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Pear Fruits Ripening Response to Ethylene and Temperature Treatments

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ABSTRACT

An experiment was carried out on two cultivars of pears (Pyrus communis L.) spadona and compote cv. with a factorial complete randomized design to study the effects of ethylene and temperature treatments on fruit ripening. The experiment included three treatments in addition to the control which was remaining the fruits on trees, the first treatment was keeping the fruits at 7 C° with exposure to ethylene gas (300 mg/l) for 24 hours, the second and third treatments were putting the fruits in the ripening cabinet at room temperature 20±1 C° either for 8 days, or 12 days. Results indicate that the compote cultivar differed significantly in decreasing weight loss and fruits firmness and increasing fruits peel pigments content and peroxidase enzyme activity compared to the spadona cultivar. A slower ripening process was gained from control treatment where the fruits remained non-ripened compared to other treatments, whereas ripening fruits at 20±1C° for 12 days fastened the ripening process by giving the highest TSS, and weight loss percent, besides lowest fruits firmness. For the condition of northern Iraq, the best treatment for ripening pear fruits is to treat them with ethylene gas or ripen the fruits at 20±1C° for 8 days.

1. INTRODUCTION

Pears fruits (*Pyrus communis* L.) are considered as an important climacteric fruit that grows in the temperate zone. It is cultivated in the middle and northern parts of Iraq depending upon the cold requirement for breaking dormancy, where in Iraq, pear trees are cultivated in an area

reaching 1293 hectares giving 8625 tons in 2019 [1, 2].
Most of European pears, unlike climacteric fruits, resist ripening at harvest even when they are picked in a suitable physiological ripening stage [3], therefore artificial ripening is the choice. Artificial ripening is important for many fruits that cannot ripen easily on trees, like pears and bananas. It is a process that aims at enhancing ripening to obtain an early price [4]. This process helps in artificial ripening activation of different chemical and physical changes in fruits to gain fruits ready to eat earlier than the natural ripening.
There are many methods for fruit ripening in each locale and chemicals are used. For the chemical methods, ethylene (CH_2=CH_2), the natural gaseous plant hormone, is used for this purpose. The application of ethylene gas at limited recommended concentrations is used worldwide for fruit ripening in large-scale and commercial states [5]. Ethylene treatments induced the changes that combined with the ripening process, like, decreasing in fruit firmness, disappearing the green color due to analyzing the chlorophylls and appearing the carotenoids and other coloring pigments, and synthesizing the distinguished variety of color, sugar accumulation, lowering acidic content, converting non-soluble pectin to soluble pectin, disappearing bitter and astringent tastes, and increasing fruit respiration in climacteric fruits [6, 7].
Many studies were conducted about the effects of temperature and ethylene as ripening treatments on pear, such that of Sugar and Einhorn [8] and Makkumrai et al. [9] or the effects of both factors such that of Chino et al. [10], whom they found that most chemical and physical characters of pear can be altered significantly, where these factors are used.
This study aimed to compare some ripening treatments including ethylene and temperature on edible characteristics of two cultivars of pear.

2. METHODS AND MATERIALS

2.1Plant Materials and Ripening Treatments

Yellow-green fruits of two cultivars Spadona and Compote cv. of (*Pyrus communis* L.) were selected and considered as the first factor of the experiment which was conducted in two-way factorial-CRD, each cultivar fruits divided into four groups which were the levels of the second factor (three ripening treatments, in addition to the control); the first group was the control in which fruits remained on trees without any treatment (Table 1), fruits of the second group kept in the ripening cabinet at 7 C° and exposed to ethylene gas (300 mg/l) for 24 hours, fruits of the third group placed in the ripening cabinet at ambient temperature 20±1 C° for 8 days, and fruits of the fourth group putted in the ripening cabinet at the ambient temperature of 20±1C° for 12 days. The experiment data was taken in two different seasons; 2015 and 2016.

Table 1: Table 1: Average of temperature, relative humidity, and amount of rainfall during the remaining fruits on trees for the control, throughout 2015 and 2016.

