.9a	0.46cd	5.06a
0.6	2.95	4.29a	50.4a	0.46cd	5.03a

[x] Values within columns followed by the same letter are not significantly different at 5% level of Newman & Keuls method.

The duration of storage of fruits under MAP at ambient temperature (= 20° C) was more than two months (Fig. 7). Although, it might appear that the duration is exaggerated, data of three years of experiments show an average length of storage duration of 6 to 8 weeks. Boylan-Pett (1986) reported 41 days of storage at 20° C.

This length in time is based first on external appearance and second on quality attributes. For the latter parameter, fruits after extended storage period had developed an off flavor which indicates the onset of fermentation. This undesirable flavour disappears in some cases after fruits are exposed to air for 12 to 24 hours. MA packages tended to increase the number of fruits with decay. The pathogen development are important when fruits are packed with their calyx or when CO_2 build up within the package is excessive. Fruit decay was positively correlated with fruit weight in the bags.

This study shows that MA packaging is a promising alternative approach to prolong postharvest life of tomato at warm temperatures. Design and optimization of the package was discussed. Modification of O_2 and CO_2 in the atmosphere surrounding the commodity by selecting a suitable film and fruit physiological stage could improve fruit quality, reduce weight loss and other wastage and consequently increase the life harvested tomato.

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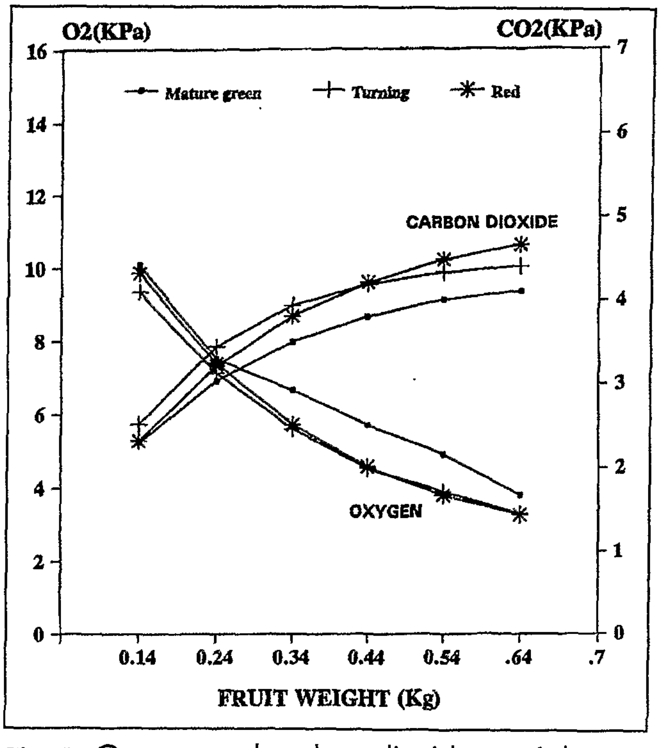


Fig. 1. Oxygen and carbon dioxide partial pressures (kPa) at steady state for tomato fruits at an ambient temperature (20 $\pm$ 2^0 C)

