MECHANISM OF PASTY TEXTURE DEVELOPMENT IN STONYHARD PEACH FRUIT UPON ETHYLENE TREATMENT

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CHAPTER I

INTRODUCTION

Peaches (*Prunus persica* (L.) Batsch) are perishable fruits which soften and senesce rapidly at ambient temperatures after harvest. As peach fruits soften, their shelf-life becomes limited due to an associated susceptibility to injury. Therefore, flesh firmness is a very important determinant of quality for peaches. It is probably the most reliable index of maturity, affecting both edible quality and shelf-life (Maness et al., 1993).

Fruit softening during ripening is a complex process that presumably involves structural changes in the fruit cell walls. It is thought that these changes are brought about through the action of cell wall hydrolases degrading various cell wall polymers (Fischer and Bennett, 1991). For softening to occur, polymeric interactions in the cell walls of adjacent cells must be weakened to allow the cells to move with respect to one another. A morphologically distinct layer called middle lamella, the area between primary cell walls of adjoining cells, forms a rather continuous intercellular matrix. This layer is rich in pectic polysaccharides and is believed to be the region of the cell wall most affected during fruit softening.

Softening in many fruits is associated with textural changes that are believed to result from disassembly of the primary cell wall. The general polymeric composition of

the primary cell wall consists approximately of 30% cellulose, 30% hemicellulose, 35% pectin, and 5% protein in dicotyledonous plants (McNeil et al., 1984), although pectin content may be higher in fruit cell walls. A model of the plant primary cell wall describes a network of cellulose microfibrils embedded in a matrix of pectin and hemicellulose polymers, with additional components like structural proteins (Carpita and Gibeaut, 1993). During fruit softening, pectins (Fisher and Bennett, 1991) and hemicellulose (Lashbrook, 1997) typically undergo solubilization and depolyermerization that are thought to contribute to wall loosening and disintegration, although the relative extent and timing may be different between different fruit species. Pectins are a major component of the primary cell walls, existing in the cell wall either as "smooth" regions of a linear copolymer of α(1-4) galacturonic acid residues or "hairy" regions consisting of rhamnogalacturonan repeating disaccharides that have attached α(1-2) linked rhamnosyl residues that may be substituted with arabinose or galactose-rich side chains.

One of the most studied cell wall hydrolases has been polygalacturonase (PG). Until recently PG was generally considered to be the primary enzyme involved in the softening process. Endo-PG (EC 3.2.1.15) hydrolyses α(1~4) galacturonosyl linkages in pectin and it breaks down pectin randomly along the interior of the polymer chain. Exo-PG (EC 3.2.1.40) hydrolyzes a single reducing sugar from the nonreducing end of a pectin polymer chain. These two forms of PG have been purified and characterized in a number of fruits (Pressey and Avants, 1976; Moshrefi and Luh, 1983; Chan and Tam, 1982). In mango, Roe and Bruemmer (1981) reported good correlation between loss of firmness and PG activity. Chaimanee (1992) studied PG from mesocarp tissue of mango fruits at different stages of ripening and found that the increase in both exo-PG and endo-

PG activities correlated well with the increase in ripeness. Ahrens and Huber (1990) found PG activity was highly correlated with tomato pericarp softening, but only moderately correlated with softening of whole fruit.

Both endo- and exo-PG have been characterized in peaches (Pressey and Avants, 1973). PG was not detectable in unripe peaches, but activity appeared when the fruits began to soften and then increased sharply as ripening proceeded. Increase in enzyme activity paralleled the formation of water soluble pectin and the molecular weight of the solubilized pectin decreased during fruit ripening. At the unripe stage, both clingstone and freestone cultivars had virtually no PG activity; ripe clingstone peaches had exo-PG activity whereas ripe freestone peaches had both endo-PG and exo-PG as well as high levels of water-soluble pectin (Pressey and Avants, 1978). Downs et al (1990) observed two forms of exo-PG during the development of freestone and semi-freestone peaches. One form increased 36 fold and the other increased 90 fold from 42 days to 99 days after bloom.

PG-dependent pectin disassembly has been most extensively studied in ripening tomato, and the introduction of molecular genetic techniques has provided a direct means of determining the contribution of PG activity to fruit softening. In transgenic tomato fruit in which PG mRNA accumulation was suppressed 99% by the expression of antisense PG transgene, pectin solubilization remained at wild-type levels, but depolymerization of chelator-soluble polyuronides was suppressed (Smith et al., 1990). These same transgenic fruits softened at the same rate as with wild-types, demonstrating that high levels of PG activity were not necessary for normal softening during ripening of tomato, and fruits can ripen normally even with very low levels of PG. Carrington et al

(1997) found that softening of pericarp in transgenic fruit was not effected by suppression of endo-PG until the fruit reached the red stage of ripeness. They did find that red fruit softened more slowly in transgenic fruit than in wild types.

PG has been found in a number of fruits: peach (Pressey and Avants, 1973), pear (Pressey and Avants, 1976), kiwifruit (Wegrzyn and MacRae, 1992), tomato (Ahrens and Huber, 1990), avocado (Kutsunai et al.,1993) and mango (Chaimanee, 1992). Nogata (1993) found low levels of PG in strawberry fruits in which Barnes and Patchett (1976) failed to find these activities. Meanwhile, low levels of PG have also been detected in apples under rigorous examination (Wu et al, 1993). A chimeric gene consisting of the PG structural gene controlled by a E8 promoter was introduced into mutant *rin* tomato fruits that normally fail to soften and that do not express PG (Giovannoni et al., 1989). In the transgenic fruit, PG activity, pectin solubilization and depolymerization were restored to near wild-type levels. However, these tomato fruits did not soften and were not altered in other ripening parameters such as pigment accumulation, implying that PG-mediated pectin disassembly is not sufficient for normal softening to occur in *rin* tomato fruit.

Although endo-PG is generally considered to be an important enzyme involved in the softening process, the anti-PG tomato work and other structural polysaccharide work presents considerable evidence suggesting that endo-PG is not exclusively responsible for cell wall structural changes that occur during ripening (Huber, 1984; Seymour et al., 1987; Smith et al, 1988; Tucker and Grierson, 1982). In some fruits, like ripe clingstone peaches (Pressey and Avants, 1978), only exo-PG activity was detected. Furthermore, endo-PG activity in hot pepper (Gross et al., 1986) and muskmelon (McCollum et al., 1989) was demonstrated not to be the responsible enzyme for pectic polymer

solubilization during softening. The failure of endo-PG to play a significant role in early softening or to have the sole function in pectin degradation indicates that other cell wall hydrolases, perhaps active against other pectic regions and other polysaccharides, may be important. One group of cell wall hydrolases that may play a role in cell wall degradation are the glycosidases. Among them, β-galactosidase has been most studied (Ranwala et al., 1992; Ian De Veau et al., 1993; Ross, 1993).

β-galactosidase (EC 3.2.1.23) is widely distributed in various plant tissues, including developing fruits. It acts in an exo-fashion, removing single galactosyl residues from the non-reducing end of polysaccharides and oligosaccharides (Ross et al., 1994; Fry, 1995). Studies on apple (Bartley, 1974), hot pepper (Gross et al., 1986), muskmelon (Ranwala et al., 1992), pear (Kitagawa et al., 1995), avocado (Ian De Veau et al., 1993), tomato (Pressey, 1983) and mango (Ali et al., 1995) have indicated remarkable increases in the activity of β-galactosidase during ripening. One β-galactosidase isozyme in tomato that increases in activity during ripening has exhibited the ability to hydrolyze galactose rich polysaccharide in vitro from cell walls (Pressey, 1983). These findings suggest the possible involvement of β-galactosidase in modification of cell wall components during fruit ripening.

The loss of arabinose from cell wall fractions during ripening has been observed in apples (Yoshioka et al., 1994), tomatoes (Gross, 1979), Japanese pears (Yamaki et al., 1979) and kiwifruits (Redgwell et al., 1992). α-Arabinosidase acts in an exo-fashion, removing single arabinosyl residues from the non-reducing end of polysaccharides and oligosaccharides (Ross et al., 1994; Fry, 1995). Tateishi et al. (1996) observed a 15-fold increase in the levels of α-arabinosidase with fruit ripening. Arabinose exists mainly as

the side chains of the backbone of homogalacturonan and rhamnogalacturonan (Yoshioka et al, 1994), so it is possible that arabinosidases are responsible for the removal of these side chains and render the pectin backbone more accessible to PG or other pectic enzymes. Other glycosidases, such as xylosidases, glucosidases and mannosidases may also play their roles in a similar manner in fruit softening (Lecas et al, 1991; Roene et al, 1991; Watkins et al, 1988). Little is known about glycosidases in peaches.

Pectic polysaccharides are major constituents of the primary cell wall, coexisting with other polysaccharides such as hemicellulose and cellulose, forming a crosslinked matrix network. It is thought that the breakdown of the covalent bonds and perhaps noncovalent bonds holding this structure leads to loosening of the stability of this network between adjacent cells in tissue and eventally leading to loss of tissue firmness. Ripening associated modifications in sugar composition and apparent molecular size of pectins and hemicellulose have been reported in many fruits. In avocado, molecular sizes of pectic polymers and hemicelluloses extracted from fruit mesocarp cell wall shifted from larger to smaller polymers during ripening (Ranwala et al., 1992). Huber (1993) observed a marked downshift in molecular weight distribution of cell wall hemicellulose of tomato fruits during ripening. Similarly, a hemicellulose fraction extracted from hot pepper fruit cell walls was modified during ripening, resulting in a shift from high to low molecular weight (Gross et al., 1986). In muskmelon, molecular sizes of pectin and hemicellulose polymers from fruit mesocarp cell walls shifted from larger to smaller polymers during ripening (Ranwala et al., 1992). In kiwifruit, three distinct molecular size classes of hemicellulose were observed, with a proportional increase in the smaller polymers with fruit ripening (Redgwell et al., 1991). Ripening of nectarines resulted in

solubilization of pectic polymers of high molecular sizes and concurrent galactan side chain removal from pectic polymers. Solubilized pectic polymers were depolymerized to lower molecular sizes as ripening progressed (Dawson et al., 1992). Recently, depolymerization of hemicelluloses has also been shown in peach softening (Hedge and Maness, 1998). Both pectin and hemicelluloses were also depolymerized in muskmelon (Rose et al., 1998).

In addition to the depolymerization of both pectic and hemicellulosic polymers, a characteristic feature of ripening fruit is the loss of neutral sugars (primarily galactose and arabinose) from the cell wall of strawberry (Huber, 1984), muskmelon (McCollum, 1989), kiwifruit (Soda, 1987; Redgwell, 1992), hot pepper (Gross, 1986), avocado (Huber, 1993), pear (Yoshioka, 1992) and peaches (Fishman, 1993).

Softening of peaches has long been attributed to the conversion of protopectin to soluble forms (Chapman and Horvat, 1990; Pressey and Avants, 1978; Shewfelt, 1965). Pressey et al. (1971) correlated an appearance of PG activity with an increase in water-soluble pectin and fruit softening. The molecular weight of chelator soluble pectins and alkaline soluble fraction in melting flesh peaches was less than that for nonmelting flesh peaches (Fishman et al., 1993).

Peach softening during ripening has been attributed to the enzymatic degradation of pectic polymers (Pressey, 1977). In melting flesh peach 'Redskin' fruit mesocarp, molecular weight of chelator soluble pectin decreased considerably during ripening and storage. In nonmelting flesh peach 'Suncling' fruit mesocarp, molecular weight of chelator soluble pectin and alkaline soluble fraction was relatively constant during on-

tree ripening and storage (Fishman, 1993). Hegde and Maness et al. (1996) noted that both pectin and hemicellulose were modified during peach ripening.

The Stonyhard 'J12-119' mutation of peach fruit dramatically reduces ethylene biosynthetic capacity and confers novel fruit softening characteristics to freestone peaches. Fruit softening can be initiated to obtain a desirable melting flesh texture, or a pasty texture, depending on the concentration and duration of exposure to exogenous ethylene. When treated with 0 ppm ethylene for 48 h, the fruits still remain firm; when treated with lppm ethylene for 48hrs, they obtain a normal soft texture; when treated with l00 ppm ethylene for 48 h, they obtain a "pasty" texture, which is characterized as a slimy or pasty consistency at cut surfaces, accompanied by a slight reduction in mesocarp free water.

Stonyhard fruits were selected for this research for their uniqueness in that they remain firm at room temperature for about 10 days compared to normal peach fruits ('Cresthaven') whose firmness decreases in 3 days after harvest at horticultural maturity. When treated with ethylene at different concentrations in a very short period of time (up to 48 h), Stonyhard fruits soften to an edible firmness, but different textures (normal soft texture and pasty texture) are obtained . Therefore, it provides a very good system to study textural changes associated with fruit softening. The objectives of this research were to investigate the mechanism of pasty texture development by determining differences between Stonyhard and normal peach fruit during ethylene-induced ripening for selected cell wall degrading enzymes and in cell wall polysaccharide structure.

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CHAPTER II

Mechanism of Pasty Texture Development in Stonyhard Peach Fruits upon Ethylene Treatment

---The Effects of PG and other enzymes

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Abstract

Stonyhard (New Jersey selection 'J12-119') peach fruit was compared to 'Cresthaven' fruit as control to study softening and textural changes during ethylene-induced ripening. Without ethylene exposure, 'J12-119' fruit remained firm for 48 h at room temperature. After exposure to 1 ppm or 100 ppm ethylene for 48 h, fruit softened at a rate similar to 'Cresthaven'. However, 1 ppm treated fruit attained a normal juicy texture while 100 ppm treated fruit attained a pasty texture. 'Cresthaven' fruit softened to a normal juicy texture with either ethylene treatment. Cell wall endo-polygalacturonase (endo-PG) was not detectable in 'J12-119' fruit without ethylene exposure. With 1 ppm ethylene exposure, it increased at a rate similar to 'Cresthaven', and with 100 ppm ethylene exposure, it was double that of 1 ppm treated fruit after 24 h of exposure. Low levels of endo-PG were detected in 'Cresthaven' fruit not exposed to ethylene, 1 ppm treatment led to an increase which was comparable to that of 1 ppm treatment in 'J12-119'. However, endo-PG in 100

ppm treated fruit was very similar to that of 1 ppm by 24 h, though high levels of endo-PG were observed at 48 h. Attainment of the pasty texture in 100 ppm treated 'J12-119' fruit may have been related to release of large quantities of pectic polysaccharides as a result of the sudden increase in endo-PG activity. β-galactosidase, α-mannosidase and α-galactosidase are major glycosidases in both fruits, and their activities increased during fruit softening in both cultivars.

Key words: Peach, endo-polygalacturonase, softening, pasty texture

Introduction

Peaches (*Prunus persica* (L.) Batsch) are perishable fruits which soften and senesce rapidly at ambient temperatures after harvest. As peach fruits soften, their shelf-life becomes limited due to an associated susceptibility to injury. Therefore, flesh firmness is a very important determinant of quality for peaches. It is probably the most reliable index of maturity, affecting both edible quality and shelf-life (Maness *et al*, 1993).

Softening in many fruits is associated with textural changes that are believed to result from disassembly of the primary cell wall. The general polymeric composition of the primary cell wall consists approximately of 30% cellulose, 30% hemicellulose, 35% pectin, and 5% protein in dicotyledonous plants (McNeil et al., 1984), although pectin content may be higher in fruit cell walls. A model of the plant primary cell wall describes a network of cellulose microfibrils embedded in a matrix of pectic and hemicellulose polymers, with additional components like structural proteins (Carpita and Gibeaut, 1993). During fruit softening, pectins (Fisher and Bennett, 1991) and hemicellulose

(Lashbrook, 1997) typically undergo solubilization and depolyermerization that are thought to contribute to wall loosening and disintegration, although the relative extent and timing may be different between different fruit species. Pectins are a major component of the primary cell walls, existing in the cell wall either as "smooth" regions of a linear copolymer of α(1-4) galacturonic acid residues and "hairy" regions consisting of rhamnogalacturonan repeating disaccharides that have attached α(1-2) linked rhamnosyl residues that may be substituted with arabinose or galactose-rich side chains.

The cell wall disintegration is believed to be brought about through the action of cell wall hydrolases degrading various cell wall polymers (Fischer and Bennett, 1991). For softening to occur, polymeric interactions in the cell walls of adjacent cells must be weakened to allow the cells to move with respect to one another. A morphologically distinct layer called the middle lamella, the area between primary cell walls of adjoining cells, forms a rather continuous intercellular matrix. This layer is rich in pectic polysaccharides originating from cell walls of each of the adjoining cells and is believed to be the region of the cell wall most affected during fruit softening.

One of the most studied cell wall hydrolases has been polygalacturonase (PG). Until recently PG was generally considered to be the primary enzyme involved in the softening process. Endo-PG (EC 3.2.1.15) hydrolyses α(1~4) galacturonosyl linkages in pectin and it breaks down pectin randomly along the interior of the polymer chain. Exo-PG (EC 3.2.1.40) hydrolyzes a single reducing sugar from the nonreducing end of a pectin polymer chain. These two forms of PG have been purified and characterized in a number of fruits (Pressey and Avants, 1976; Moshrefi and Luh, 1983; Chan and Tam, 1982). In mango, Roe and Bruemmer (1981) reported good correlation between loss of

firmness and PG activity. Chaimanee (1992) studied PG from mesocarp tissue of mango fruits at different stages of ripening and found that the increase in both exo-PG and endo-PG activities correlated well with the increase in ripeness. Ahrens and Huber (1990) found PG activity was highly correlated with tomato pericarp softening but only moderately correlated with softening of whole fruit.

Two forms of PG have been characterized in peaches (Pressey and Avants, 1973). PG was not detectable in unripe peaches, but activity appeared when the fruits began to soften and then increased sharply as ripening proceeded. Increase in enzyme activity paralleled the formation of water soluble pectin and the molecular weight of the solubilized pectin decreased during fruit ripening. At the unripe stage, both clingstone and freestone cultivars had virtually no PG activity; ripe clingstone peaches had exo-PG activity whereas ripe freestone peaches had both endo-PG and exo-PG as well as high levels of water-soluble pectin (Pressey and Avants, 1978). Downs et al. (1990) observed two forms of exo-PG during the development of freestone and semi-freestone peaches. One form increased 36 fold and the other increased 90 fold from 42 days to 99 days after bloom, respectively.

