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Research Article

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Water loss of some plant fruits through plant waxy layers at different temperature levels

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ABSTRACT

The plant cuticle forms the interface between the aerial environment and the living cells of the plant. Therefore, the cuticle has to manage multiple physiological and ecological functions like controlling water loss. One of the physical factors influenced water permeability of cuticles is temperature. We tested the response of cuticular water permeability of three different fruits using different temperature levels, start from 15 to 45 C°. We measured the water permeances of the whole fruits of tomato, grape and plume using the concept of our previous studies with isolated plant cuticles. The results showed that all fruits appeared increasing in their water permeances when temperature level was increased. Above 25 C°, the water loss of all plant species was very high and varied among the fruits at all levels.

Key words: Water permeability; Water loss; Plant cuticle; Fruits; Plant wax

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INTRODUCTION

Most plant species possess specific adaptations to their habitats. One basic adaptation of plants for their survival on the mainland is the plant cuticle. Studies of Silurian and Devonian plant fossils showed that cuticles are very resistant and the oldest known cuticles are over 400 million years old [1],[13]. The cuticle is defined as a heterogeneous, extracellular biopolymer [3], [10], which is synthesized by epidermal cells [5]. The plant cuticle is a hydrophobic, continuous and flexible thin membrane [12] consisting of two lipid fractions; the polymer matrix (cutin) and cuticular waxes which are deposited on the outer surface and embedded in the matrix [4]. The cuticle forms an effective barrier against desiccation and thus, the main function of the cuticle is the reduction of water loss from plants when the stomata are closed [8].

Cuticular permeability is influenced by physical (temperature, humidity, pH) and chemical (adjuvants, pollutants) factors. Many studies and investigations of cuticular permeability showed that water permeability was increased by increasing temperature [9], relative humidity[2], [11] and by increasing pH [8]. In this work, we tested the influence of water permeances of three fruit species through plant cuticle at different temperature levels.

EXPERIMENTAL SECTION

Plant material: Mature fruits of tomato *Lycopersicon esculentum* Mill., grape *Vitis vinifera* L., and plume *Prunus domestica* L. were purchased on the market of Benghazi city, Libya, in 2014. They were selected for their size uniformity of each fruit type and were visually investigated to exclude any damages or infections by microorganisms. The area of each fruit cuticle calculated using the fruit radius which determined manually (Table 1).

Table 1: The uniformity of the fruit size. The radius was determined manually using Vernier caliper and subsequently used to find out the exposed area of fruit cuticle to silica gel

FRUIT RADIUS (cm)

No.	Tomato	Grape R	Grape Y	Plume
1	2.6	2.4	2.5	3.3
2	2.7	2.4	2.6	3.3
3	2.7	2.4	2.3	3.2
4	2.5	2.5	2.3	3.5
5	2.5	2.5	2.2	3.7
6	2.5	2.4	2.4	3.6
7	2.5	2.4	2.3	3.4
8	2.3	2.5	2.5	3.9
9	2.4	2.4	2.3	
10	2.4	2.4	2.3	
MEAN	2.51	2.43	2.37	3.49
S.D	0.13	0.05	0.13	0.24

Measurement of water loss: Water permeability of fruit cuticular membranes was determined using a gravimetric method. 10 fruits of each plant species were placed in closed polyethylene boxes above silica gel. In order to prevent damage of the membranes; a flat metal net was placed between the fruits and silica gel granules. The boxes prepared in this way were incubated in an incubator (Binder, Tuttlingen, Germany) at 15,25,35and 45 ± 0.5 C°, respectively. The incubation period was overnight in all fruits. After incubating fruits at each temperature level, Water loss was monitored by weighing the fruits every 1 to 2 hours for 4 to 5 times. Water loss was determined with a microbalance (Sartorius Analytic BP 221S, Göttingen, Germany). Amounts of water diffused across the fruit membranes were summed up and plotted as a function of time (Figure 1). Rates of water loss were calculated from linear regression lines fitted to the plotted data.