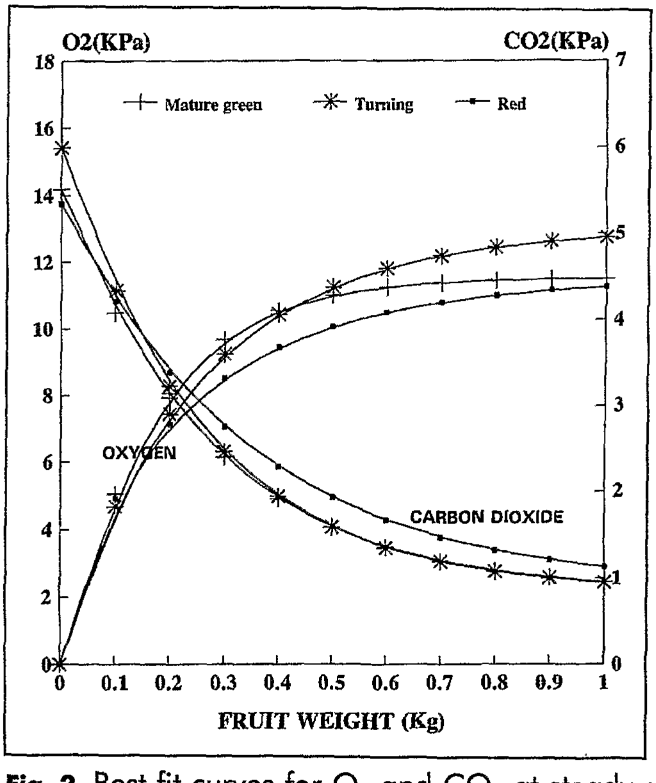
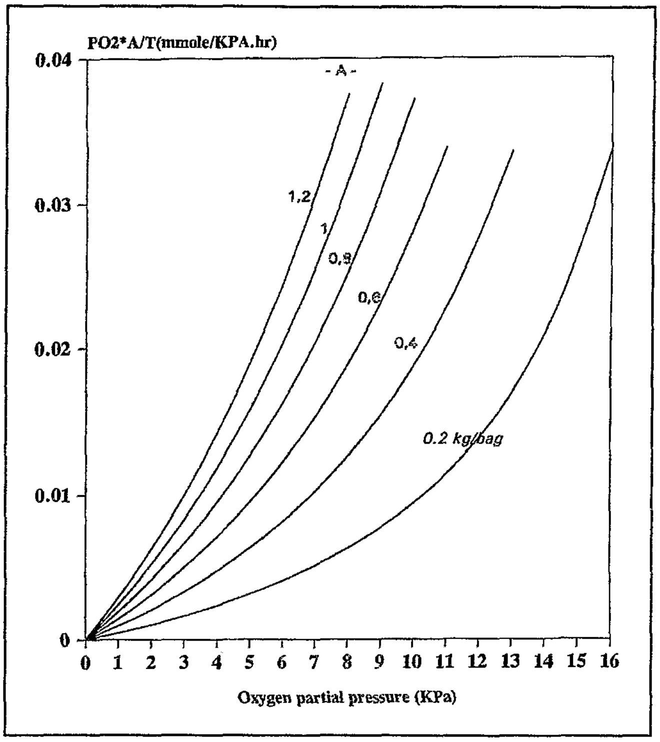
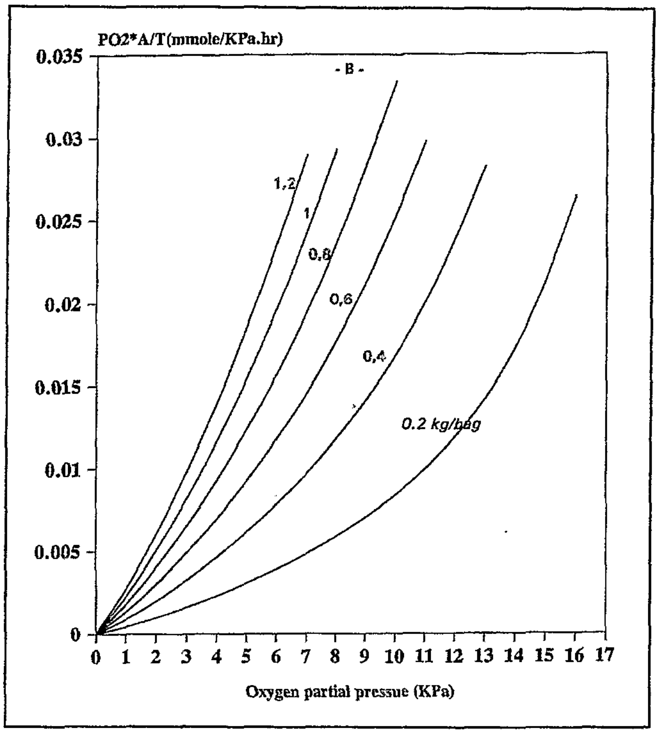