PG-dependent pectin disassembly has been most extensively studied in ripening tomato, and the introduction of molecular genetic techniques has provided a direct means of determining the contribution of endo-PG activity to fruit softening. In transgenic tomato fruit in which PG mRNA accumulation was suppressed 99% by the expression of antisense PG transgene, pectin solubilization remained at wild-type levels, but depolymerization of chelator-soluble polyuronides was suppressed (Smith et al, 1990). These same transgenic fruits softened at the same rate as wild-types, demonstrating that

high levels of PG activity are not necessary for normal softening of pericarp tissues during ripening of tomato, and fruits can ripen normally even with very low levels of PG. PG has been found in a number of fruits: peach (Pressey and Avants, 1973), pear (Pressey and Avants, 1976), kiwifruit (Wegrzyn and MacRae, 1992), tomato (Ahrens and Huber, 1990), avocado (Kutsunai et al., 1993) and mango (Chaimanee, 1992). Nogata (1993) found low levels of PG in strawberry fruits in which Barnes and Patchett (1976) failed to find these activities. Meanwhile, low levels of PG have also been detected in apples under rigorous examination (Wu et al., 1993). A chimeric gene consisting of the PG structural gene controlled by a promoter was introduced into mutant *rin* tomato fruits that that normally fail to soften and that do not express PG (Giovannoni et al, 1989). In the transgenic fruit, PG activity, pectin solubilization and depolymerization were restored to near wild-type levels. However, these tomato fruits did not soften and were not altered in other ripening parameters such as pigment accumulation, implying that PG-mediated pectin disassembly was not sufficient for normal ripening or softening to occur.

Although endo-PG is generally considered to be the primary enzyme involved in the softening process, there is considerable evidence suggesting that endo-PG is not exclusively responsible for cell wall structural changes that occur during ripening (Huber, 1984; Seymour et al., 1987; Smith et al, 1988; Tucker and Grierson, 1982). In some fruits, like ripe clingstone peaches (Pressey and Avants, 1978), only exo-PG activity was detected. Furthermore, endo-PG activity in hot pepper (Gross et al., 1986) and muskmelon (Mcollum et al., 1989) was demonstrated not to be the responsible enzyme for pectic polymer solubilization during softening. The failure of endo-PG to play a significant role in early softening or to have the sole function in pectin degradation

indicates that other cell wall hydrolases may be important. One group of cell wall hydrolases that may play a role in cell wall degradation are the glycosidases. Among them, β-galactosidase has been most studied (Ranwala et al., 1992; Ian De Veau et al., 1993; Ross, 1993).

Many fruit softening investigations have concentrated on the question of how pectin solubilization is achieved. In kiwifruit, Redgwell (1990) found that initiation of galactose loss from the cell wall was one of the first changes during fruit softening and that its loss occurred particularly from a highly branched galactan tightly bound to the cell wall. Concomitant with this loss was a five-fold increase in β-galactosidase activity which peaked with maturity (Ogawa et al., 1990). In the case of nectarine, normal fruit ripening resulted in the solubilization of pectic polymers of higher molecular weight from cell wall material with a concurrent removal of galactan side chain from the pectic polymers (Dawson et al., 1992). Carrington et al. (1993) suggested that tomato fruits exhibited a notable PG-independent decline in galactose in pectin fractions in addition to the loss of galactose from the cell wall associated with PG activity. From these findings, it was proposed that the PG-independent loss of galactose is an important event in pectin solubilization associated with softening. This proposal was further supported by the observation that the decline in cell wall galactose precedes or accompanies an increase in soluble polyuronides (Gross and Wallner, 1979; Kim et al, 1991). Galactose, primarily in β(1-4) linkage, is a side chain component of the rhamnogalacturonan backbone (O'Neil et al., 1990). Thus, it is possible that β-galactosidase is responsible for the removal of these side chains (Pressy, 1983; Seymour et al, 1990) and perhaps this removal collapses non-covalent interactions of side chains between several adjacent polysaccharide chains,

which establish the cell wall structure.

β-galactosidase (EC 3.2.1.23) is widely distributed in various plant tissues, including developing fruits. It acts in an exo-fashion, removing single galactosyl residues from the non-reducing end of polysaccharides and oligosaccharides (Ross et al., 1994; Fry, 1995). Studies on apple (Bartley, 1974), hot pepper (Gross et al., 1986), muskmelon (Ranwala et al., 1992), pear (Kitagawa et al., 1995), avocado (Ian De Veau et al., 1993), tomato (Pressey, 1983) and mango (Ali et al., 1995) have indicated remarkable increases in the activity of β-galactosidase during ripening. One β-galactosidase isozyme in tomato that increases in activity during ripening has exhibited the ability to hydrolyze galactose rich polysaccharide in vitro from cell walls (Pressey, 1983). These findings suggest possible involvement of β-galactosidase in modification of cell wall components during fruit ripening.

The loss of arabinose from cell wall fractions during ripening has been observed in apples (Yoshioka et al, 1994), tomatoes (Gross, 1979), Japanese pears (Yamaki et al., 1979) and kiwifruits (Redgwell et al., 1992). Tateishi et al. (1996) observed a 15-fold increase in the levels of α-arabinosidase with fruit ripening. Arabinose exists mainly as the side chains of the backbone of homogalacturonan and rhamnogalacturonan (Yoshioka et al., 1994), so it is possible that arabinosidase is responsible for the removal of these side chains and render the pectin backbone more accessible to PG. Other glycosidases, such as xylosidases, glucosidases and mannosidases may also play their roles in a similar manner in the fruit softening (Lecas et al., 1991; Roene et al., 1991; Watkins et al., 1988). Little is known about glycosidases in peaches.

Stonyhard peach fruit were selected for this research due to the unique nature this

mutation imparts on softening and textural characteristics of peach fruit. Firmness decreases only very slowly at room temperature for up to 10 days compared to normal peach fruits whose firmness decreases to an edible level within 3 days after harvest at horticultural maturity. When treated with ethylene, all fruit soften at a rate consistent with peaches without the Stonyhard mutation, but different textures (1 ppm, juicy; 100 ppm, pasty) are obtained depending on ethylene concentrations. A "pasty" texture is characterized as a slimy or pasty consistency at cut surface, and a slight reduction in mesocarp free water. The Stonyhard fruit provided a very good system to study textural differences during fruit softening. The objective of this research was to probe the mechanism of pasty texture versus normal texture obtained during softening in response to ethylene treatment by investigating PG and selected glycosidase changes. It was hoped that the enzymic study would help clarify the softening mechanism of 'J12-119' peach fruits, and lead to a better understanding of undesirable texture development during softening in peaches.

Materials and Methods

The Stonyhard selection 'J12-119' and 'Cresthaven' peach fruit were harvested at horticultural maturity (physiological maturity) and were air-shipped from the Rutgers Fruit Research Station at Cream Ridge, New Jersey to laboratory facilities in Stillwater, Oklahoma in early August of 1996 and 1997. To ensure maximum fruit uniformity, too green or too ripe fruits and damaged fruits were discarded, and the remaining fruit were separated into sets of 10 fruits each for ethylene treatment. A zero time control was immediately processed as described below. Fruit were divided into two subsets of five

fruits (10 fruits per treatment) into two 3.8 L jars outfitted with inlet and outlet ports. The jars were sealed, and treated continuously with 0, 1 or 100 ppm ethylene for up to 48 h. Air flow was 0.5 L•min $^{-1}$ and ethylene concentrations were obtained by mixing standard ethylene (Scott Specialty Air, Philadelphia, PA, USA) with breathing air at a 1:9 (v/v) ratio. Air mixtures were humidified prior to fruit exposure. Fruit were taken from each treatment at 0, 24 and 48 h for sampling.

Mesocarp resistance to puncture was determined after removal of pericarp on opposite cheeks of each fruit using an Effgi penetrometer (Alfonsine, Italy) with a standard 8 mm probe.

Extractable juice was determined by using four mesocarp samples per fruit (two from each cheek) using a #7 cork borer (inner diameter 1cm, samples cut to 1cm in length). Mesocarp plug weight was obtained, and each plug was placed on top of glass wool inside a syringe barrel. Samples were then centrifuged at 5000g for 5 minutes. Extractable juice was expressed as a percentage of weight of liquid expressed from the mesocarp plug to the original mesocarp plug weight.

Fruits were pitted, quartered and pericarp was removed. Three replications of 50g mesocarp from 10 fruits were then frozen in liquid nitrogen to await enzyme extraction and analysis.

PG and glycosidase extraction and assay was essentially carried out as described by Cutillas-Iturralde et al. (1993) with some modifications. 50 g frozen mesocarp were homogenized in 80 mL 50 mM NaAc (pH 5.0) + 0.1% polyvinylpyrridone + 5 mM 2-mercaptoethanol (Sigma Chemical Co., St. Louis, MO, USA) at speed 5 for 1 minute using an Omnimixer homogenizer (OMNI International, Waterburg, Connecticut, USA).

The homogenate was centrifuged at 9630 g for 15 minutes at 4 °C. The supernatant was obtained after filtering through 4 layers of cheesecloth and was used for soluble enzyme determination. The pellet was then washed twice with 0.2% cold sodium sulfite, and then extracted with 50 mL 50 mM NaAC (pH 5.0) + 0.1% PVP + 5 mM 2-mercaptoethanol with 500 mM NaCl for 3 h with constant stirring at 4 °C and then centrifuged at 9630 g for 15 minutes. The supernatant was used for cell wall associated enzyme assay. All extraction procedures were carried out at 4 °C.

Endo-PG was estimated as a decrease in viscosity of polygalacturonic acid. Reaction mixtures, containing 3 mL 2% polygalacturonic acid in 50 mM NaAC (pH 5.0) and 2 mL crude enzyme, were incubated for 10 h at 37 °C in a water bath. A viscometer (Cannon Instrument Co., State College, PA, USA. Ubbelohde type, IH7-14) was used to determine the relative change in viscosity at 20 °C, with initial viscocity measured just after mixing the enzyme extract and polygalacturonic acid and final viscocity measured after incubation at 37 °C. One unit of enzyme was defined as the amount that results in 0.001 centistoke decrease in viscosity of polygalacturonic acid per hour at 37 °C.

Exo-PG was measured as the hydrolytic release of reducing groups from polygalacturonic acid. Reaction mixtures containing 1 mL 0.5% polygalacturonic acid and 1 mL crude enzyme in 50 mM NaAC (pH 4.4) were incubated for 8 hours at 37 °C. The reaction was stopped by the addition of 1 mL 100 mM cold borate (pH 9.0). Increases in reducing groups were measured at 274 nm by the method of Gross (1982) with α-D-galacturonic acid as standard, using a time-zero blank in which enzyme extracts were added to the polygalacturonic acid immediately before addition of borate

buffer. One unit of enzyme was defined as the amount of enzyme that produced 1 μg (5.15 nmoles) reducing group per hour at 37 °C.

Enzyme activity determination of glycosidase (galactosidase, glucosidase, xylosidase, arabinosidase and mannosidase) was based on the release of *p*-nitrophenol from the corresponding *p*-nitrophenylpyranoside. Enzyme extracts of 0.1 mL were added to 0.9 mL reaction mixture containing final concentration of 2.5 mM *p*-nitrophenylpyranoside in 50 mM NaAC buffer at the appropriate pH for each glycosidase (determined by preliminary tests). For β-galactosidase, β-xylosidase, α-arabinosidase, β-arabinosidase and α-mannosidase, pH was 4.0; for α-galactosidase, α-glucosidase, α-xylosidase, β-glucosidase and β-mannosidase, pH was 5.0. The reaction was allowed to proceed for 1 hour at 37 °C and was terminated by adding 5 mL 100 mM sodium carbonate. The concentration of liberated *p*-nitrophenol was determined by reading the absorbance at 410 nm (Ranwala et al., 1992). One unit of enzyme was defined as the amount of enzyme that catalyzed the liberation of 1 nmole *p*-nitrophenol per minute at 37 °C (Ranwala et al., 1992).

RESULTS

Fruit firmness

Fruit firmness of 'J12-119' remained fairly constant for 48 h without ethylene exposure (from 66 N to 65 N); but upon ethylene exposure of 1 ppm and 100 ppm for 48 h, the firmness decreased to similar levels regardless of ethylene concentration, from 66 N to 15 N and 12 N, respectively (Fig 1). 'Cresthaven' fruit decreased in firmness from 67 N to 59 N within 48 h without ethylene exposure; When exposed to 1 ppm and 100 ppm

ethylene for 48 h, fruit firmness decreased to 27 N and 15 N, respectively; exhibiting a ethylene concentration dependent decrease in fruit firmness (Fig. 1).

PG activity

Endo-PG activity increases correlated well with firmness decreases ($r = -0.984^{**}$ for 'J12-119'; $r = -0.918^{**}$ for 'Cresthaven'). In 'J12-119', endo-PG was not detected for 48 h without ethylene treatment (Fig. 2). Endo-PG increased continuously for 48 h with 1 ppm ethylene treatment, whereas endo-PG for 100 ppm ethylene treatment nearly doubled that of 1 ppm treatment after both 24 h and 48 h. In 'Cresthaven', low levels of endo-PG were detected without ethylene treatment, increasing from 1.9 U/g FW to 3.8 U/g FW within 48 h (Fig 2); endo-PG for 1 ppm ethylene treatment increased similarly to that of 1 ppm ethylene treatment for 'J12-119'. Unlike 'J12-119', endo-PG for 100 ppm ethylene treatment increased only similarly to that of 1 ppm ethylene treatment by 24 h; however by 48 h endo-PG increased fast to a higher level (55.5 U/g FW).

Exo-PG activities in 'J12-119' and 'Cresthaven' were very similar; exo-PG for 1 ppm treatment was very similar to the 0 ppm treatment. However, exo-PG for 100 ppm ethylene treatment in 'J12-119' and 'Cresthaven' increased very fast to 66.7 U/g FW and 64.7 U/g FW, respectively (Fig. 3).

GalA content of ethanol precipitate recovery

In parallel with endo-PG activity changes was the GalA content of ethanol precipitate recovery. In 'J12-119', it was extremely low (0.16 mg/g FW) and remained fairly constant when ethylene was excluded (Fig. 4); GalA content of the ethanol precipitate increased very fast upon ethylene exposure. Exposure to 1 ppm ethylene continuously for 48 h led to an ethanol precipitate of 1.52 mg/g, whereas exposure to 100

ppm continuously for 48 h resulted in a higher GalA content of ethanol precipitate recovery, 1.72 mg/g FW. In 'Cresthaven', GalA content of the ethanol precipitate was 0.30 mg/g FW initially and increased much faster than 'J12-119' when ethylene was excluded, to 0.78 mg/g FW. GalA content of Ethanol precipitate was similar to those of 'J12-119' when treated with ethylene, with a higher content for fruits exposed to 100 ppm ethylene continuously for 48 h (1.90 mg/g FW) than in 'J12-119' (1.72 mg/g FW).

Extractable juice

Extractable juice in both cultivars increased upon ethylene treatment. In 'J12-119', extractable juice increased only slightly without exposure to ethylene (Fig. 5). It increased substantially at 24 h to 35.5% and 40.1% for 1 ppm and 100 ppm ethylene treatment, respectively. By 48 h, extractable juice increased slightly for 1 ppm fruit and stayed essentially the same for 100 ppm fruit. In 'Cresthaven', extractable juice increased slowly without exposure to ethylene, from 5.8% to 7.2% (Fig. 5). Unlike 'J12-119' extractable juice increased slightly to 10.8% and 14.7% for the first 24hrs for 1 ppm and 100 ppm ethylene treatment, respectively. By 48 h extractable juice increased to 29.4% and 31.7%, respectively.

Glycosidase activity

Two categories of glycosidases can be classified according to their level of activities. High level of activities (15-70 U/g FW) included α-mannosidase, α-galactosidase, and β-galactosidase. Low level (0-15 U/g FW) included β-glucosidase, β-arabinosidase, β-mannosidase, β-xylosidase, α-glucosidase, and α-arabinosidase. We did not detect any level of α-xylosidase activities.

α-Mannosidase activity was lower in 'J12-119' than in 'Cresthaven' for every

treatment except 100 ppm ethylene after 48 h exposure (Fig. 6). There was a consistent dose response for 'J12-119' but not for 'Cresthaven'. β-galactosidase of 'J12-119' increased steadily (Fig. 7). β-Galactosidase in 'Cresthaven' increased up to 24 h; by 48 h 1 ppm and 100 ppm treatments decreased. α-Galactosidase in 'J12-119' and 'Cresthaven' also increased steadily upon exposure to ethylene, and there was also a dose response for 'J12-119' (Fig 8).

β-Glucosidase activity was lower in 'J12-119' than in 'Cresthaven' (Fig. 9). There was a slight ethylene dose response for 'J12-119' after 48 h of treatment. β-Glucosidase in 'Cresthaven' increased for up to 24 h then decreased thereafter. β-Arabinosidase activity was slightly higher in ethylene exposed fruit of 'J12-119' than that of 'Cresthaven' (Fig. 10). There was an ethylene dose response for 'J12-119', but not for 'Cresthaven'. Low levels of β-xylosidase activity were detected in 'J12-119' at the initial treatment (prior to ethylene exposure) (0.3 U/g FW); but no activity was detected in 'Cresthaven' (Fig. 11). For 48 h the β-xylosidase activities increased to 5.7 and 17.5 U/g FW in the 1 ppm and 100 ppm ethylene treatments, respectively; and there was also a dose response for 'J12-119'. Low levels of β-xylosidase (2.6 U/g FW) were only detected with 100 ppm ethylene treatment for 48 h in 'Cresthaven'. α-Arabinosidase activity in 'J12-119' increased steadily and was dose-responsive upon ethylene treatment (Fig. 12). α-Arabinosidase activity in 'Cresthaven' increased up to 24 h then decreased by 48 h. β-Mannosidase was the only glycosidase observed that decreased during 48 h of observation (Fig. 13). There was still a dose response for 'J12-119'. The levels of α-glucosidase in 'J12-119' and 'Cresthaven' were very low, increasing only from 0.6 U/g FW to 1.5 U/g FW upon 100 ppm ethylene treatment for 48 h (data not shown).

There was a high correlation in 'J12-119' between galactose loss from cell wall and increasing β-galactosidase activity (r = -0.936) (Fig. 14), and between arabinose loss from cell wall and β-arabinosidase (r = -0.983) (Fig. 15). β-galactosidase activity increased from 29.6 U/g FW to 64.0 U/g FW, and at the same time galactose content in the cell wall decreased from 5.7 μmole/g FW to 4.3 μmole/g FW after exposure to 100 ppm ethylene for 48 h. Cell wall galactose loss probably was related to β-galactosidase activity increase in 'J12-119'. β-arabinosidase activity increased from 3.0 U/g FW to 8.0 U/g FW, and cell wall arabinose content decreased from 12.6 μmole/g FW to 8.2 μmole/g FW after 100 ppm ethylene treatment for 48 h. There was also a high correlation in 'Cresthaven' between galactose loss from cell wall and β-galactosidase activity, and between arabinose loss from cell wall and β-arabinosidase (data not shown). In addition to cell wall loss of arabinose and galactose, galacturonic acid, rhamnose, fucose and glucose was also lost from the cell wall. In spite of the increase of β-xylosidase and α-mannosidase activity upon ethylene treatment, cell wall xylose and mannose content remained fairly constant.