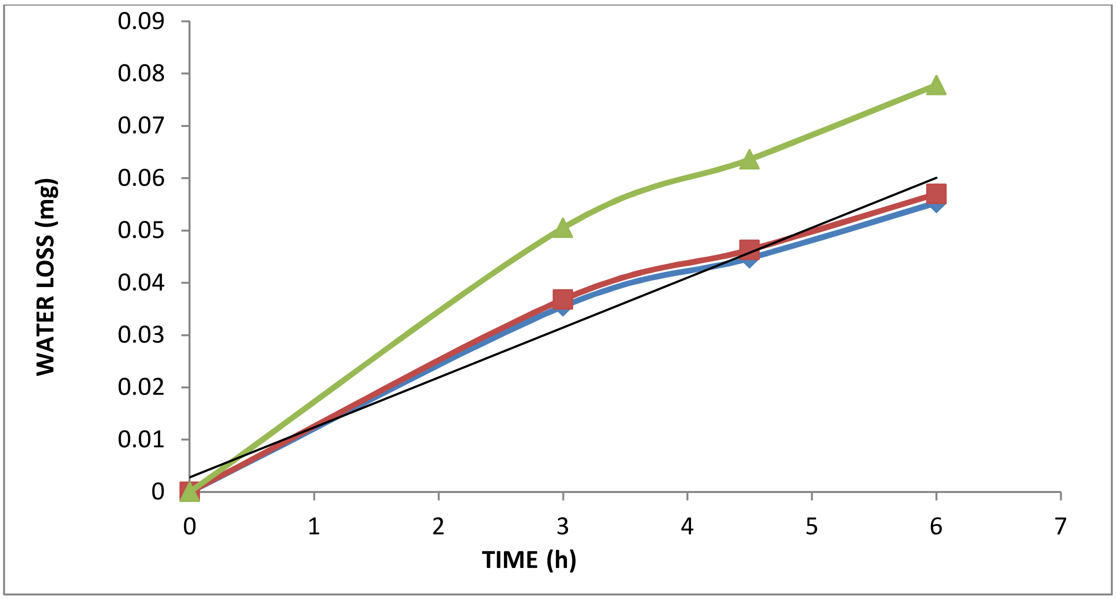

Figure 1; Water loss through fruit cuticles per time. The correlation factor between water loss and time (R^2) must be high. Here it was more than 0.97 in all fruits and used in linear regression to calculate the rates of water loss

Calculations of fruit cuticular water permeance: water permeance of each isolated fruit species was determined using the equation:

$$P = F / (A \cdot \Delta c)$$

Where P is permeance, F ($g\cdot s^{-1}$) represents the flow rate, A (cm^2) the area of the fruit cuticle and Δc ($g\cdot m^{-3}$) the driving force for diffusion. The water permeance of each individual fruit was calculated. After that, the mean of total permeances of each fruit species was determined.

Sample size and statistical analysis
Regression equations were fit to transpiration kinetics and means of permeances of 10 fruits were calculated. Results are given as means with standard error.

RESULTS

The results showed that the water permeance of all type fruits were increased by increasing temperature (Figure 2). Green grape fruits were appeared water permeability higher than other fruits even when they compared with the same fruit type but has different colour (black). The results showed also that the permeance at 25 C°, which can be described as optimum temperature for all plants, was 9.6607E-08 for green grape fruits, while it was 5.33028E-08 for black grape fruits (Table 2).

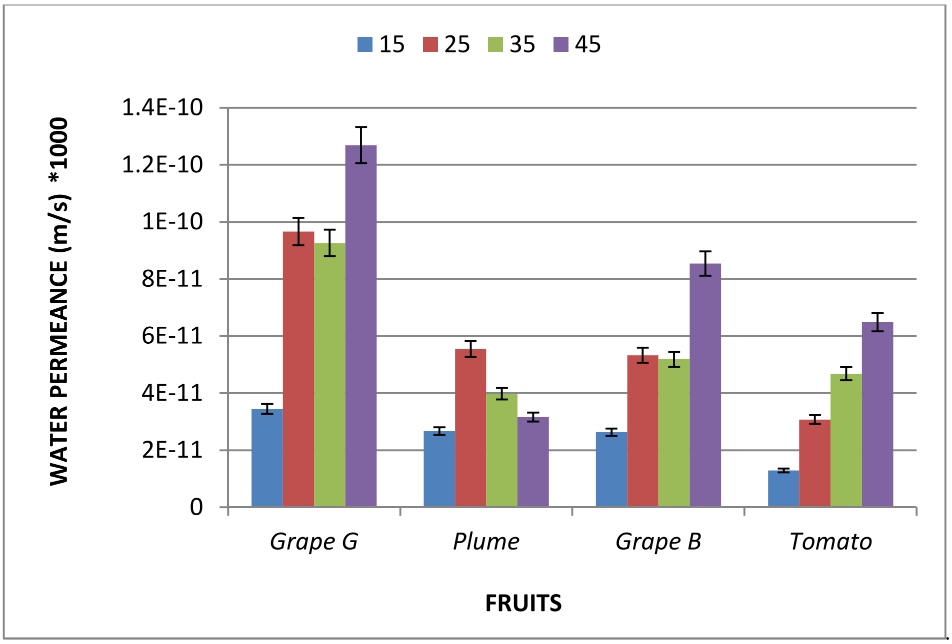

Figure 2; Increasing water permence of different fruits at different temperature levels started from 15 to 45 C°