Fig. 2. Best fit curves for O_2 and CO_2 at steady state for different fruit weights within packages stored at ambient temperature (20 $\pm$ 2^0 C)





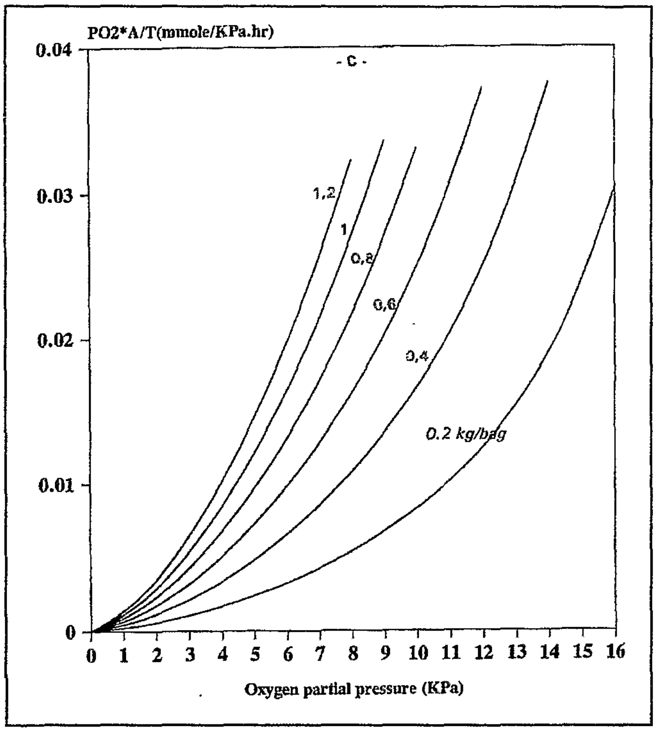


Fig. 3. Prediction of film characteristics (mmol/kPa.hr) for different fruit weights (kg) and fruit physiological stage (A) mature green, (B) turning and (C) red color for desired oxygen partial pressure (kPa) at steady state.