DISCUSSION

Stonyhard mutation of peach fruit dramatically reduces ethylene biosynthetic capacity and confers unique softening characteristics to the fruit. Fruit softening can be initiated to obtain a desirable melting flesh texture, or a pasty texture, depending on the concentration and duration of exposure to exogenous ethylene. When treated with 0 ppm ethylene for 48 h, the fruits still remain firm (Fig. 1). When treated with 1 ppm or 100

ppm for 48 h, similar firmness but different textures were obtained; when treated with 1 ppm ethylene for 48 h, they obtain a normal soft texture; when treated with 100 ppm ethylene for 48 h, they become "pasty", which is characterized as a slimy or pasty consistency at cut surface, and a slight reduction in mesocarp free water.

Possible pasty mechanism

Pectin solubilization is thought to be a very important determinant of the fruit softening process. Abnormal solubilization probably results in abnormal textures, among which is pasty and mealy in peaches and nectarines. Mealiness is a physiological disorder during ripening after prolonged periods of cold storage. The affected fruits are lacking in juice and have a dry mealy texture (Dawson and Watkins, 1995). Mealiness has been ascribed to reduced PG activity and limited pectin solubilization (Ben-Arie, 1980; Mollendroff and Villiers, 1988; Mollendroff et al., 1992).

Pasty is an abnormal texture obtained by exposing Stonyhard fruit to 100 ppm ethylene continuously for 48 h. It is characterized by a slimy, or a pasty consistency at cut surface, accompanied by a slight reduction in mesocarp free water during fruit softening. Pasty texture is not obtained in fruits by exposure to 1 ppm ethylene continuously for 48 h, nor in 'Cresthaven' fruits exposed to 1 ppm and 100 ppm ethylene continuously for 48 h. We have observed pastiness in four other peach selections with the Stonyhard gene, but never in fruit not containing the Stonyhard gene.

Both cell wall exo-PGs in 'J12-119' and 'Cresthaven' increased upon ethylene treatment, the response pattern for both cultivars were very similar (Fig. 3). When endo-PG was examined, there existed a major difference in 'J12-119' and 'Cresthaven'. In 'J12-119', no endo-PG was detected when ethylene was excluded from the fruits (Fig. 1).

One ppm ethylene stimulated endo-PG activity from 0 to 20.9 U/g FW in 48 h. Endo-PG activity of the 100 ppm ethylene treatment nearly doubled that of 1 ppm ethylene treatment for both 24 h and 48 h treatment durations. Low levels of endo-PG (1.9 U/g FW) were observed over a 48 h time period when ethylene was excluded from the 'Cresthaven' fruit. Activity increased to 3.8 U/g FW by 48 h (Fig 2). Exposing 'Cresthaven' fruits to 1 ppm ethylene resulted in a increase in endo-PG activity similar to 1 ppm ethylene treatment in 'J12-119' for 24 h and 48 h period. Exposing the fruits to 100 ppm for 24 h resulted in a similar endo-PG activity as 1 ppm, but its activity increased by 48 h to 55.5 U/g FW.

In 'Cresthaven', low levels of endo-PG were detected without ethylene exposure, and limited pectin solubilization had probably ocurred as evidenced by an increase in buffer soluble polysaccharides during the 48 h time period (Fig. 4). This preprocessing probably produced nicks in the pectin so that when fruit were treated with ethylene, the increased endo-PG activity acted on pre-cut pectin and more lower molecular weight pectin may have been solubilized. In 'J12-119' we did not detect any level of endo-PG when ethylene was excluded and there was no increase in buffer soluble polysaccharides. There was no preprocessing of pectin polymers. When treated with ethylene, endo-PG increased very fast, the endo-PG activity of 100 ppm was nearly double that of 1 ppm treatment by 24 h of exposure. In a very short period period of time, a large amount of pectin solubilization occurred. This sudden outburst of pectin solubilization may have produced large amounts of high molecular weight soluble pectin, which could form a gel-like consistency and be responsible for the pasty texture.

Extractable juice is reduced in mealy fruits due to gel formation of solubilized high molecular weight pectin as a result of reduced PG activity during cold storage (Mollendorff et al., 1992). Extractable juice of the Stonyhard fruit was only slightly decreased to produce the pasty texture. Since the pasty texture in Stonyhard fruit apparently resulted from a sudden increase in endo-PG, pectin may have been over-solubilized. The slimy appearance of mesocarp tissue at cut surfaces could be attributed to an over abundance of soluble pectin.

Possible role of glycosidase in pasty texture development

The softening that occurs during the ripening of many fruits is presumbly the result of enzymatic modifications of cell wall polysaccharides. The wall degradation that results in fruit softening could require both PG to reduce polygalacturonide chain length and other enzymes to hydrolyse neutral polymers that contribute to the stability of the total polysaccharide cell wall matrix. Glycosidase is such a class of enzymes that acts in a exo-fashion, attacking poly- and oligosaccharides progressively from the nonreducing terminal and release monosaccharides. Due to their mode of action, they may not play an important part in cell wall disassembly via hydrolysis; but by removing some side chains, they may render inner structure of cell walls more accessible to pectic enzymes, or simply remove or relax spatial entanglement.

β-Galactosidase was the major glycosidase in 'J12-119' and 'Cresthaven' (30-70 U/g FW; Fig. 7) and the activities were similar and increased steadily upon harvest, as has been shown in mango (Ali et al., 1995), muskmelon (Ranwala et al., 1992), pear (Tateishi et al., 1996), tomato (Carrington et al., 1996), cherry (Barrett et al., 1994), apple (Ross et al., 1994), and hot pepper (Gross et al., 1986).

α-Mannosidase was another major glycosidase in 'J12-119'and 'Cresthaven' and it also steadily increased upon ethylene treatment, in agreement with mango (Ali et al., 1995) and tomato (Watkins et al., 1988). However, α-mannosidase remained constant in muskmelon (Ranwala et al., 1992) and pear (Tateishi et al., 1996). 1 ppm and 100 ppm ethylene stimulated α-mannosidase activity for up to 24 h (Fig. 6). By 48 h, α-mannosidase levels continued to increase in 'J12-119' and was dose responsive, whereas that of 100 ppm ethylene treatment of 'Cresthaven' decreased.

α-Galactosidase activity in 'J12-119' and 'Cresthaven' was very similar and consistently increased upon ethylene treatment, in agreement with mango (Ali et al., 1995), muskmelon (Ranwala et al., 1992), and pear (Tateishi et al., 1996). 1 ppm and 100 ppm ethylene stimulated α-galactosidase activity for up to 24 h (Fig. 9). By 48hr, α-galactosidase levels continued to increase in 'J12-119' and was dose responsive, whereas that of 100 ppm ethylene treatment of 'Cresthaven' decreased.

β-Glucosidase in 'J12-119' increased only slightly upon ethylene treatment, in agreement with muskmelon (Ranwala et al., 1992), and pear (Tateishi et al., 1996). β-Glucosidase in 'Cresthaven' increased for up to 24 h; by 48 h β-glucosidase levels of 1 ppm and 100 ppm ethylene treatment decreased. β-Xylosidase in 'Cresthaven' remained fairly constant, similar to that in pear. β-Xylosidase activity in 'J12-119' increased very fast upon 100 ppm ethylene treatment. α-Xylosidase was not detected in 'J12-119' and 'Cresthaven' as in pear (Tateishi et al., 1996).

The optimum activity of glycosidases is carried out against *p*-nitrophenyl-β-D-glycopyranoside at the optimum pH, which might be different from the cell wall pH environment and the native cell wall substrate. For example, the optimum activity of β-

galactosidase against *p*-nitrophenyl-β-D-galactopyranoside was at pH 3.2, but against a galactan purified from kiwifruit cell walls was pH 4.9. The difference in pH might be due to the different affinity for different substrates (Ross et al., 1993).

β-galactosidase has been purified and characterized and its activity against native cell wall substrates has been shown in tomato (Pressy, 1983), muskmelon (Ranwala et al., 1992), kiwifruit (Ross et al., 1993), and apple (Ross et al., 1994). β-galactosidase can release galactose from kiwifruit cell wall galactan and sodium carbonate soluble pectic fraction (Ross et al, 1993). Though the amount of galactose released by β-galactosidase in vitro is unlikely to be sufficient to account for the observed loss of galactose in vivo during ripening, evidence has suggested that even limited in vivo β-galactosidase activity on the cell wall pectins could have a significant effect on pectin solubility through decreasing the ability of pectin molecules to aggregate (De Veau et al., 1993). Thus, limited β-galactosidase activity on the side chains of pectic backbone could have major implications for the matrix of the cell wall in rendering cell wall components more accessible to other cell wall degrading enzymes. In fact, β-galactosidase extracted from cell walls of ripe muskmelon was able to degrade larger pectin polymers from unripe fruit cell walls to smaller size polymers in vitro (Ranwala et al., 1992). The strong correlation between β-galactosidase activity, loss of tissue firmness, and increased pectin solubility and degradation was observed in mango (Ali et al., 1995), hot pepper (Gross et al., 1986), apple (Waller, 1978), and muskmelon (McCollum, 1989). Therefore, β-galactosidase might play an important role in cell wall pectin modification and softening of fruits during ripening, especially in these PG-low fruits. In this research, levels of most glycosidases, including β-galactosidase, increased for 1 ppm and 100 ppm ethylene

treatment for up to 48 h in 'J12-119' and was dose responsive; whereas levels of these enzymes in 'Cresthaven' increased for 1 ppm and 100 ppm ethylene treatment for up to 24 h, by 48 h the levels of these glycosidases decreased for either 100 ppm ethylene treatment or both 1 ppm and 100 ppm ethylene treatments. One possibility for a contribution of the glycosidases to pasty texture in 'J12-119' fruit is that continued increase in glycosidase activity may help to solubilize polysaccharides, thus resulting in more ethanol precipitate in 'J12-119' than in 'Cresthaven' for the 100 ppm ethylene treatment for 48 h. However, an examination of ethanol precipitate recovery revealed that more ethanol precipitate was produced in 'Cresthaven' than in 'J12-119' for the 100 ppm ethylene treatment for 48 h (Fig. 4). Hence, continued increase in glycosidase activity did not contribute to solubilzation of polysaccharides. It remains to be seen whether continued increase in glycosidase activity will affect molecular weight change of solubilized polysaccharides.

Xyloglucan endotransglycosylase (XET) has been implicated in xyloglucan metabolism recently (Percy et al., 1996). This enzyme is proposed to cut and rejoin intermicrofibrillar xyloglucan chains causing cell wall loosening for plant cell expansion. Since xyloglucan is modified during softening (Hegde and Maness, 1998; Lashbrook, 1997), it is possible that XET could play an important role in fruit softening. Determination of XET in peaches may provide more enzymic insight into the softening mechanism.

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FIGURE LEGENDS

Figure Page

1. The effect of ethylene on fruit firmness in 'J12-119' and 'Cresthaven' peach fruits. Fruits were exposed to 0 ppm, 1 ppm or 100 ppm ethylene and were sampled just prior to treatment and after 24 h and 48 h exposure. The X axis represents treatment duration in hours and the Y axis represents firmness, measured as resistance to puncture on opposite cheeks of 10 fruit per treatment. Bars are standard error of the mean for each treatment.
◆····◆····◆ 'J12-119' 0 ppm; ▲·····▲····▲ 'J12-119' 1 ppm;
■····■····■ 'J12-119' 100 ppm; ◆—◆—◆ 'Cresthaven' 0 ppm;
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3. The effect of ethylene on fruit exo-PG activity in 'J12-119' and 'Cresthaven' peach fruits. Fruits were exposed to 0 ppm, 1 ppm or 100 ppm ethylene and were sampled just prior to treatment and after 24 h and 48 h exposure. The X axis represents treatment duration in hours and the Y axis represents exo-PG activity, measured as increase in reducing groups for pooled mesocarp samples from 10 fruit per treatment. One unit of enzyme was defined as the amount that produced 1 μg (5.15 nmoles) reducing group per hour at 37 °C. Bars are standard error of the mean for each treatment.
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Bars are standard error of the mean for each treatment.....49

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Figure 1

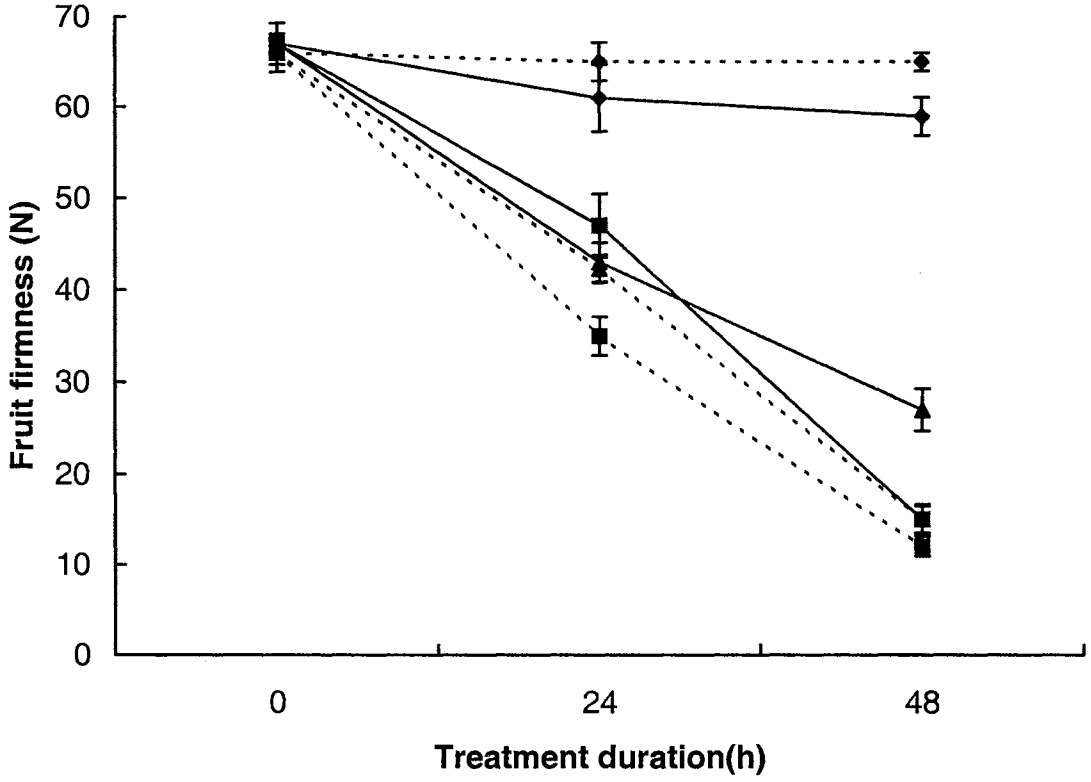

70
60
50
40
30
20
10
0
Fruit firmness (N)
0
24
48
Treatment duration(h)

Figure 2

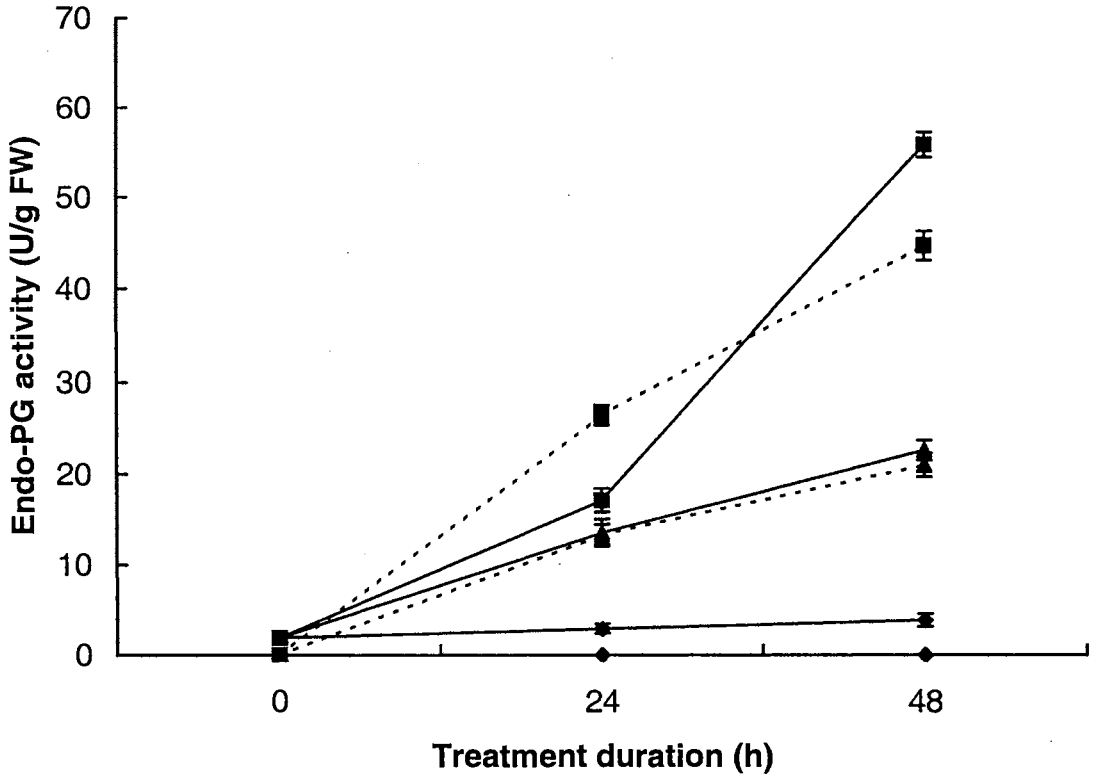

70
60
50
40
30
20
10
0
Endo-PG activity (U/g FW)
0
24
48
Treatment duration (h)