Month (Cultivars)	Air Temperature C°		Relative Humidity %		Rainfall (mm)	
	2015	2016	2015	2016	2015	2016
June (Spadona)	35.2	34.5	59.0	50.8	-	-
October (Compote)	23.5	23.9	86.4	52.6	98.9	0.4

2.2Studied Characteristics

Where the ripening period was ended, the following parameters were recorded in the laboratories of Koya University as follows: weight loss which calculated as a percentage of the loss of water in comparison with the initial weight [11], fruits firmness measured on pared surfaces on the opposite sides of each fruit using a penetrometer with a 7.9 mm diameter tip and expressed in terms of kg/cm2 [12], total sugars were estimated according to Joslyn [13] by using mixing 1 ml of the sample extraction with (5%) Phenol, and 5 ml concentrated sulfuric acid (H_2SO_4), by using a spectrophotometer at absorbance 490-nanometer wavelengths, the absorbance for different solutions was taken. Standard solutions were

prepared from glucose. Total soluble solids (TSS) was estimated in freshly prepared juice by using a hand-refractometer according to A.O.A.C. [14], total acidity estimated by titrating freshly prepared juice with 0.1N sodium hydroxide, and phenolphthalein as indicator, expressed as mg of malic acid per gram as it mentioned in Ranganna [15]. The reference that total chlorophylls and carotenoids pigments were determined, where 0.25g of fresh fruits peel of each experimental unit were taken, then mixed with 10 ml 80% acetone, 1 ml of this extraction was taken to add to 9 ml of acetone, chlorophyll a, chlorophyll b and total chlorophyll were measured by a spectrophotometer (PD-303) at 642 nm, 660 nm, and 470 nm wavelengths. Finally, peroxidase enzyme activity as absorbing units per gram of fruit was determined as mentioned in Nezih [16] by weighing 0.1 g of fresh fruit with 10 ml of buffer solution put in a blender then filtered by medical gauze and got the sample extract. Then a mixture of 0.1 ml of the sample extract, 1 ml of H_2O_2 solution, and 1 ml of guaiacol solution has been prepared, then, directly afterward measured in a spectrophotometer (GENESYS 10 UV Spectrometer, Thermo Electron Corporation, USA) and recorded the result at 420 nm wavelengths.

2.3Statistical Analysis

A complete randomized design as factorial experiment Two-way ANOVA CRD (two cultivars x four ripening treatments) with 3 replicates was used in this study. Analysis of variance was used for data analysis by using the SAS program. Duncan`s multiple range test ($P \leq 0.05$) was used for comparing the treatment's means [17].

3. RESULTS and DISCUSSION

Results in tables 2,3 and 4 showed that the compote cultivar records the lowest values ($P \leq 0.05$) of weight loss (1.59 and 3.78%), total acidity (0.87 and 1.41%), peroxidase enzyme activity (2.53 and 1.84 absorbing unit/minute/ml) for both study seasons, chlorophyll b (0.09 mg/ml) and total chlorophylls (0.17 mg/ml) for second season, whereas it records the highest values of fruit firmness (14,13 and 20.42 Kg/cm^2), total sugars (16.72 and 12.26%), TSS (12.90 and 13.00%) for both seasons, a, b and total chlorophylls and total carotenoids (0.08, 0.14, 0.22 and 0.09 mg/ml) for first season compared to spadona cultivar. Although, the time of fruit maturing and remaining on trees was different between spadona and compote cultivars; June for spadona and October for compote (Table 1), most of the differences in characteristics of the two studied cultivars are controlled by genetic factors [18] as a result of differences in internal hormones, enzyme activities, and fruit structure, where fruits with more cells density and less internal spaces are firmer [19, 20], which reflects on the characteristics of the cultivars of the same species to a significant level, as shown in weight loss, fruit firmness and total sugars (Table 3 and 4).

Regarding ripening treatments, from the results of the same tables, it appears that the control had the slower ripening process for both seasons where it recorded the lowest values of weight loss (0%), total sugars (12.11 and 8.55%), TSS (11.90 and 11.77%), peroxidase enzyme activity (2.50 and 2.38%) and total carotenoids (0.04 and 0.14 mg/ml) compared to other ripening treatments that record highest values significantly of fruits firmness (14.97 and 19.00 Kg/cm^2), total acidity (1.59 and 1.83 %) and total chlorophylls (0.27 and 0.38 mg/ml) for both seasons respectively. Fruits ripened at 20±1C° for 12 days increased significantly fruits weight loss, total sugars, TSS and total carotenoids, whereas it decreased significantly fruits content of chlorophyll a, b and total carotenoids compared to the control and ethylene ripening treatment.