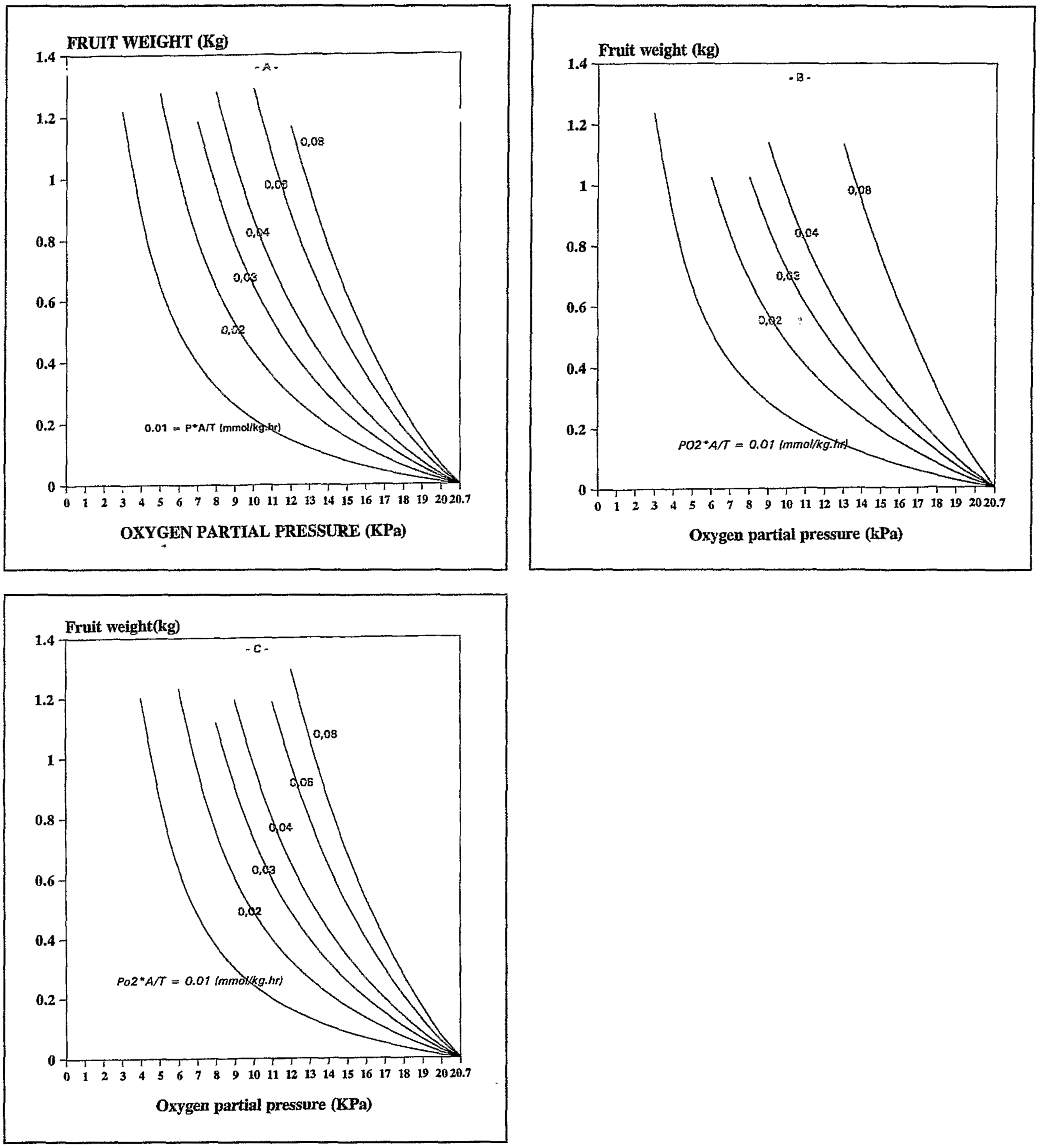


Fig. 4. Prediction of fruit weight (kg) for different film characteristics (mmol/kPa.hr) and oxygen partial pressure (kPa) for different fruits mature green (A), turning (B) and (C) red color.

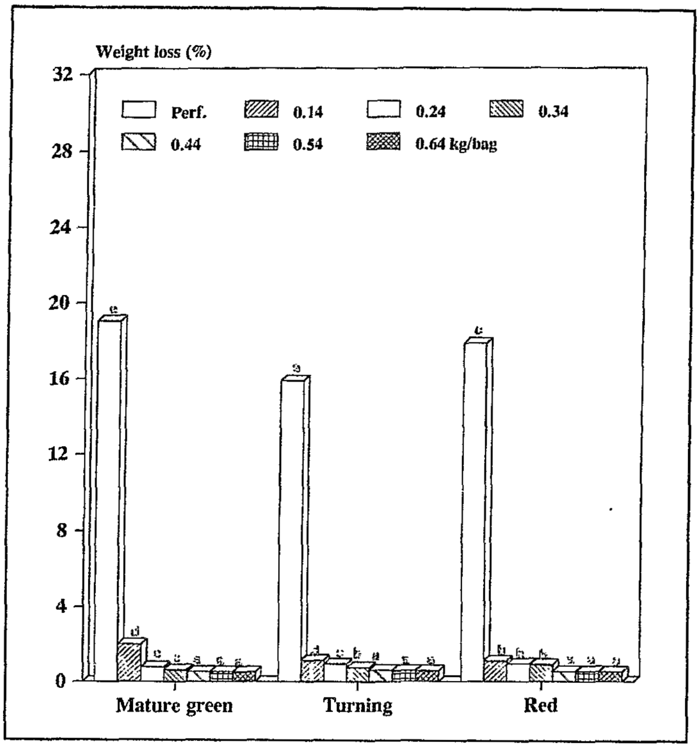


Fig. 5. Weight loss (%) of tomato fruits kept in MA packaging at ambient temperature