Figure 3

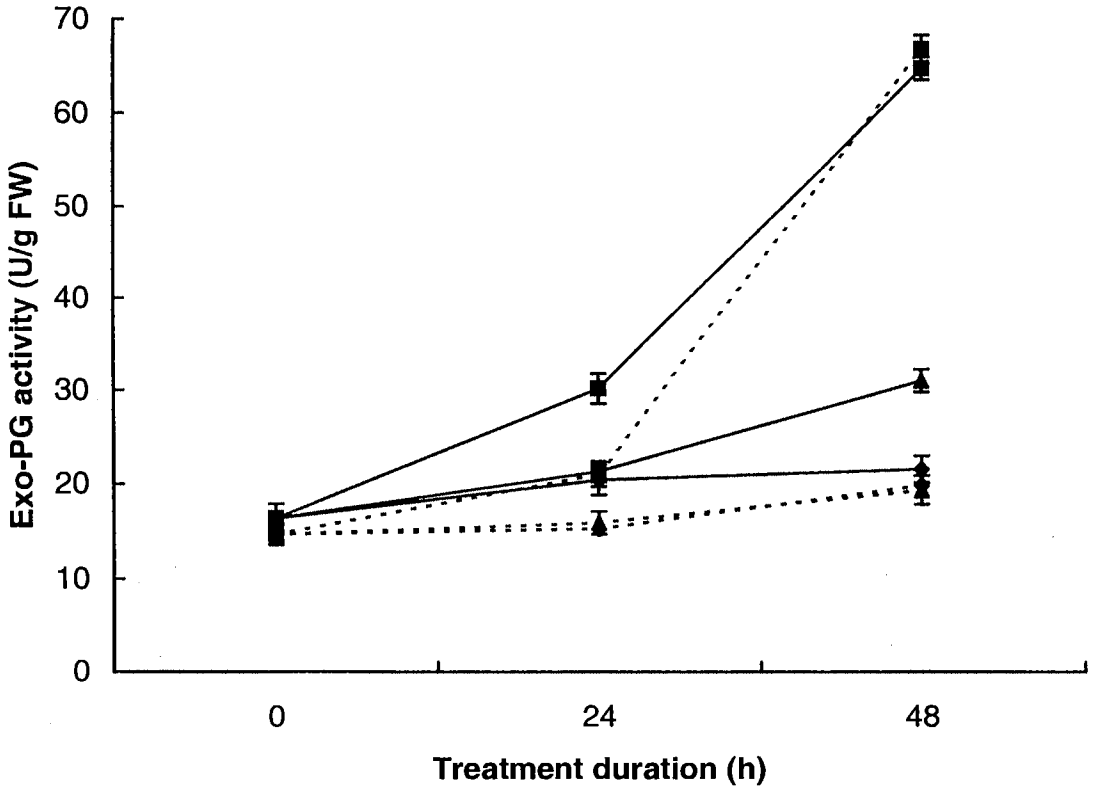

70
60
50
40
30
20
10
0
Exo-PG activity (U/g FW)
0
24
48
Treatment duration (h)

Figure 4

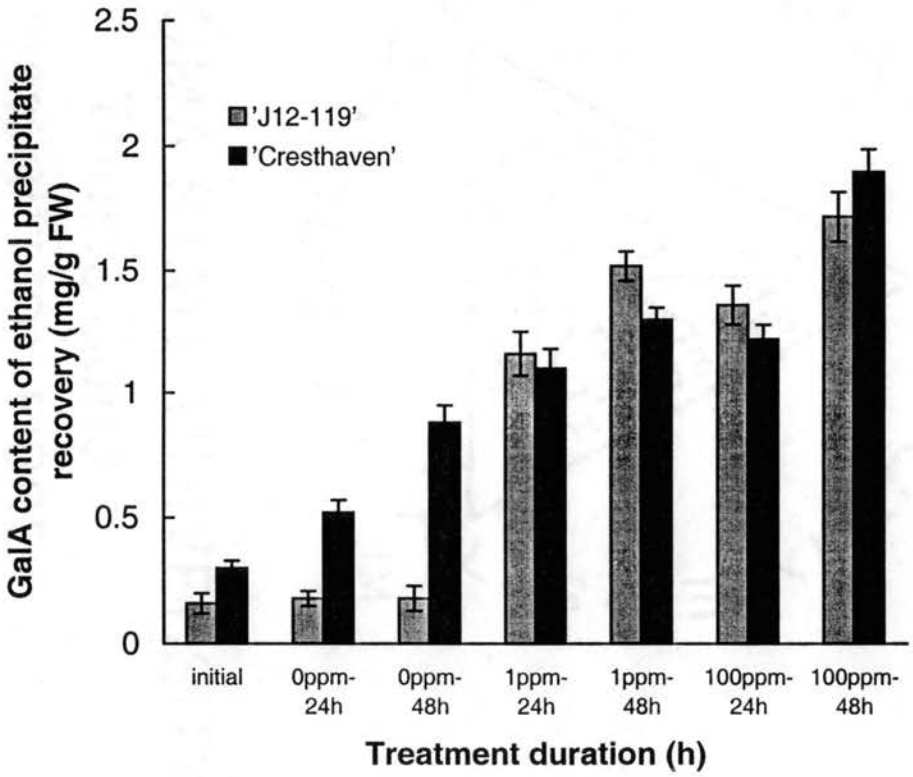

GalA content of ethanol precipitate recovery (mg/g FW)
2.5
2
1.5
1
0.5
0
'J12-119'
'Cresthaven'
initial
0ppm-24h
0ppm-48h
1ppm-24h
1ppm-48h
100ppm-24h
100ppm-48h
Treatment duration (h)

Figure 5

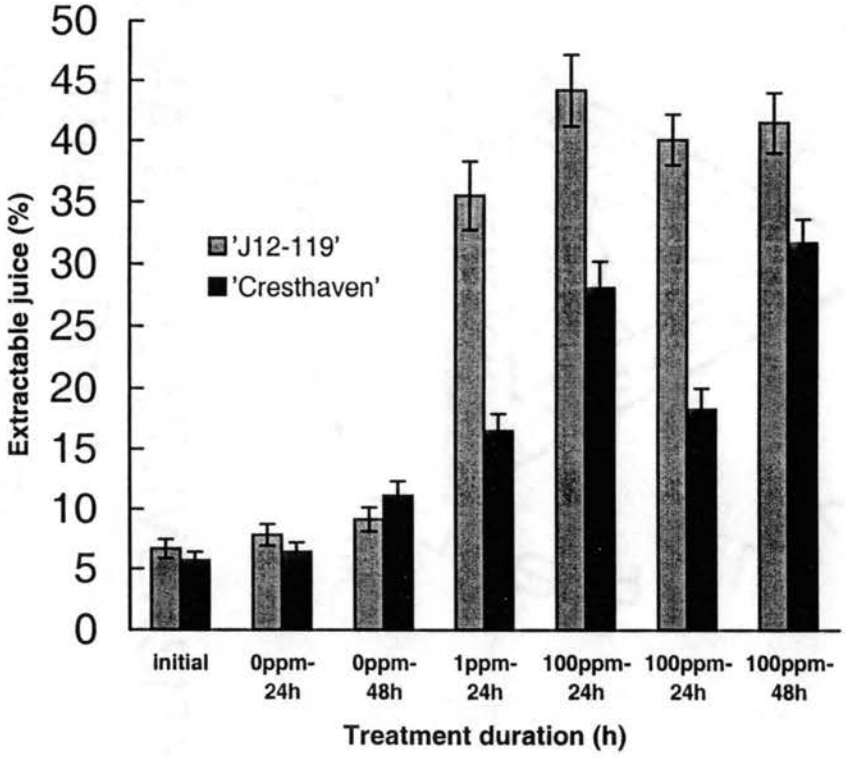

Extractable juice (%)
50
45
40
35
30
25
20
15
10
5
0
'J12-119'
'Cresthaven'
initial
0ppm-24h
0ppm-48h
1ppm-24h
100ppm-24h
100ppm-24h
100ppm-48h
Treatment duration (h)

Figure 6

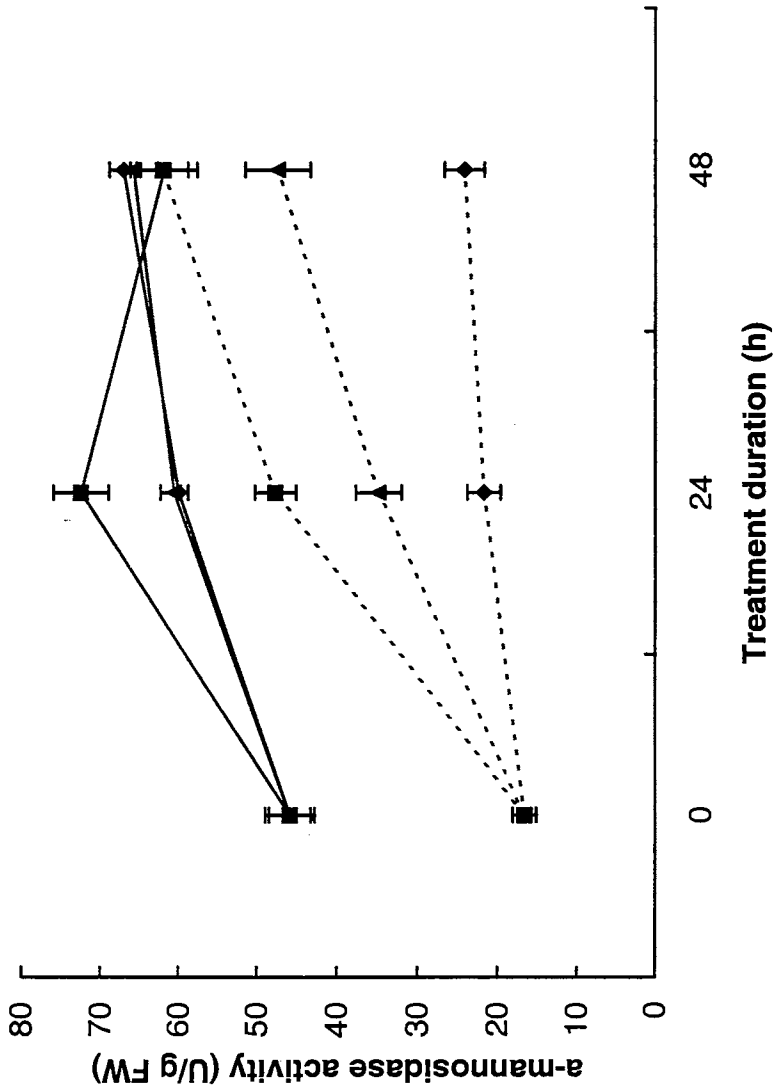

a-mannosidase activity (U/g FW)
0
10
20
30
40
50
60
70
80
0
24
48
Treatment duration (h)

Figure 7

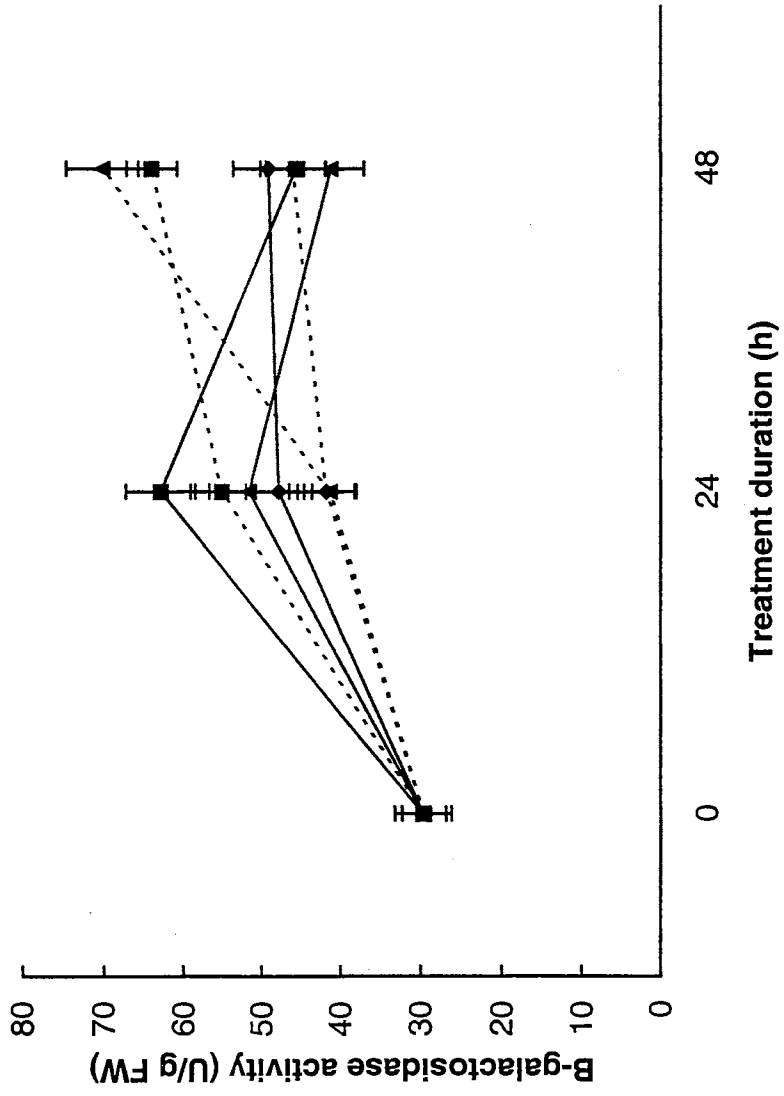

B-galactosidase activity (U/g FW)
80
70
60
50
40
30
20
10
0
0
24
48
Treatment duration (h)

Figure 8

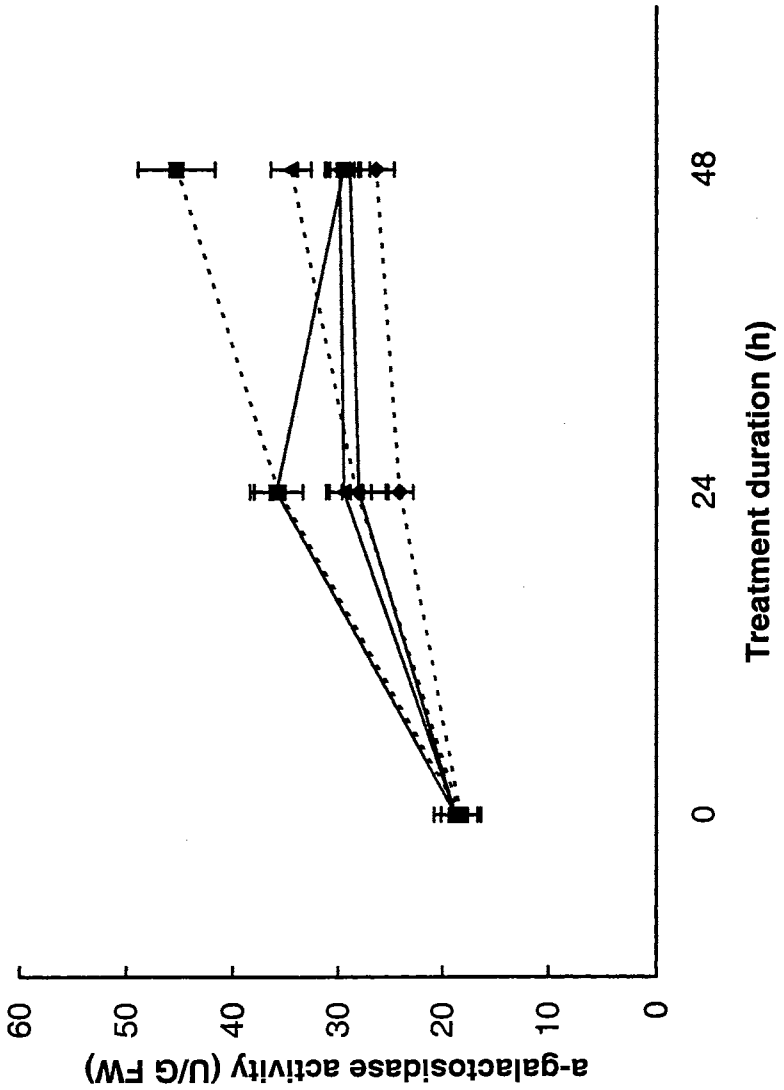

a-galactosidase activity (U/G FW)
60
50
40
30
20
10
0
0
24
48
Treatment duration (h)

Figure 9

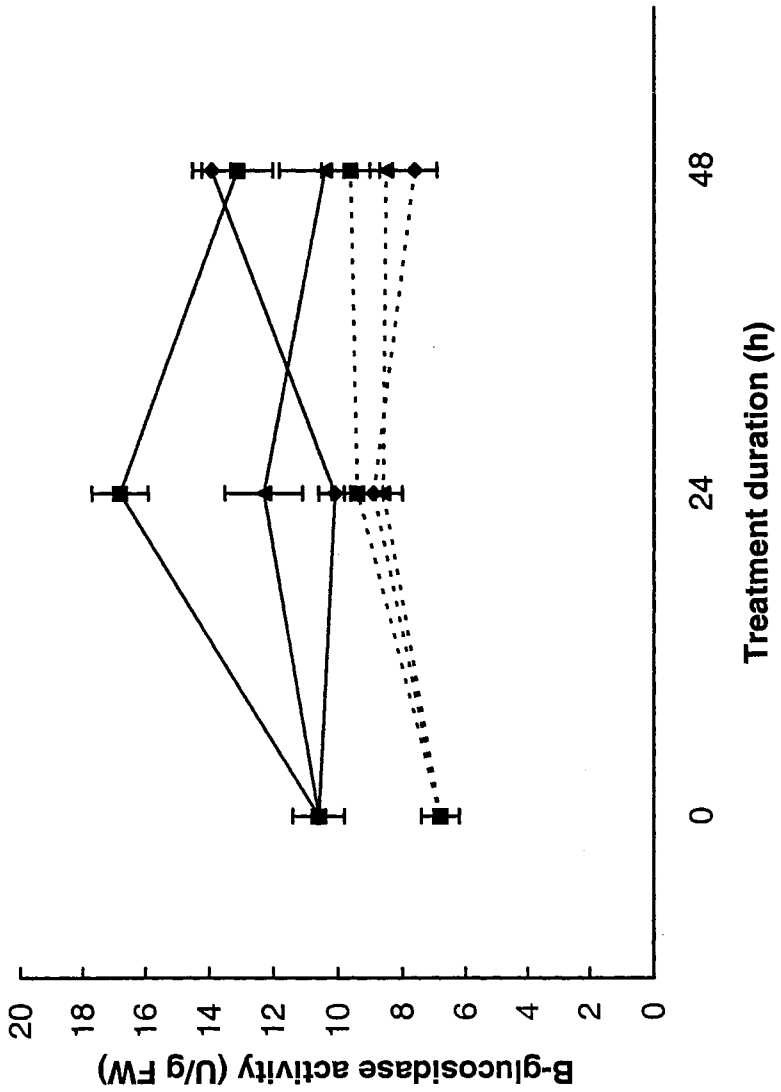

B-glucosidase activity (U/g FW)
0
2
4
6
8
10
12
14
16
18
20
0
24
48
Treatment duration (h)