Regarding the interaction effects between the cultivar and ripening treatments, the trend was the same for each factor individually, where interactions of compote cultivar with different ripening treatments recorded the lowest values in respect to each of fruits weight loss, total acidity, peroxidase activity, and with the highest fruit firmness, total sugars, TSS, and total carotenoids characteristics compared to the spadona cultivar. From the results, it was clear that the ripening process for control fruits was slower compared to other treatments for both compote and spadona cultivars. For all studied characteristics, it is also clear that the response

of the spadona cultivar to ethylene was greater than the response of the compote cultivar in most studied characteristics (Table 2, 3 and 4). Faster ripening was seen when fruits ripened in a chamber with 20±1 C° for 12 days for both spadona and compote cultivars.
The fruit's weight loss during the ripening process may be due to the sudden increase in the respiration rate [22], or because of the ongoing respiration and transpiration processes during ripening [23].

Table 2: Effects of cultivar, ripening treatments, and their combinations on fruit weight loss, firmness, and total sugars during two seasons for spadona and compote pear cultivars.

Treatments	Weight Loss (%)		Firmness (Kg/cm^2)		Total Sugars (%)	
	2015	2016	2015	2016	2015	2016
Cultivars						
Spadona	6.10^{a}	8.10^{a}	7.48^{b}	10.13^{b}	13.03^{b}	8.4^{b}
Compote	1.59^{b}	3.78^{b}	14.13^{a}	20.42^{a}	16.72^{a}	12.26^{a}
Ripening treatments						
Control	0.00^{d}	0.00^{c}	14.97^{a}	19.00^{a}	12.11^{c}	8.55^{b}
Ethylene	4.94^{b}	6.54^{b}	10.58^{b}	16.75^{b}	14.16^{bc}	8.85^{b}
20±1C° for 8 days	3.96^{c}	6.85^{b}	10.75^{b}	13.75^{c}	17.20^{a}	12.35^{a}
20±1C° for 12 days	6.47^{a}	10.38^{a}	6.92^{c}	11.58^{d}	16.02^{ab}	11.55^{a}
Interactions between cultivars and ripening treatments						
Spadona x Control	0.00^{f}	0.00^{e}	13.93^{b}	16.7^{d}	10.65^{c}	8.1^{b}
Spadona x Ethylene	8.66^{b}	12.6^{a}	4.50^{e}	10.8^{e}	14.11^{c}	8.1^{b}
Spadona x 20±1C° for 8 days	6.16^{c}	8.40^{c}	9.00^{d}	7.5^{f}	13.17^{c}	8.9^{b}
Spadona x 20±1C° for 12 days	9.60^{a}	11.4^{b}	2.50^{e}	5.5^{f}	14.18^{c}	8.5^{b}
Compote x Control	0.00^{f}	0.00^{e}	16.00^{a}	21.3^{ab}	13.58^{c}	9.0^{b}
Compote x Ethylene	1.23^{e}	0.5^{e}	16.67^{a}	22.7^{a}	14.21^{c}	9.6^{b}
Compote x 20±1C° for 8 days	1.76^{e}	5.3^{d}	12.50^{bc}	20.0^{bc}	21.23^{a}	15.8^{a}
Compote x 20±1C° for 12 days	3.35^{d}	9.3^{c}	11.33^{c}	17.7^{cd}	17.86^{b}	14.6^{a}

Means in the same column followed by the same symbol are not significantly different at $p \leq 0.05$ level based on the Duncan test.

Table 3: Effects of cultivars, ripening treatments, and their combinations on fruit total soluble solids (TSS), total acidity, and peroxidase activity during two seasons for spadona and compote pear cultivars.