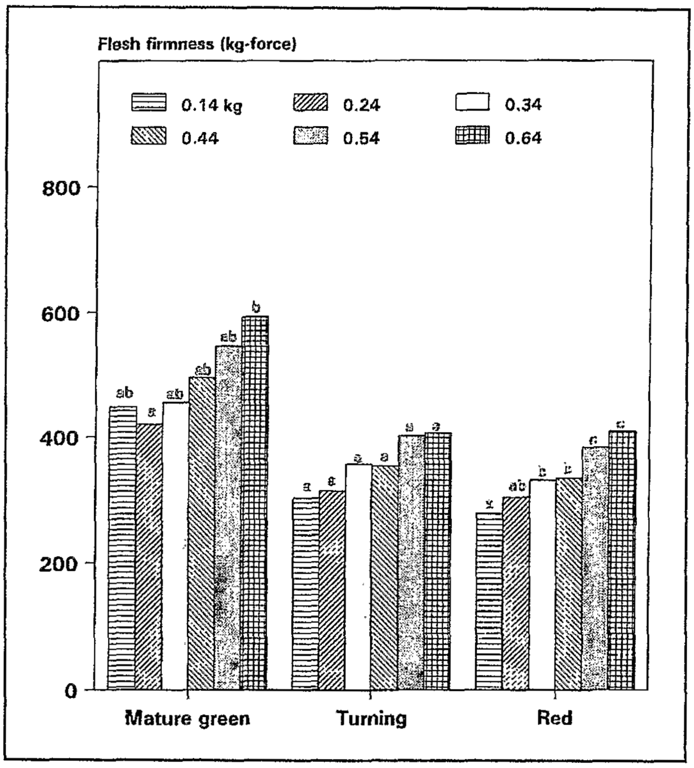


Fig. 6. Flesh firmness (kg-force) of tomato fruits from packages with different fruit weights after 4 weeks of storage at ambient temperature.

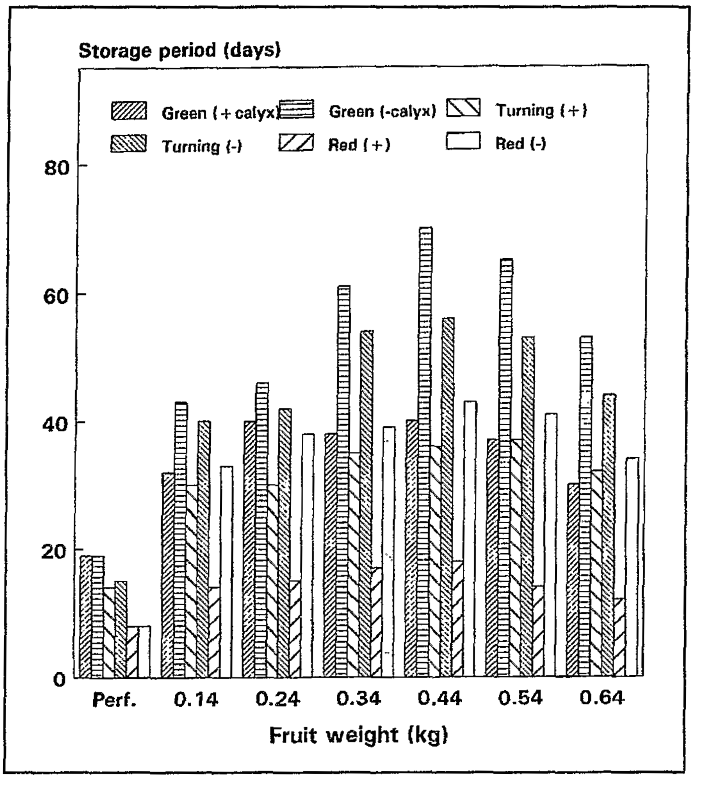


Fig. 7. Storage duration (days) of tomato fruits with or without calyx stored at ambient temperature for 4 weeks of storage.