Figure 10

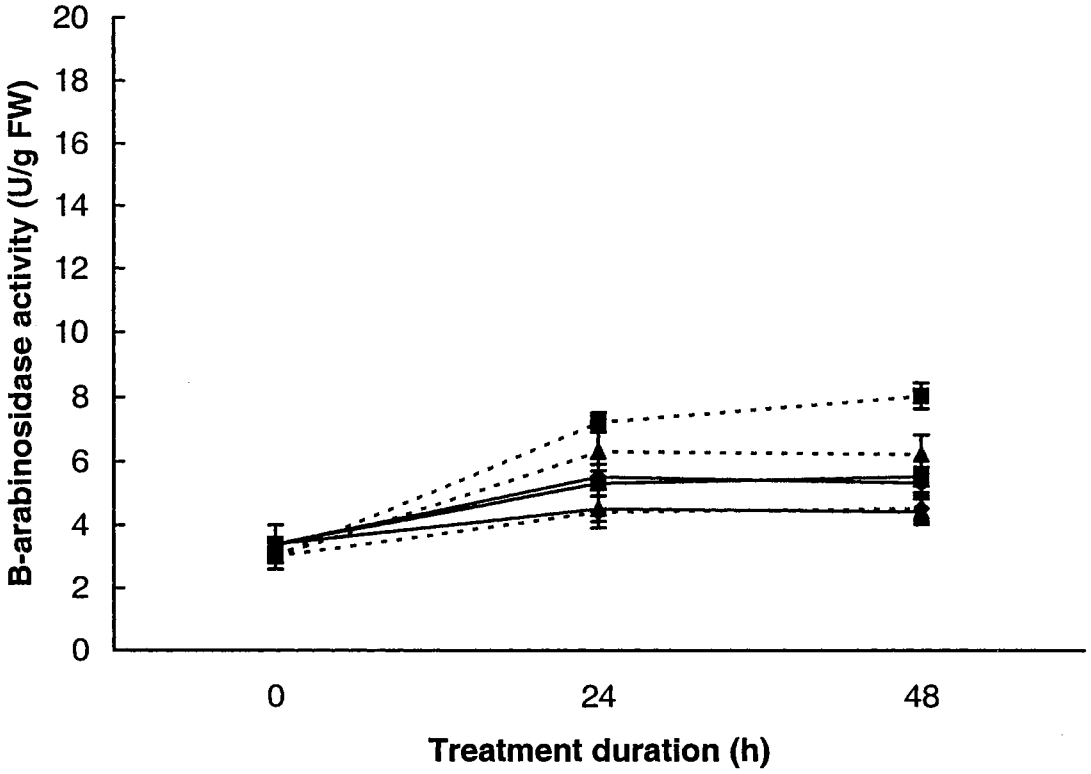

B-arabinosidase activity (U/g FW)
20
18
16
14
12
10
8
6
4
2
0
0
24
48
Treatment duration (h)

Figure 11

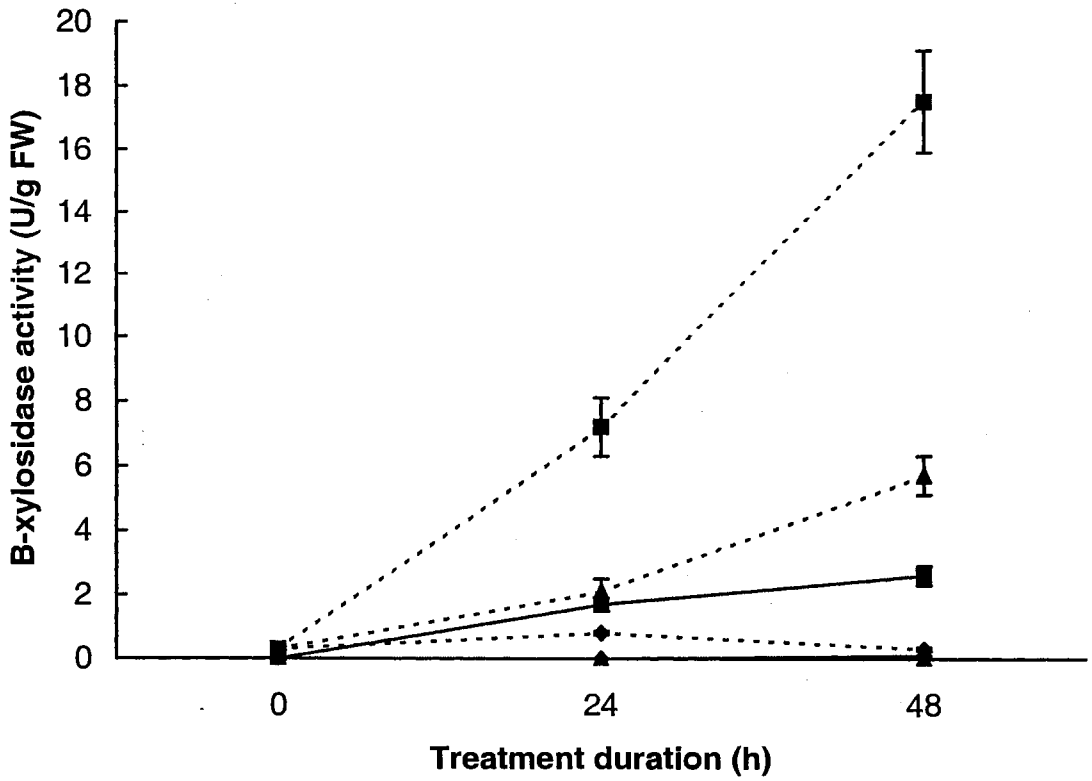

B-xylosidase activity (U/g FW)
20
18
16
14
12
10
8
6
4
2
0
0
24
48
Treatment duration (h)

Figure 12

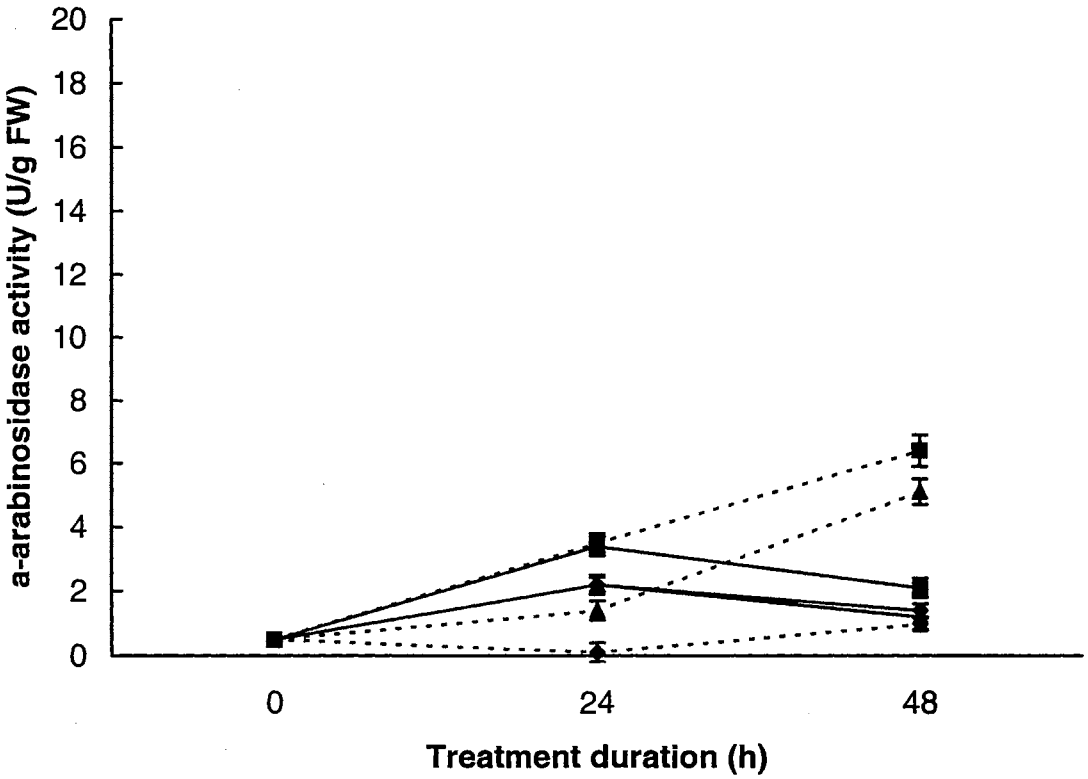

a-arabinosidase activity (U/g FW)
20
18
16
14
12
10
8
6
4
2
0
0
24
48
Treatment duration (h)

Figure 13

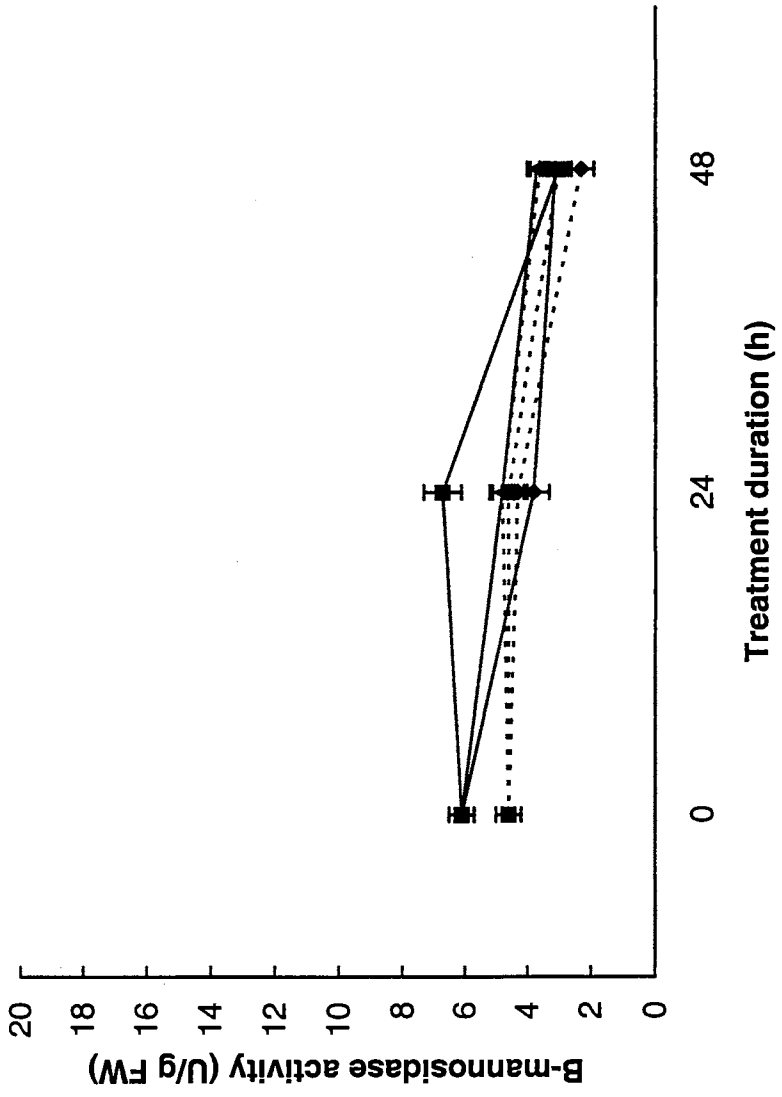

B-mannosidase activity (U/g FW)
20
18
16
14
12
10
8
6
4
2
0
0
24
48
Treatment duration (h)

Figure 14

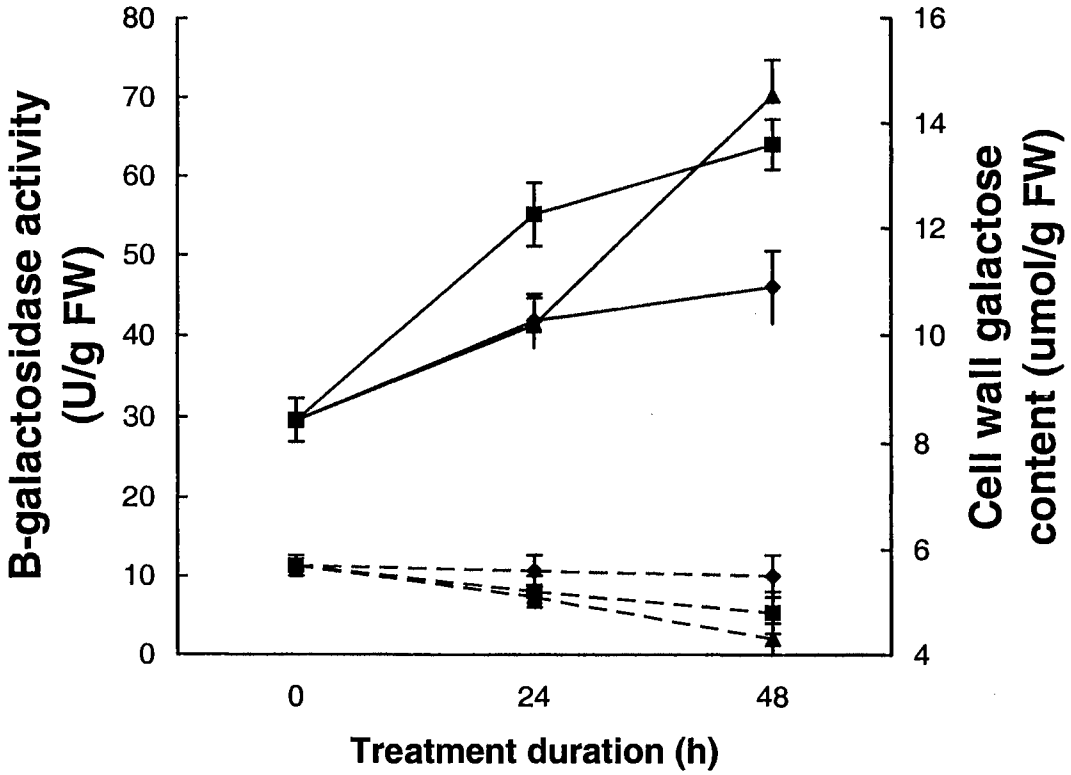
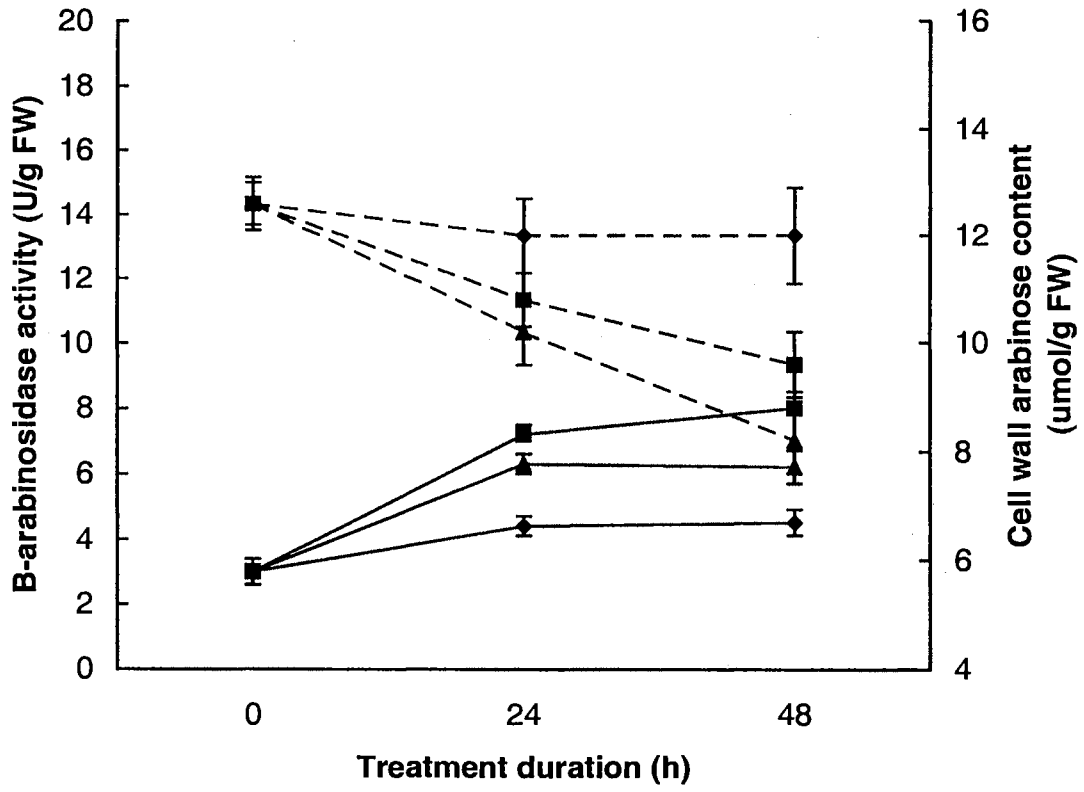

B-galactosidase activity (U/g FW)
Cell wall galactose content (umol/g FW)
80
70
60
50
40
30
20
10
0
16
14
12
10
8
6
4
0
24
48
Treatment duration (h)

Figure 15


B-arabinosidase activity (U/g FW)
Cell wall arabinose content (umol/g FW)
Treatment duration (h)
0
24
48
0
2
4
6
8
10
12
14
16
18
20
4
6
8
10
12
14
16

CHAPTER III

Mechanism of Pasty Texture Development in Stonyhard Peach Fruits upon Ethylene Treatment

---The changes of apparent molecular mass of pectin and hemicellulose extracts

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Abstract

Stonyhard (New Jersey selection'J12-119') peach (*Prunus persica* (L.) Batsch) fruits were used to study softening and textural changes during ripening. Without ethylene exposure, firmness of 'J12-119' remained fairly constant at room temperature. When exposed to 1 ppm or 100 ppm ethylene for 48 h, these fruit softened at a rate consistent with control fruit ('Cresthaven') and to a similar firmness. However, 1 ppm treated fruit attained a normal juicy texture while 100 ppm attained a pasty texture. 'Cresthaven' fruit softened to a normal juicy texture with either ethylene treatment. Enzymatically inactive cell walls were prepared from mesocarp tissues of 'J12-119' and 'Cresthaven' fruits prior to ethylene exposure and following 24 h and 48 h of ethylene exposure. Pectin-associated and hemicellulose-associated polysaccharides were sequentially extracted from the cell

walls and were subjected to size exclusion chromatography. Buffer soluble polysaccharides, prepared from mesocarp tissue by grinding in low molarity buffer and precipitation of the supernatant with ethanol, exhibited a slight molecular mass downshift of homogalacturonan like polymers in 'J12-119' but extensive molecular mass downshift of homogalacturonan like polymers in 'Cresthaven' after 48 h of exposure to 100 ppm ethylene. In Na_2CO_3-cold extracts and Na_2CO_3-warm extracts of 'J12-119' and 'Cresthaven', no clear molecular mass downshift was observed. Large rhamnogalacturonan like polymers were solubilized in these extracts. 1 M KOH cold extracts in both 'J12-119' and 'Cresthaven' separated into 3 apparent molecular mass peaks. Large molecular mass rhamnogalacturonan-xylan complex decreased in apparent molecular mass and could hardly be detected after 48 h of exposure to 1 ppm and 100 ppm ethylene.. Intermediate-sized xyloglucan polymers began to downshift between 24 and 48 h of exposure. Hemicelluloses in 4 M KOH extracts exhibited extensive downshift of apparent molecular mass. Attainment of pasty texture in 100 ppm treated 'J12-119' fruits may have been related to sudden release of large quantities of pectic polysaccharides which were not depolymerized, and of sufficient size to gel and impart the characteristic pasty or slimy consistency at cut surfaces.