Table 2; Water permeability of different fruits at 25 C°

Fruit	*Grape G*	*Plume*	*Grape B*	*Tomato*
Mean	9.6607E-08	5.54943E-08	5.33028E-08	3.08E-08
SD	4.13862E-08	1.61826E-08	9.85531E-09	6.89E-09

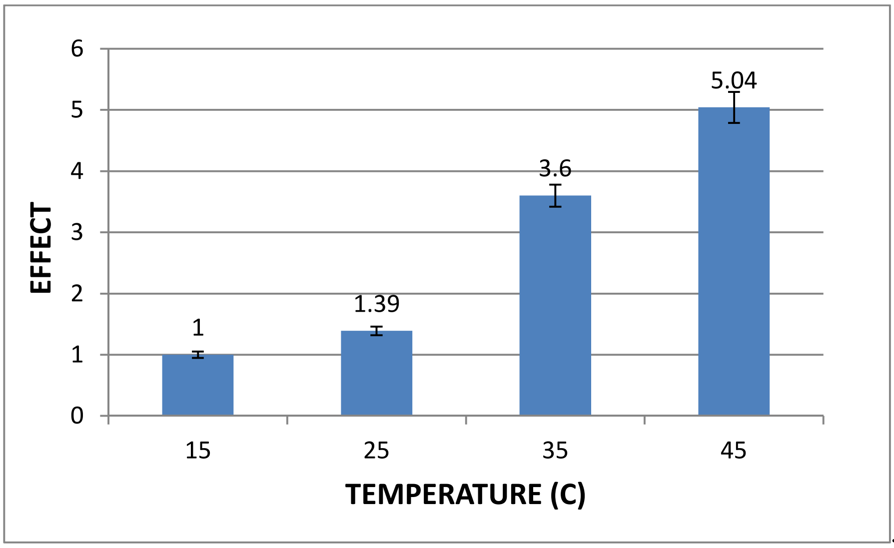

Figure 3; The effect of temperature on water permeability of tomato fruits. The effect was obtained by divided water permeance after treatment by that at 15 C° (*P15/P15, P25/P15, P35/P15* and *P45/P15*)

The effect of temperature on water permeability was clear when the temperature level was increased by 10 C°. It was increased linearly from factor 1 at 15 C° to factor 5.04 at 45 C° (Figure 3).

DISCUSSION

From the results, it is clear that all fruit species appeared high water permeances through the cuticular membrane. Even though some of these fruits reflected less water loss than others, but they are still in the level. Water permeabilities of plant cuticles from different species are highly variable. They differ not only among different species, but also differ within the same species. They can even vary within the cuticles obtained from the same organ (leaf or fruit). Interspecific variability varies over 2.5 orders of magnitude [7]. Even thought the fruits used in this study revealed different permeances; but cuticular water permeability is not correlated to the thickness or to wax coverage of their cuticle [7]. These differences might caused by chemical compounds in their pigments and this is clear in grape fruits with different colors (Figure 2). In addition, the differences of water permeabilities are caused by ecophysiological adaptations that are genetically fixed. Studies of fruit cuticles indicated that their water permeances were about 10 times higher than those of leaf cuticles with highest water permeabilities [7].

It is obvious that cuticular waxes play an important and a decisive role in determining permeabilities of cuticles. They form the transport barrier even though they make up only a small percentage of the total mass of the cuticle. The barrier properties of the cuticle depend to a large extent on cuticular waxes. Therefore, the transport across the plant cuticle mainly depends on the wax layer, which consists of crystals that are embedded within a cutin matrix of amorphous material. The crystals, or impermeable flakes [6], reduce the volume of the barrier available for diffusion and lead to a highly tortuous paths across it. The effect of temperature (P_{after}/P_{before}) was increased by increasing temperature level from 15 to 45 C°. This might increase solubility of wax flakes and subsequently, the crystals became more permeable. And therefore, water permeability of fruits was increased rapidly by increasing temperature level by factor 10 C°.

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