Treatments	Total soluble solids (%)		Total acidity (%)		Peroxidase activity (absorbing unit/minute/ml)	
	2015	2016	2015	2016	2015	2016
Cultivars						
Spadona	11.85^{b}	11.80^{b}	1.64^{a}	2.00^{a}	4.31^{a}	3.35^{a}
Compote	12.90^{a}	13.00^{a}	0.87^{b}	1.41^{b}	2.53^{b}	1.84^{b}
Ripening treatments						
Control	11.90^{b}	11.77^{c}	1.59^{a}	1.83^{a}	2.50^{b}	2.38^{a}
Ethylene	12.20^{b}	12.37^{b}	1.15^{bc}	1.63^{a}	3.78^{a}	2.05^{a}
20±1C° for 8 days	12.40^{b}	12.43^{b}	1.31^{b}	1.64^{a}	3.63^{a}	3.03^{a}
20±1C° for 12 days	13.01^{a}	13.03^{a}	0.97^{c}	1.71^{a}	3.77^{a}	2.92^{a}
Interactions between cultivars and ripening treatments						
Spadona x Control	11.20^{c}	11.1^{c}	2.41^{a}	2.05^{a}	3.23^{b}	3.47^{ab}
Spadona x Ethylene	12.00^{bc}	12.3^{b}	1.14^{c}	1.95^{a}	4.60^{a}	2.63^{a-d}

Spadona x 20±1C° for 8 days	11.60^{bc}	11.5^{c}	1.88^{b}	1.94^{a}	4.37^{a}	3.33^{a-c}
Spadona x 20±1C° for 12 days	12.60^{ab}	12.3^{b}	1.14^{c}	2.08^{a}	5.03^{a}	3.97^{a}
Compote x Control	12.60^{ab}	12.4^{b}	0.76^{d}	1.61^{ab}	1.77^{c}	1.30^{d}
Compote x Ethylene	12.40^{ab}	12.5^{b}	1.16^{c}	1.31^{b}	2.97^{b}	1.47^{cd}
Compote x 20±1C° for 8 days	13.20^{a}	13.3^{a}	0.74^{d}	1.35^{b}	2.90^{b}	2.73^{a-d}
Compote x 20±1C° for 12 days	13.40^{a}	13.8^{a}	0.80^{d}	1.35^{b}	2.50^{bc}	1.87^{b-d}

Means in the same column followed by the same symbol are not significantly different at $p \leq 0.05$ level based on the Duncan test.

Table 4: Effects of cultivars, ripening treatments, and their combinations on some pigments in fruit peel of spadona and compote pear cultivars during two seasons.

Treatments	**Chlorophyll a**		**Chlorophyll b**		**Total chlorophylls**		**Total carotenoids**	
	(mg/ml)							
	2015	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**
Cultivars								
Spadona	0.02^{b}	0.10^{a}	0.08^{b}	0.18^{a}	0.09^{b}	0.28^{a}	0.02^{b}	0.09^{b}
Compote	0.08^{a}	0.08^{a}	0.14^{a}	0.09^{b}	0.22^{a}	0.17^{b}	0.09^{a}	0.18^{a}
Ripening treatments								
Control	0.08^{a}	0.19^{a}	0.19^{a}	0.20^{a}	0.27^{a}	0.38^{a}	0.04^{c}	0.14^{b}
Ethylene	0.07^{a}	0.12^{b}	0.16^{b}	0.18^{a}	0.24^{b}	0.30^{b}	0.06^{bc}	0.17^{b}
20±1C° for 8 days	0.03^{b}	0.02^{c}	0.04^{c}	0.08^{b}	0.06^{c}	0.11^{c}	0.06^{b}	0.22^{a} 0.20^{a}
20±1C° for 12 days	0.02^{b}	0.03^{c}	0.03^{c}	0.08^{b}	0.06^{c}	0.10^{c}	0.08^{a}	
Interactions between cultivars and ripening treatments								
Spadona x Control	0.01^{e}	0.23^{a}	0.16^{b}	0.25^{a}	0.17^{b}	0.48 ^{a}	0.02^{c}	0.09^{b}
Spadona x Ethylene	0.03^{d}	0.13^{b}	0.08^{c}	0.18^{b}	0.10^{c}	0.31 ^{b}	0.02^{c}	0.10^{b}
Spadona x 20±1C° for 8 days	0.01^{e}	0.01^{c}	0.03^{d}	0.14^{b}	0.04^{d}	0.15 ^{c}	0.01^{c}	0.10^{b}
Spadona x 20±1C° for 12 days	0.01^{e}	0.02^{c}	0.03^{cd}	0.14^{b}	0.05^{d}	0.16 ^{c}	0.03^{c}	0.08^{b}
Compote x Control	0.14^{a}	0.14^{b}	0.23^{a}	0.14^{b}	0.37^{a}	0.28 ^{b}	0.06^{b}	0.10^{b}
Compote x Ethylene	0.12^{b}	0.10^{b}	0.25^{a}	0.18^{b}	0.37^{a}	0.29 ^{b}	0.09^{a}	0.13^{b}
Compote x 20±1C° for 8 days	0.04^{c}	0.04^{c}	0.04^{cd}	0.03^{c}	0.09^{cd}	0.06 ^{d}	0.10^{a}	0.24^{a}
Compote x 20±1C° for 12 days	0.03^{d}	0.03^{c}	0.03^{cd}	0.02^{c}	0.07^{cd}	0.05 ^{d}	0.10^{a}	0.24^{a}