Introduction

Ripening in many fruits is associated with textural changes that are believed to result from disassembly of the primary cell wall. This includes modifications of the structure and composition of the constituent polysaccharides and the potential alteration of the covalent and non-covalent interactions between different polysaccharides, mainly

through a range of cell wall hydrolases (Fischer and Bennett, 1991). PG was once thought to be the major enzyme involved in cell wall structural modifications leading to tissue softening (Hobson and Grierson, 1993; Huber, 1983). However, molecular genetic approaches have revealed that PG may not be exclusively responsible for softening and attention has been given to other enzymes such as β-galactosidase (Seymour et al., 1987; Smith, 1988; Ranwala et al., 1992).

Enzyme studies alone will not reveal the subtle modification of specific cell wall polymers that occur during ripening. The structural characterization of these polymers during softening may provide important insight into the mechanism of the softening process.

Pectic polysaccharides are major constituents of primary cell wall, coexisting with other polysaccharides such as hemicellulose and cellulose, forming a crosslinked matrix network (Carpita and Gibeaut, 1993). It is thought that the breakdown of the bonds holding this structure leads to loosening of the stability of this network, which results from degradation of cell wall components, causing loss of tissue firmness. Ripening associated modifications in sugar composition and apparent molecular size of pectins and hemicellulose have been reported in many fruits. In avocado, molecular sizes of pectic polymers and hemicelluloses extracted from fruit mesocarp cell wall shifted from larger to smaller polymers during ripening (Ranwala et al., 1992). Huber (1983) observed a marked change in molecular weight distribution of cell wall hemicellulose of pericarp in tomato fruits. During ripening, there was a great downshift of molecular mass of hemicelluloses. Similarly, a hemicellulose fraction extracted from hot pepper fruit cell walls was modified during ripening, resulting in a shift from high to low molecular

weight (Gross et al., 1986). In muskmelon, molecular sizes of pectin and hemicellulose polymers from fruit mesocarp cell walls shifted from larger to smaller polymers during ripening (Ranwala et al., 1992). In kiwifruit, three distinct molecular size classes of hemicellulose were observed, with a proportional increase in the smaller polymers with fruit ripening (Redgwell et al., 1991). Ripening of nectarines resulted in solubilization of pectic polymers of high molecular sizes and concurrent galactan side chain removal from pectic polymers. Solubilized pectic polymers were depolymerized to lower molecular sizes as ripening progressed (Dawson et al., 1992). Recently, depolymerization of hemicelluloses has also been shown in peach softening (Hedge and Maness, 1998). Both pectin and hemicelluloses were also depolymerized in muskmelon (Rose et al., 1998).

In addition to the depolymerization of both pectic and hemicellulosic polymers, a characteristic feature of ripening fruit is the loss of neutral sugars (primarily galactose and arabinose) from the cell wall of strawberry (Huber, 1984), muskmelon (McCollum, 1989), kiwifruit (Soda, 1987; Redgwell, 1992), hot pepper (Gross, 1986), avocado (Huber, 1993), pear (Yoshioka, 1992) and peaches (Fishman, 1993).

Softening of peaches has long been attributed to the conversion of protopectin to soluble forms (Chapman and Horvat, 1990; Pressey and Avants, 1978; Shewfelt, 1965). Pressey et al. (1971) correlated an appearance of PG activity with an increase in water-soluble pectin and fruit softening. The molecular weight of chelator soluble pectins and alkaline soluble pectins in melting flesh peaches was less than that for nonmelting flesh peaches (Fishman et al., 1993).

Peach softening during ripening has been attributed to the enzymatic degradation of pectic polymers (Pressey, 1977). In peach 'Redskin' melting flesh fruit mesocarp,

molecular weight of chelator soluble pectin decreased considerably during ripening and storage. In peach 'Suncling' nonmelting flesh fruit mesocarp, molecular weight of chelator soluble pectin and alkaline soluble fraction were relatively constant during on-tree ripening and storage (Fishman, 1993). Hegde and Maness (1996) noted that both pectin and hemicellulose were modified during peach ripening.

Stonyhard mutation of peach fruit dramatically reduces ethylene biosynthetic capacity and confers novel fruit softening characteristics to freestone peaches. Fruit softening can be initiated to obtain a desirable melting flesh texture, or a pasty texture, depending on the concentration and duration of exposure to exogenous ethylene. When treated with 0 ppm ethylene for 48 h, the fruits remain firm; when treated with 1 ppm ethylene for 48 h, they obtain a normal soft texture; when treated with 100 ppm ethylene for 48 h, they attain a "pasty" soft texture, which is characterized as a slimy or pasty consistency at the cut surfaces, accompanied by a slight reduction in mesocarp free water.

Peach fruits with the Stonyhard mutation were selected for this research because of their uniqueness in that they remain firm at room temperature for about 10 days compared to normal peach fruits whose firmness decreases within 3 days after harvest at horticultural maturity. When treated with ethylene at different concentrations in a very short period of time (up to 48 h), 'J12-119' fruits soften to edible firmness, but to two different textures (normal soft, 1 ppm; "pasty" soft, 100 ppm) are obtained . Therefore, it provided a very good plant system to study textural changes associated with fruit softening.

The objective of this research was to investigate the mechanism of pasty texture versus normal texture obtained during ripening of peach fruit. Cell wall polysaccharide

sugar composition changes and changes in apparent molecular size were assessed by size exclusion chromatography for various cell wall extracts obtained during ripening of ethylene treated 'J12-119' fruits and 'Cresthaven' peach fruits.

Materials and Methods

'J12-119' (Stonyhard selection) and 'Cresthaven' (used as control without Stonyhard gene) peach fruits harvested at horticultural maturity (physiological maturity) and air-shipped from the Rutgers Fruit Research Station at Cream Ridge, New Jersey to laboratory facilities in Stillwater, Oklahoma in 1997. To ensure maximum fruit uniformity, too green or too ripe fruits and damaged fruits were discarded and the remaining fruits were separated into sets of 10 fruits each for ethylene treatment. A zero time control was immediately processed as described below. Fruits were treated continuously with 0, 1 or 100 ppm ethylene for up to 48 h. Air flow was 0.5 $L \bullet min^{-1}$ and ethylene concentrations were obtained by mixing standard ethylene (Scott Specialty Gas, PA, USA) with breathing air at a 1:9 (v/v) ratio. 10 fruits were taken from each treatment at 0, 24 and 48 h for sampling.

Mesocarp resistance to puncture was determined after removal of pericarp on opposite cheeks of each fruit using an Effgi penetrometer (Alfonsine, Italy) with a standard 8 mm probe.

Preparation of cell walls Enzymatically inactive cell walls were prepared essentially as described by Huber (1991). Fruit mesocarp was separated from the pericarp and stone, placed on ice and diced into small pieces. Mesocarp tissue was then homogenized for 6 minutes on ice with Tris-saturated phenol at a ratio of 1 part fruit

tissue to 3 parts of Tris-saturated phenol, using an Omnimixer homogenizer (OMNI International, Waterbury, CT, USA) set at speed 6 (three successive bursts of 2 minutes each). After one hour of stirring, the homogenate was then filtered through 2 layers of miracloth over a buchner funnel. The residue was washed with water to remove phenol smell, and then transferred to a scintered glass funnel and washed with 1 L chloroform: methanol (1:1, v/v) followed by washes with acetone (1 to 2 L) until a fluffy consistency was obtained. Cell wall residue was dried in an oven at 60 °C to remove acetone and stored in a brown bottle.

Buffer soluble polysaccharide recovery Buffer soluble polysaccharide was prepared by the method of Dick and Labavitch (1989). 100 mL of 40 mM HEPES (pH 7.0) was added to 100 g diced mesocarp and ground on ice using an Omnimixer homogenizer at speed 6 for 3 bursts of 2 minutes each. The samples were then filtered through 4 layers of miracloth and the residue was discarded. Four volumes of 95% ethanol were added to the supernatant and boiled for 20 minutes. After storage at 2 °C for 24 h, precipitated material was collected by centrifugation (8000 g, 5 minutes). The pellet was suspended by stirring in 50 mL 50 mM Na-acetate (pH 5.0) at 20 °C until solution appeared complete and the mixture was centrifuged as above. The supernatant was added to 4 volumes of 95% ethanol and stirred at 2°C overnight. The precipitated material was again collected by centrifugation and dissolved in 80 mL of 50 mM Na-acetate and stirred for 30 minutes to completely dissolve the pellet, then centrifuged at 8000 g for 5 minutes and the pellet was discarded. The supernatant was then dialyzed with a 6000-8000 molecular-weight-cut-off dialysis membrane and was then lyophilized.

Extraction of cell walls Cell walls were extracted sequentially to obtain

pectin-associated and hemicellulose-associated polysaccharides as described by Selvendran et al. (1985) with some modifications. Cell walls (1 g) were hydrated in 100 mL of 500 mM imidazole (pH 7.0) plus 0.05% sodium azide in vacuo and then stirred continuously for 12 h at 1 °C. Samples were centrifuged to obtain residue. The residue was then reextracted with 500 mM imidazole for an additional 2 h at 20-22 °C, followed by centrifugation and 4 distilled water washes. Imidazole and water washes for both temperatures were combined, dialyzed against deionized water and then lyophilized. The imidazole extracted residues were then extracted with 100 mL 0.05 M sodium carbonate plus 20 mM sodium borohydride for 16 h at 1 °C. The residue was further extracted with the same concentration and volume of sodium carbonate and sodium borohydride for 3 h at 20-22 °C. The supernatants designated as sodium carbonate (cold) and sodium carbonate (warm) were adjusted to pH 5.0 with acetic acid and dialyzed separately with 6 changes of water and then lyophilized.

The depectinated residues were extracted with a graded series of KOH, from 1 M to 4 M, to extract hemicellulose-associated polysaccharides. In all cases except the final extraction, 10 mM sodium borohydride was added to convert reducing sugars into alcohols and prevent the peeling reaction. The final extraction medium contained 4% boric acid. The residues were extracted with 100 mL 1 M KOH plus 10 mM sodium borohydride first for 2 h at 1 °C and then 2 h at 20-22 °C. Further extraction was carried out with 100 mL 4 M KOH plus 10 mM sodium borohydride for 2 h at 20-22 °C and then with 4 M KOH plus 4% boric acid for 2h at 20-22°C. The supernatants were adjusted to pH 5.0 with acetic acid and then dialyzed against deionized water and lyophilized. The

final residue was also lyophilized after rinses with 150 mL deionized water 2 times. All extracts were weighed after lyophilization.

Size exclusion chromatography Size exclusion chromatography was carried out on a column (1 cm × 50 cm) of Toyopearl HW65S (Supelco Inc., Bellefonte, PA, USA) which has a separation range for globular proteins about 8×10^4 to 8×10^6 Daltons. Samples (15-30 mg) were dissolved in 3 mL 1 M imidazole (pH 7.0) prior to injection. Samples of 1.5 mg (150-500 μL) were injected and eluted with 300 mM ammonium acetate (pH 5.0) at a flow rate of 0.5 mL per minute. Peaks were detected using a Waters R401 (Water Associates, Framingham, MA, USA) refractive index detector at an attenuation of 8x. Fractions were collected at 1 minute intervals and pooled based on the elution time of peaks of interest. Pooled samples were dried under vacuum and rinsed thoroughly with water to remove volatile elution buffer salts. Fractions were analyzed for sugar composition by GLC. The column was calibrated periodically with pullulan standards of molecular weight of 853 kD, 380 kD, 186 kD, 100 kD, 48 kD, 23 kD, 12 kD (Polymer Laboratories, Amherst, MA, USA).

Sugar composition analysis Samples were methanolyzed and trimethylsilated for GLC as described by Komalavilas and Mort (1989). Trimethylsilated sugars (1 μL) were injected onto a DB-1 fused silica capillary column (0.25 mm×30 m, 0.25 μm film thickness, J&W Scitific, Folsom, CA, USA) installed in a Varian 6000 gas chromatograph (Varian Associates, Walnut Creek, CA, USA) equipped with a cool on column injector and FID detector, using helium as carrier gas. The sample was injected at 105 °C, and then the temperature was raised to 160 °C at 10 °C per minute and held for 4

minutes before being raised to 200 °C at 1 °C per minute. Sugars were identified according to authentic standards and quantified using inositol as internal standard.

Results and Discussion

In this study, we characterized changes in apparent molecular mass of polysaccharides during ethylene-induced softening of 'J12-119' and 'Cresthaven' . 'J12-119' was used for its unique softening characteristcs imparted by the Stonyhard gene. 'J12-119' fruits remain firm at room temperature for about 10 days compared to peach fruits without the Stonyhard gene ('Cresthaven') whose firmness decreases in 3 days after harvest at horticultural maturity. When treated with ethylene at either 1 or 100 ppm in a very short period of time (up to 48 h), 'J12-119' fruits soften to an edible firmness, but different textures (melting soft texture, 1 ppm; pasty soft texture, 100 ppm) are obtained. Therefore, it provides a very good plant system to study textural changes associated with fruit softening. We used cell wall preparation procedures designed to inactivate cell wall hydrolases to eliminate their capacity to alter cell wall components during cell wall preparation and during subsequent extraction steps (Huber, 1991; Hegde and Maness, 1996).

The firmness of 'J12-119' fruits remained fairly constant, whereas that of 'Cresthaven' decreased slightly (Table 1) when ethylene was excluded over a 48 h time period at 22-25 °C. However, both 'J12-119' and 'Cresthaven' fruits softened extensively upon ethylene treatment, the degree of which depended on ethylene concentration and exposure duration. Polysaccharides were solubilized from the cell walls as illustrated by the fact that buffer soluble polysaccharides increased (Table 1) and the yield of crude cell

wall of ethylene-treated fruits decreased as the ethylene concentration and exposure duration increased (Table 2a, 2b). Ethylene can also trigger rapid and dramatic changes to fruit firmness in kiwifruit (Macrae et al., 1988).

Cell walls contained considerable percentage of galacturonosyl, arabinosyl, galactosyl and xylosyl residues in 'J12-119' and 'Cresthaven', and arabinose was the major neutral sugar in both cultivars (Table 2a, 2b). As fruit softened in response to ethylene treatment, cell walls exhibited a slight increase in xylosyl and arabinosyl residues and a steady decrease in galacturonosyl residue on a mole percent basis. In fact, on the basis of sugar weight obtained from gas chramatography, most neutral sugars were lost from the cell wall during ethylene-induced softening (Table 3a, 3b). 'J12-119' fruits lost 35% arabinose, 33% rhamnose, 31% fucose, 5% mannose, 25% galactose and 28% glucose; 'Cresthaven' fruits lost 34% arabinose, 38% rhamnose, 42% fucose, 20% mannose, 47% galactose and 40% glucose from the cell wall, and xylose remained fairly constant in both cultivars after 100 ppm ethylene exposure for 48 h. The loss of pectin associated neutral sugars, arabinose and rhamnose, on a weight basis from the cell wall implied that pectic polymers were modified during ethylene-induced softening. The loss of hemicellulose associated neutral sugars, fucose and glucose, on a weight basis from the cell wall implied that hemicellulose was modified during softening. The loss of arabinose and galactose from cell wall is typical of many fruit species and has been reported in a number of other fruits (Gross and Sams, 1984; McCollum, 1989; Simandjuntak et al, 1996; Seymour, 1990). No major difference existed between 'J12-119' and 'Cresthaven' in cell wall sugar composition on a mole percent basis.

Buffer soluble polysaccharides were presumbly depolymerized in vivo in fruits. As fruits softened, ethanol precipitate yield from buffer soluble polysaccharides increased in both cultivars (Table 1). The greatest decrease in cell wall yield within cultivars coincided with the greatest ethylene-induced loss of firmness. Buffer soluble polysaccharides contained high percentage of pectin-associated sugar residues. Buffer soluble polysaccharides exhibited a consistent decrease in arabinosyl and galactosyl residues (Table 4a, 4b) and a consistent increase in galacturonosyl residue on a mole percent basis in response to ethylene treatment. This fraction contained increasing amount of galacturonosyl residue as fruit softened due to ethylene exposure, compensating for the decreased galacturonosyl residue content of the cell walls (Table 2a, 2b). The same phenomenon has been observed in tomato pericarp (Carrington et al., 1993) and muskmelon (Rose et al., 1998). However, Hegde and Maness (1996) observed a decrease in galacturonosyl residues as fruit softened in aqueous phenol buffer soluble polysaccharides. If hemicellulose has also been solubilized in vivo during softening, a higher percentage of xylose and glucose should have been observed, as in the case of kiwifruit in which 7-day-ripening fruit water-soluble fraction showed a marked increase in the xylose and glucose content on a mole percent basis when compared to harvest and 1-day-ripening fruit (Redgwell et al., 1990). However, failure to observe a higher mole percentage of xylose and glucose does not necessarily mean that hemicelluloses are not solubilized during softening, since they might be solubilized to small oligmers or monosaccharides and be lost during polymer precipitation steps.

The buffer soluble extracts in both 'J12-119' and 'Cresthaven' separated into three apparent molecular mass peaks, a high apparent molecular mass peak, represented by

peak 1, an intermediate apparent molecular mass peak, represented by peak 2, and a small apparent molecular mass peak, represented by peak 3 (Fig. 16a, 16b). In 'J12-119', peak 1 decreased and peak 2 increased when fruit were exposed to ethylene and then remained fairly constant. There was a slight decline in molecular weight of peak 2 after 48 h of 100 ppm ethylene with elution time to peak midpoint increasing from 42 minutes to 44 minutes. Peak 3 decreased considerably in amount upon ethylene treatment. The most notable decline for peak 3 was in the 100 ppm-24 h treatment, but by 48 h of 100 ppm ethylene it increased coincident with the slight shift of peak 2 towards lower apparent molecular weight. In 'Cresthaven', apparent molecular weight downshifts where noticeable with either ethylene treatment, especially between the 24 h and 48 h 100 ppm ethylene treatment (Fig. 16b). The ability of 'Cresthaven' fruit to respond to continuous ethylene treatment by reducing size of recovered buffer soluble polysaccharides may have contributed to its ability to soften to a normal juicy texture after 48 h exposure to 100 ppm ethylene. Conversely, the sudden release of large quantities of high apparent molecular weight polymers from 'J12-119' may be a major contributing factor to the "pasty" characteristic Stonyhard fruit exhibits in response to 100 ppm ethylene for 48 h.

For both cultivars, peak 1 was rich in arabinosyl, rhamnosyl, galactosyl and galacturonosyl residues (Table 5a, 5b). Low ratio of galacturonosyl to rhamnosyl and high arabinosyl residue content implied the presence of rhamnogalacturonan like polymers due to the decline in predominance of peak 1 upon ethylene treatment. These polymers were apparently partially depolymerized during ethylene exposure, regardless of ethylene concentration. Peak 2 was also rich in arabinosyl, rhamnosyl, galactosyl and galacturonosyl residues, but the high ratio of galacturonosyl to rhamnosyl and low

arabinosyl residue content implied the presence of homogalacturonan like polymers. In 'J12-119', these homogalacturonan-like polymers were only slightly depolymerized during ethylene-induced softening, but in 'Cresthaven' these homogalacturonan like polymers were extensively depolymerized during ethylene-induced softening, especially by 48 h of exposure to 100 ppm ethylene. Peak 3 was also rich in arabinosyl, rhamnosyl, galactosyl and galacturonosyl residues. The fact that galacturonosyl residue content in peak 3 was lower than peak 2 but higher than peak 1, combined with the observation that rhamnosyl residues were the same to slightly lower, and arabinosyl residue content in this peak was intermediate between peak 1 and peak 2, suggested the possible presence of both homogalacturonan like polymers and rhamnogalacturonan like polymers in peak 3. Molecular mass downshift of soluble polyuronide was also observed in muskmelon (Rose et al, 1998) and pear (Dick and Labavitch, 1988). Combined with the size exclusion data (Fig. 16a, 16b), homogalacturonan-like polymers in 100 ppm, 48 h 'J12-119' fruit were only slightly depolymerized, whereas the same polymers in 'Cresthaven' were definitely depolymerized. The "pasty" characteristic could result from pectin gel formation, from the large amount of high apparent molecular weight homogalacturonan polysaccharides solubilized during 100 ppm ethylene, 48 h exposure of 'J12-119'. The presence of these high apparent molecular mass homogalacturonan-like polymers in the buffer soluble fraction for 'J12-119' implies a possible presence of them at cut fruit surfaces, and could represent the slimy consistency as the pectin gel.

Imidazole extracts were enriched in galacturonosyl and arabinosyl residues (Table 6a, 6b). As fruit softened in response to ethylene treatment, there was a consistent increase in arabinosyl, a decrease in galacturonosyl residue, and a slight increase in

galactosyl and rhamnosyl residues on a mole percent basis. Imidazole is thought to extract pectin by chelation of calcium similar to CDTA or EDTA and reprents a homogalacturonan-type polymer, probably originating from the middle lamella, as has been suggested in other species (Seymour et al., 1990; Cutillas-Itturralde et al., 1993). The decline in galacturonosyl residue mole percent by 48 h of ethylene treatment may have been due to homogalacturonan loss as a buffer soluble fraction, which would have been lost during cell wall preparation. A decrease in yield of this extract occurred in response to ethylene treatment. Combined with the high pectin content of the buffer soluble polysaccharides (Table 4a, 4b), it was likely that imidazole soluble polysaccharides were solubilized in response to ethylene treatment and were at least partially present in the buffer soluble fractions of ethylene treated fruits.

Imidazole extracts in both 'J12-119' and 'Cresthaven' separated into two apparent molecular mass peaks, a high apparent molecular mass peak, represented by peak 1, and a lower apparent molecular mass peak, represented by peak 2 (Fig. 17a, 17b). As fruit softened during ethylene exposure there was proportional decrease in size of peak 1 relative to peak 2. Peak 1 contained a higher mole percentage of arabinosyl, rhamnosyl and galactosyl reisdues, and lower mole percentage of galacturonosyl residue than peak 2 (Table 7a, 7b). The lower ratio of galacturonosyl to rhamnosyl residue of peak 1 and the higher ratio of arabinosyl to rhamnosyl residue implied more rhamnogalacturonan like polymers in peak 1. A higher ratio of galacturonosyl to rhamnosyl residue of peak 2, and the lower ratio of arabinosyl to rhamnosyl residue implied more homogalactutonan like polymers in peak 2. There was a noticable downshift in apparent molecular weight of peak 2, and a decrease in predominance of peak 1, for both 'J12-119' and 'Cresthaven' in

the size exclusion chromatograms in response to contonued ethylene treatment.. In tomato (Huber, 1983), strawberry (Huber, 1984), avocado (Huber and O'Donoghue, 1993), muskmelon (McCollum et al.,1989; Ranwala et al., 1992), and persimmon (Cutillas-Itarralde et al., 1993), a decrease in large molecular size polymers and a concomitant increase in the lower molecular weight polymers during softening was observed in the EDTA extracts. In apple (Fisher et al., 1994) no clear shift towards either a lower or a higher average molecular weight was reported. Apparent molecular size of imidazole extracts in "Belle of Gorgia" peach fruits seemed to neither upshift nor downshift during peach fruit softening except with increased solubilization of larger homogalacturonan like polymers (Hegde and Maness, 1998). In the present study, there was a clear and progressive downshift in apparent molecular mass of imidazole extracts from both 'J12-119' and 'Cresthaven' in response to ethylene-induced softening. As the fruit ripened and the physical state of the cell wall changed, the homogalacturonan-rich pectin fraction, thought to predominate in the middle lamella, was cleaved into smaller polysaccharides and lost during cell wall preparation. The increase in yield of buffer soluble polysaccharides (Table 4a, 4b) with duration of ethylene treatment supports this assumption. This would contribute to weakening of cell-to-cell interactions and result in softening of the tissue, as was demonstrated in response to ethylene. The imidazole extracts then represented only pectin still bound in cell walls by ionic interaction which had been degraded by pectic enzymes such as PG, and should have declined in yield and in apparent molecular size. Another contributing factor could have been a post-ethylene surge of polysaccharide synthesis in response to the sudden induction of changes in the cell wall, as has been reported in tomato (Mitcham et al., 1989).

The imidazole insoluble pectic polysaccharides were further extracted using Na_2CO_3 to hydrolyze weak ester crosslinks (Waldron and Selvendran, 1992). Extraction with Na_2CO_3 at 1 °C deesterfies the pectins, thus minimizing the degradation by β-elimination, and extraction at room temperature is known to solubilize certain pectic polymers that are in association with hemicellulose polymers (Selvendran and O'Neil, 1987).

Na_2CO_3-cold extracts were enriched in galacturonosyl and arabinosyl residues, and yields were similar and declined during ethylene-induced softening for 'J12-119' and 'Cresthaven' (Table 8a, 8b). As fruit softened in response to ethylene treatment, there was a consistent increase in arabinosyl and a slight increase in galactosyl and rhamnosyl residues and a consistent decrease in galacturonosyl residue on a mole percent basis, quite similar to that of imidazole extracts. However, a higher percentage of arabinosyl residue and lower ratio of galacturonic acid to rhamnose in this extract indicates a more rhamnogalactutonan origin. Na_2CO_3-warm extracts were also enriched in galactosyl and rhamnosyl residues as well as galacturonosyl and arabinosyl residues, with considerably lower yields than cold extracts (Table 9a, 9b). However, this extract contained much less less galacturonosyl residue and much more galactosyl, rhamnosyl and arabinosyl residues on a mole percent basis, further implying a rhamnogalacturonan origin.

Na_2CO_3-cold extracts in both 'J12-119' and 'Cresthaven' separated into two apparent molecular mass peaks, a high apparent molecular mass peak (peak 1), and a lower apparent molecular mass peak (peak 2) (Fig. 18a, 18b). As fruit softened in response to ethylene treatment there was proportional increase in size of peak 1 relative to peak 2, and peak 2 decreased slightly in apparent molecular size. Both peaks were

enriched in rhamnosyl, arabinosyl and galacturonosyl residues (Table 10a, 10b). Peak 2 contained more galacturonosyl residue and less arabinosyl and rhamonosyl residue than peak 1. Like the imidazole extracts, the lower ratio of galacturonosyl to rhamnosyl residue of peak 1 and the higher ratio of arabinosyl to rhamnosyl residue implied more rhamnogalacturonan like polymers in peak 1. A higher ratio of galacturonosyl to rhamnosyl residue of peak 2, and the lower ratio of arabinosyl to rhamnosyl residue, implied more homogalacturonan like polymers in peak 2. However, the ratio of galacturonosyl to rhamnosyl residue of peak 1 in this extract was 1.5:1, compared to 6:1 in the imidazole extracts, suggesting purer rhamnogalacturonan like polymers in the large molecular size peak in the Na_2CO_3-cold extracts. No major difference was found in this fraction between 'J12-119' and 'Cresthaven' in the size exclusion chromatograms.

Na_2CO_3-warm extracts in both 'J12-119' and 'Cresthaven' separated into two apparent molecular mass peaks, a polydisperse high apparent molecular mass peak (peak 1), and a lower apparent molecular mass peak (peak 2) (Fig. 19a, 19b). As fruit softened there was proportional increase in the proportion of peak 1 relative to peak 2. However, peak 1 in 'Cresthaven' was much prominent than that in 'J12-119'. Unlike imidazole and Na_2CO_3 cold extracts, sugar composition of both peaks in this fraction remained relatively consistent for different treatments (Table 11a, 11b). Both peaks were enriched in rhamnosyl, arabinosyl, galactosyl and galacturonosyl residues. Peak 2 contained only slightly higher galacturonosyl residue than peak 1. The ratio of galacturonosyl to rhamnosyl residue of both peaks in this extract was very low (1.5:1 to 3:1), suggesting purer rhamnogalacturonan like polymers apparently distributed throughout all polysaccharides, with a predominance of larger apparent molecular mass polysaccharides

in response to continued ethylene treatment in Na_2CO_3-warm extracts.

In contrast to the observation in muskmelon (Rose et al., 1998) and persimmon (Cutillas-Itarralde et al., 1993) in which there was a molecular weight downshift during softening in Na_2CO_3 extracts, and in contrast to the observation in apple (Fisher et al., 1994) and in nectarine (Dawson et al., 1992) in which hardly any molecular weight shift was noticed, peach Na_2CO_3 extracts appeared to follow a different pattern of change in molecular weight during ethylene-induced softening, with increased solubility of large rhamnogalacturonan like polymers in softened fruits.

The imidazole extracts, Na_2CO_3-cold extracts and Na_2CO_3-warm extracts showed a consistent increase in galactosyl, rhamnosyl and arabinosyl residues, and a concomitant decrease in GalA on a mole percent basis during softening in response to ethylene treatment. The relative increase in galactosyl, rhamnosyl and arabinosyl residues in these polymers during softening suggested a preferential loss of the backbone structure of the. homogalacturonan-like polysaccharides. This could occur by the action of polygalacturonase on unsubstituted sequences of the backbone which could release polygalacturonic acid fragments. The relative decrease in galactosyl, rhamnosyl and arabinosyl residues and relative increase in galacturonic acid residue in buffer soluble extracts support this hypothesis.

In the imidazole extracts, Na_2CO_3-cold extracts and Na_2CO_3-warm extracts, hemicellulose associated sugar residues (xylosyl, mannosyl and fucosyl) were extremely low. Glucose, if present, was considered to be only a minor component of the solubilized pectins.

Depectinated cell walls were further extracted with increasing concentrations of

KOH to solubilize hemicelluloses. Alkali solubilizes the hemicellulose associated polysaccharides by disrupting hydrogen bonding between hemicellulose and cellulose microfibrils (Selvendran et al., 1985). 1 M KOH was used to extract more loosely bound hemicelluloses, whereas 4 M KOH was used to extract more tightly bound hemicelluloses.

1 M cold KOH extracts were particularly enriched in fucosyl, xylosyl and glucosyl residues and yields increased slightly (Table 12a, 12b), compared with the decline in yield for imidazole extracts, Na_2CO_3-cold extracts and Na_2CO_3-warm extracts during ethylene-induced softening. Fucose is thought to be present in cell walls predominantly as a xyloglucan side chain (Hayashi, 1989). Extracts at 1 °C (Table 12a, 12b) had a much higher mole percentage of xylosyl, glucosyl and fucosyl residues and a 3 times higher extraction yield compared with extracts at 20-22 °C (Table 13a, 13b). The amount of pectin-associated sugar residues (GalA, rhamnosyl and arabinosyl) versus hemicellulose associated sugar residues (xylosyl, glucosyl and fucosyl) increased substantially in warm extracts compared with cold extracts. Cold 1 M KOH appeared to extract a more highly purified xyloglucan fraction with less pectic polymers than warm 1 M KOH extracts.

1 M KOH-warm extracts (Table 13a, 13b) had a much lower mole percentage of xylosyl, glucosyl and fucosyl residues and about one third extraction yield compared with 1 M KOH-cold extracts (Table 12a, 12b). The amount of pectin-associated sugar residues (GalA, rhamnosyl and arabinosyl) versus hemicellulose associated sugar residues (xylosyl, glucosyl and fucosyl) increased substantially in warm extracts compared with cold extracts. The galacturonosyl and arabinosyl residues in the warm 1 M KOH extracts

decreased whereas xylosyl and glucosyl residues increased as fruits softened in response to ethylene. Warm 1 M KOH appeared to extract some xyloglucan as well as some pectic polymers that were either associated with xyloglucan by some kind of linkage or simply physically entangled in the xyloglucan, similar to that found by Hegde and Maness (1998).

1 M KOH cold extracts in both 'J12-119' and 'Cresthaven' separated into 3 apparent molecular mass peaks, a high apparent molecular mass peak (peak 1), an intermediate apparent molecular mass peak (peak 2), and a lower apparent molecular mass peak (peak 3) (Fig. 20a, 20b). In 'J12-119', peak 1 began to decrease and could hardly be detected by 48 h of ethylene treatment (1 ppm and 100 ppm). Peak 2 remained fairly constant even after 24 h of ethylene treatment; it shifted to smaller apparent molecular weight after 48 h of ethylene treatment. In 'Cresthaven', peak 1 decreased after 24 h of 100 ppm ethylene treatment, at an earlier stage than 'J12-119'; and at later stages of ethylene-induced softening it could hardly be detected either. Peak 2 shifted towards smaller molecular weight range, but also at an earlier stage (1 ppm-24 h) than 'J12-119'. Peak 3 in both cultivars did not show appreciable changes. Xylose, glucose, galactose and arabinose constituted the major sugars of peak 3 (Table 14a, 14b). High mole percentage of galacturonosyl, rhamnosyl and arabinosyl residues in peak 1 suggested that some large rhamnogalacturonan-like polymers were present in the 1 M KOH-cold extracts and the virtual disappearance of peak 1with continued ethylene exposure indicated loss of this hemicellulose associated rhamnogalacturonan fraction, perhaps as a consequence of prior extraction with imidazole or Na_2CO_3, or loss as a buffer soluble fraction. One difference for peak 1 between 'J12-119' and "Cresthaven' was in the ratio of galacturonic acid to

rhamnose; prior to ethylene treatment, the ratio for 'J12-119' was 3:1, but for 'Cresthaven' it was close to 1:1. Ratios approached 1:1 after treatment with ethylene for both cultivars. In 'Cresthaven', peak 1 began to decrease at 100 ppm-24 h and hardly existed at 100 ppm-48 h; meanwhile mole percentage of xylose decreased after 24 h of 100 ppm ethylene treatment to 16% and further to 7% at 48 h treatment. In 'J12-119', peak 1 began to decrease at 1 ppm-48 h and hardly existed at 100 ppm-48 h; meanwhile mole percentage of xylose began to decrease to 14% and further to 11% at 100 ppm-48 h. In both cultivars, the ratio of xlylose to glucose increased in response to 1 ppm 24 h ethylene treatment, but the ratio increased in 'J12-119' and decreased in 'Cresthaven' after 24 h of 100 ppm ethylene treatment. 'Cresthaven' exhibited a dose response in reduction of the ratio within 24 h of treatment whereas 'J12-119' did not. This implied that xylan might be present in peak 1 and was degraded to smaller molecular size during ethylene-induced softening, together with rhamnogalacturonan like polymers in peak 1. Putative xylan-pectin complexes in ripening tomato fruits (Seymour et al., 1990) have been described, although little has been reported to suggest a role for xylan metabolism in cell wall disassembly during fruit softening. Xylosyl, glucosyl and galactosyl residues were associated with higher percentage of fucosyl residues in peak 2 compared with the other two peaks. Peak 2 appeared to be most fucosylated xyloglucan-like polymer similar to that previously found by Hegde and Maness (1998). This peak decreased in apparent molecular mass during ethlene-induced softening, indicating that a general decrease in apparent molecular mass for xyloglucan like polymer may have been associated with later stages of ethylene-induced softening in both cultivars, although 'Cresthaven' responded to the lower ethylene concentration more quickly (within 24 h) than 'J12-119'

(within 48 h). Peak 3 was rich in mannosyl residue as well as xylosyl, glucosyl, galactosyl and fucosyl residues. Rich mannosyl residues in peak 3 probably suggested the presence of small pieces of manan or galactomannan. Sugar composition of peaks 2 and 3 remained relatively constant within cultivars during peach ethylene-induced softening.

1 M KOH warm extracts in both 'J12-119' and 'Cresthaven' separated into 3 apparent molecular mass peaks, a high apparent molecular mass peak (peak 1), an intermediate apparent molecular mass peak (peak 2), and a lower apparent molecular mass peak (peak 3) (Fig. 21a, 21b). During treatment with both ethylene concentrations, in 'J12-119', peak 1 remained relatively constant, peak 2 showed appreciable downshift at later stages of ethylene-induced softening, and peak 3 remained relatively constant. In 'Cresthaven', peak 1 decreased considerably and could hardly be detected at later stages of ethylene-induced softening, peak 2 decreased relatively to peak 3, and peak 3 remained relatively constant. Peak 1 was especially rich in arabinosyl residue in both cultivars (Table 15a, 15b), probably from arabinan which may have been the side chain of a hemicellulose-associated pectin polymer. Both peaks 2 and 3 were rich in both pectin-associated sugar residues (GalA, rhamnosyl and arabinosyl) and hemicellulose-associated sugar residues (xylosyl, glucosyl and fucosyl). Downshift of peak 2 implied that some pectin polymers and hemicellulose polymers were depolymerized during ethylene-induced softening in both cultivars.