Means in the same column followed by the same symbol are not significantly different at $p \leq 0.05$ level based on the Duncan test.

The firmness of any fruit depends mainly on cell wall density and storage materials like pectin, starch, etc., so decreasing fruit firmness is due to transforming non-soluble pectin into soluble pectin [24] as a result of the reaction of polygalacturonase, lipoxygenase, cellulose, and pectin methylesterase enzymes which analyze cell walls and increase fruit softness [25].
The differences between two pear cultivars compote and spadona in these reactions may due to differences in their fruit`s firmness in both seasons. The decrease in fruits firmness during the ripening period reached 12 days may be due to analyzing the non-soluble pectin to soluble pectin as a result of increasing the activity of endopolygalacturonase and cellulase enzymes [26]. The results of this study agree with that of Dhillon et al. [27] where exposing pear fruits to 20±1C° decreased fruit firmness and increases fruit TSS and total sugars which are also considered as ripening markers.
Keeping high acidity in fruits from control treatment for both cultivars and seasons may be due to decreasing in respiration and ethylene production [28], and its role in decreasing pectin dissolving [29] and delaying fruits ripening. Increasing the fruit's TSS may be due to increasing the activity of hydrolysis enzymes like invertase and starch phosphorylase [30] or as a result to increasing the soluble organic material as a result of water loss from fruits (tables 2 and 3). Fruits ripened for 8 and 12 days at 20±1C° had more total sugars significantly compared to the control and ethylene treated fruits which agreed with that of Singh [31] and Dhillon and Mahajan [23].
It is found that treating fruits with ethylene or ethephon increase chlorophyll degradation and the appearance of yellow color in many fruits [22]. The changes in colors during ripening are due to carotenoids synthesis which is stimulated by chlorophyll degradation. The results agree with the findings of Kulkarni et al. [32] and Dhillon and Mahajan [23]. Treatment with ethylene accelerates the degradation of chlorophylls and the appearance of orange or yellow colors, also, the firmness of some ripening fruits and vegetables will decrease when treated with C_2H_4 (5). Peroxidase enzyme is responsible for non-preferable ripening characteristics in fruits including browning through phenol reduction [6]. It was shown that peroxidase enzyme activity decreased in the control fruits for both seasons, whereas the highest activity was recorded in the fruits ripened for 12 days at 20±1C°.
Generally, the effects of ethylene on pear fruit quality were minimal compared with the effects of temperature. These results agree with the findings of Bower et al. [7] and Retamales et al. [33] that treating pears varieties ‘Packham’s Triumph’, ‘Beurre Bosc’ and Bartlett with ethylene during the storage had slight effects.

4. CONCLUSION

From this study, it is concluded that the compote cultivar showed the best response for artificial ripening concerning weight loss compared to spadona cultivar. It is also concluded that degrees of temperature had an important role in accelerating pear ripening and improving their edible characteristics than treating them with ethylene. Exposing fruits to ethylene for 24 hours had non-significant effects on the edible characteristics of pears, whereas keeping thems at 20±1C° for 8 days improved these characteristics, so we can avoid the cost of artificial ripening with ethylene which is not available for most producers in northern Iraq. Further work about the effects of using ethylene gas in different concentrations such as 400, 500, or more is recommended, also studying the effects of prolonging the time of the exposure to ethylene gas is recommended.

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