In softening persimmon fruit the average molecular weight for xyloglucan present in 1 M KOH hemicellulose extracts increased to a certain stage and then decreased in the last stage of fruit ripening (Cutillas-Iturralde et al., 1994). A relative downshift of xyloglucan was also detected in muskmelon fruit softening (Rose et al., 1998). Our

present study of ethylene-induced peach fruit softening also shows a relative downshift in apparent molecular weight of 1 M KOH soluble polysaccharides, although the downshift occurred more quickly in 'Cresthaven' than in 'J12-119'.

4 M KOH plus 10 mM sodium borohydride extracts were similar to 1 M KOH warm extracts in terms of sugar composition, except this extract contained more xylosyl and glucosyl residue, and less arabinosyl and galacturonosyl residues than warm 1 M KOH extracts and extraction yields were substantially higher (Table 16a, 16b). The galacturonosyl and arabinosyl residues in this extract consistently decreased whereas xylosyl and glucosyl residues consistently increased as fruits softened in response to ethylene treatment, which is quite similar to these sugar changes in the warm 1 M KOH extracts.

4 M KOH plus sodium borohydride extracts separated into three apparent molecular size peaks (Fig. 22a, 22b). At early stages of softening, there was an decrease of peak 1 relative to peak 2 and peak 3; there was a downshift of peak 2 in 'J12-119' at 1 ppm-24 h stage, and there was a downshift of peak 2 in 'Cresthaven' at 100 ppm-24 h stage. By 24 h of 100 ppm ethylene treatment, or 48 h of treatment with either ethylene concentration, peak 2 appeared less equally distributed in mass in 'Cresthaven', giving the impression of 2 peaks whereas peak 2 of 'J12-119' appeared as one peak in all ethylene treatments. Peak 2 of 'J12-119' exhibited a more dramatic downshift than that of 'Cresthaven' at later stages of ethylene-induced softening. Peak 3 did not show any changes in both cultivars.

Peak 1 was especially rich in arabinosyl and low in fucosyl and rhamnosyl residues compared to peaks 2 and 3 (Table. 17a, 17b). The predominance of arabinose in

peak 1 was accentuated in 'J12-119' after 48 h of 100 ppm ethylene treatment. The low ratio of galacturonosyl to rhamnosyl residue content and decrease in predominance of peak 1 upon ethylene treatment suggested less large molecular weight rhamnogalacturonan-like polymer was solubilized at early stage of ethylene-induced peach softening, in contrast to the fact that more rhamnogalacturonan-like polymer was solubilized in imidazole extracts, Na_2CO_3-cold extracts and Na_2CO_3-warm extracts. The very high percentage of arabinose suggested a possible presence of a high molecular weight arabinan which decrease in amount in response to ethylene-induced softening. Peak 2 was rich in xylosyl, fucosyl, galactosyl and glucosyl residues as well as arabinosyl, rhamnosyl, and galacturonosyl residues, implying the presence of both xyloglucan- and rhamnogalacturonan-like polymers. In 'J12-119' peak 2 was depolymerized with time during either ethylene treatment into one polydisperse peak, and the 100 ppm-48 h treatment resulted in a smaller apparent molecular weight. Depolymerization into two polydisperse peaks was evident for 'Cresthaven', and less shift in apparent molecular weight occurred in response to 48 h of ethylene treatment compared to 24 h. Peak 3 was particularly rich in mannose compared with the other two peaks, and it contained a relatively high amount of glucose and galactose, suggesting the possible presence of small pieces of glucomannan or galactoglucomannan like polymers, as has been detected in 4 M KOH hemicellulose fraction of tomato (Seymour et al., 1990) and pineapple (Smith and Harris, 1995). The characteristic pattern of molecular size changes in 4 M KOH plus $NaBH_4$ extracts from peach fruits was unlike that observed for hemicelluloses from tomato (Huber, 1983), strawberry (Huber, 1984) and hot pepper (Gross et al., 1986) in which extensive hemicelluloses degradation occurred during

softening. Hemicelluloses in peach fruits exhibited only slight molecular mass downshift in response to ethylene-induced softening, similar to avocado (O'Donoghue and Huber, 1992), muskmelon (McCollum et al., 1989; Rose et al., 1998), kiwifruit (Redgwell et al., 1991) and persimmon (Cutillade-Iturralde et al., 1994). Hemicelluloses in apple fruit did not show appreciable changes in apparent molecular mass during softening (Percy et al., 1997).

4 M KOH plus boric acid extracts contained much higher mole percentage of pectin-associated sugar residues than hemicellulose-associated sugar residues, and a much lower extraction yield (Table 18a, 18b), compared with 4 M KOH plus sodium borohydride extracts. The extraction yields for both cultivars remained relatively unaffected by ethylene-induced softening. A higher proportion of pectin-associated sugar residues in more tightly bound hemicellulose extracts indicated that pectin and hemicellulose were associated with each other in some ways in the cell walls of peach fruits. This association could be by covalent linkage as in apple (Renard et al., 1991) and tomato (Seymour et al., 1990), or by physical entrapment of pectin by hemicellulose as in onion (McCann et al., 1990) and 'Belle of Georgia' peach (Hegde and Maness, 1998) .

4 M KOH plus boric acid extracts separated into three apparent molecular size peaks (Fig. 23a, 23b). The 1 ppm-24 h treatment resulted in a decrease of peak 2 relative to peak 1 and peak 3 in both cultivars. Then at, peak 1 decreased relative to peaks 2 and 3 in the 100 ppm-24 h treatment. Peak 2 exhibited a drastic molecular size downshift from 24 h to 48 hin either ethylene treatment and for both 'J12-119' and 'Cresthaven'. Peak 3 was relatively unaffected by 24 h of ethylene treatment, but it decreased considerably in size and separation into 2 peaks by 48 h of treatment. Peak 1 was rich in arabinosyl

residue which increased in percentage with duration of ethylene exposure and subsequent softening (Table 19a, 19b). Peak 2 was rich in arabinosyl, rhamnosyl, galactosyl and galacturonosyl residues. Peak 3 was particularly rich in mannosyl residue compared with the other two peaks, combined with high amount of glucose and galactose in this peak, suggested probably the presence of small pieces of glucomannan or galactoglucomannan like polymers, as in 4 M KOH plus sodium borohydride extracts. The insoluble residue contained a high mole percentage of glucosyl residue as well as arbinosyl,galactosyl, galacturonosyl, rhamnosyl and xylosyl residues (Table 20a, 20b). The presence of galacturonosyl and rhamnosyl residues suggested that some pectic polymers were still somehow associated with α-cellulose that resists extraction by 4 M KOH. Much of the galactose and arabinose were not extractable with 4 M KOH, but remained associated with the insoluble residue. The presence of high mole percentage of arabinosyl and galactosyl residues in the insoluble residues probably implied the existence of arabinogalactan-type polymers, as already observed in many fruit species (Redgwell et al., 1997). The inability of 4 M KOH to solubilize these arabinogalactan-type polymers suggested that they were associated more highly with the cellulose microfibrils; they probably are still associated with hemicelluloses. Residue recovery ranged between 26% to 34% among the treatments.

Pectin solubilization is a very important event of the fruit softening process. Abnormal solubilization probably results in abnormal textures, among which is pasty and mealy in peaches. Mealiness is a physiological disorder during ripening after prolonged periods of cold storage. The affected fruits are lacking in juice and have a dry mealy texture (Dawson and Watkins, 1995). Mealiness has been ascribed to reduced PG activity

and limited pectin solubilization (Ben-Arie, 1980; Mollendroff and Villiers, 1988; Mollendroff et al., 1992).

Pasty is an abnormal texture obtained by exposing 'J12-119' fruits to 100 ppm ethylene continuously for 48 h. It is characterized by a slimy, or a pasty consistency at cut surface, and a slight reduction in mesocarp free water. Pasty texture is not obtained in 'J12-119' fruits by exposure to 1 ppm ethylene continuously for 48 h nor in 'Cresthaven' fruits exposed to 1 ppm and 100 ppm ethylene continuously for 48 h.

Peach softening is associated with changes in sugar composition and in apparent molecular mass for both pectins and hemicelluloses (Hegde and Maness, 1998). In buffer soluble polysaccharides, large rhamnogalacturonan like polymers in peak 1 were depolymerized at early stages of softening, meanwhile there was an increase in homogalacturonan like polymers in peak 2 in relation to peak 1. Major difference exists for 'Crestahven' and 'J12-119' at later stages of ethylene-induced ripening. There was only a slight molecular mass downshift of homogalacturonan like polymers in 'J12-119' for the 100 ppm ethylene, 48 h treatment, but an extensive molecular mass downshift of homogalacturonan like polymers in 'Cresthaven' with the same treatment. The high proportion of high molecular weight homogalacturonan-like polymers would likely form gel, which could be responsible for the pasty or slimy constency of Stonyhard fruits. The greater depolymerization in 'Cresthaven' may have produced polymers less likely to form a gel, and thus cut surfaces did not show the slimy or pasty appearance.

Another major difference exists between 'J12-119' and 'Cresthaven' in the timing of xylan like and xyloglucan like polymers being modified. Apparent molecular weight downshift of these polymers occurred in both cultivars, but timing was different, with

both xylan like and xyloglucan like polymers being modified at an earlier stage in 'Cresthaven' than in 'J12-119'. This implies that hemicellulose modification in 'Cresthaven', like galacturonic acid content in ethanol precipitate recovery, is in a progressive manner; whereas in 'J12-119' hemicellulose modification comes in sudden way, which may ultimately affect textural changes, or may be related to the perturbed nature of softening exhibited by Stonyhard fruit.

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Table 1. Ethanol precipitate yield and resistance to puncture in 'J12-119' and 'Cresthaven' fruits.

Stonyhard			Cresthaven		
Treatment	Ethanol precipitate yield (mg/g FW)	Resistance to puncture (N)	Treatment	Ethanol precipitate yield (mg/g FW)	Resistance to puncture (N)
Initial	0.99 ± 0.04[z]	66.3 ± 1.2	Initial	0.89 ± 0.03	67.4 ± 0.9
0ppm-24h	1.00 ± 0.03	65.1 ± 1.0	0ppm-24h	1.34 ± 0.04	60.7 ± 0.7
0ppm-48h	1.13 ± 0.08	65.4 ± 0.7	0ppm-48h	1.98 ± 0.11	59.3 ± 1.5
1ppm-24h	2.11 ± 0.13	42.3 ± 1.6	1ppm-24h	2.27 ± 0.10	43.4 ± 1.2
1ppm-48h	2.27 ± 0.10	15.3 ± 1.5	1ppm-48h	2.33 ± 0.13	27.3 ± 1.4
100ppm-24h	2.36 ± 0.12	35.2 ± 1.4	100ppm-24h	2.31 ± 0.11	46.6 ± 2.7
100ppm-48h	2.46 ± 0.10	12.1 ± 1.2	100ppm-48h	3.15 ± 0.15	15.4 ± 1.1
Significance			Significance		
EL[y]	***[x]	***	EL	***	***
EQ	***	***	EQ	***	***
TL	***	***	TL	***	***
TQ	***	NS	TQ	***	NS
EL*TL	***	***	EL*TL	***	***

[z]Data are mean ± SE of three replications of each treatment.
[y]EL, ethylene linear; EQ, ethylene quadratic; TL, time linear; TQ, time quadratic; EL*TL, ethylene linear by time linear.
[x]NS,*, **, *** Non significant and significant at $P \leq 0.05, 0.01$ or 0.001, respectively.

Table 2a. Sugar composition of cell walls following various ethylene treatments in 'J12-119' peach fruits.

Treatment	Yield	Ara	Rha	fuc	Xyl	Man	GalA	Gal	GlcA	Glu
	(g/100g FW)	mole percent								
Initial	1.47 ± 0.06[z]	24.1 ± 1.7	7.2 ± 0.8	2.1 ± 0.5	9.0 ± 1.6	1.9 ± 0.3	40.2 ± 4.2	10.2 ± 1.7	2.0 ± 0.4	4.8 ± 0.8
0ppm-24h	1.45 ± 0.06	22.9 ± 1.8	7.2 ± 1.0	1.9 ± 0.3	9.2 ± 1.2	1.9 ± 0.4	39.1 ± 3.6	10.1 ± 1.9	3.1 ± 0.4	4.9 ± 0.4
0ppm-48h	1.44 ± 0.08	23.2 ± 2.0	7.5 ± 0.6	2.0 ± 0.3	9.1 ± 1.3	2.0 ± 0.3	39.0 ± 3.9	10.2 ± 1.6	2.2 ± 0.3	4.8 ± 0.4
1ppm-24h	1.08 ± 0.06	26.2 ± 2.4	9.0 ± 0.9	1.9 ± 0.3	11.6 ± 1.1	2.2 ± 0.3	31.1 ± 3.5	12.4 ± 1.3	2.1 ± 0.3	5.1 ± 0.6
1ppm-48h	1.05 ± 0.06	25.9 ± 2.2	8.4 ± 0.9	2.1 ± 0.2	13.0 ± 1.4	2.7 ± 0.4	28.0 ± 3.7	12.8 ± 1.4	2.0 ± 0.1	6.0 ± 0.6
100ppm-24h	1.10 ± 0.08	26.2 ± 2.4	8.7 ± 1.2	2.0 ± 0.3	12.9 ± 1.5	2.4 ± 0.4	29.3 ± 3.5	12.8 ± 1.9	2.1 ± 0.2	5.2 ± 0.8
100ppm-48h	0.97 ± 0.08	25.9 ± 2.2	8.1 ± 0.9	2.3 ± 0.2	13.7 ± 1.9	2.9 ± 0.4	27.3 ± 3.4	13.0 ± 2.1	2.2 ± 0.4	6.0 ± 0.5
Significance effects										
EL[y]	***[x]	NS	NS	NS	NS	NS	NS	NS	NS	NS
EQ	***	NS	NS	NS	NS	NS	*	NS	NS	NS
TL	***	NS	NS	NS	*	*	**	NS	NS	NS
TQ	**	NS	NS	NS	NS	NS	NS	NS	NS	NS
EL*TL	**	NS	NS	NS	NS	NS	NS	NS	NS	NS

[z]Data are mean ± SE of three replications of each treatment.

[y]EL, ethylene linear; EQ, ethylene quadratic; TL, time linear; TQ, time quadratic; EL*TL, ethylene linear by time linear.

[x]NS,*, **, *** Non significant and significant at $P \leq 0.05$, 0.01 or 0.001, respectively.

Table 2b. Sugar composition of cell walls following various ethylene treatments in 'Cresthaven' peach fruits.

Treatment	Yield (g/100g FW)	Ara	Rha	fuc	Xyl	Man	GalA	Gal	GlcA	Glu
		mole percent								
Initial	1.90 ± 0.04[z]	24.1 ± 2.6	8.2 ± 0.8	1.8 ± 0.4	7.9 ± 1.0	1.8 ± 0.3	36.0 ± 3.3	12.3 ± 2.2	2.0 ± 0.4	4.2 ± 0.5
0ppm-24h	1.28 ± 0.04	27.0 ± 2.4	8.1 ± 1.3	1.4 ± 0.2	8.4 ± 0.8	1.8 ± 0.2	37.0 ± 3.7	10.8 ± 1.9	2.3 ± 0.4	4.0 ± 0.7
0ppm-48h	1.22 ± 0.03	27.7 ± 2.2	9.6 ± 1.3	1.7 ± 0.3	10.1 ± 0.8	1.8 ± 0.2	33.9 ± 1.9	10.9 ± 1.7	1.4 ± 0.2	3.8 ± 0.5
1ppm-24h	1.03 ± 0.04	28.0 ± 2.3	9.7 ± 1.2	1.7 ± 0.3	9.6 ± 1.5	1.8 ± 0.3	31.0 ± 3.6	12.2 ± 1.1	2.4 ± 0.3	4.0 ± 0.4
1ppm-48h	0.98 ± 0.04	31.0 ± 1.9	10.3 ± 1.4	1.9 ± 0.4	11.2 ± 1.3	2.1 ± 0.2	26.0 ± 3.5	12.0 ± 1.4	1.0 ± 0.2	4.7 ± 0.5
100ppm-24h	1.00 ± 0.04	28.1 ± 2.0	9.2 ± 1.2	2.1 ± 0.4	9.8 ± 1.9	1.8 ± 0.3	32.4 ± 3.2	10.5 ± 1.6	2.0 ± 0.4	4.0 ± 0.4
100ppm-48h	0.89 ± 0.06	32.4 ± 2.2	9.9 ± 1.0	1.8 ± 0.4	14.5 ± 1.8	2.8 ± 0.4	20.1 ± 2.2	12.6 ± 1.2	0.9 ± 0.2	4.9 ± 0.5
Significance effects										
EL[y]	***[x]	NS	NS	NS	NS	NS	NS	NS	NS	NS
EQ	***	NS	NS	NS	NS	NS	NS	NS	NS	NS
TL	***	**	NS	NS	***	NS	***	NS	**	NS
TQ	***	NS	NS	NS	NS	NS	NS	NS	**	NS
EL*TL	**	NS	NS	NS	NS	NS	NS	NS	NS	NS

[z]Data are mean ± SE of three replications of each treatment.

[y]EL, ethylene linear; EQ, ethylene quadratic; TL, time linear; TQ, time quadratic; EL*TL, ethylene linear by time linear.

[x]NS,*, **, *** Non significant and significant at $P \leq 0.05$, 0.01 or 0.001, respectively.

Table 3a. Sugar content of cell walls following various ethylene treatments in 'J12-119' peach fruits.

Treatment	Ara	Rha	fuc	Xyl	Man	GalA	Gal	GlcA	Glu
	(μmoles/g FW)								
Initial	12.6±0.9[z]	4.0±0.5	1.1±0.1	4. 9±0.4	1.0±0.1	22.6±0.9	5.7±0.2	1.2±0.1	2.8±0.1
0ppm-24h	12.0±0.9	3.9±0.4	0.99±0.02	4.9±0.3	1. 0±0.1	21.1±1.1	5.5±0.2	1.3±0.1	2.6±0.1
0ppm-48h	12.1±0.9	3.9±0.4	1.0±0.1	5.1±0.3	1.0±0.1	21.5±1.0	5.6±0.2	1.3±0.2	2.7±0.2
1ppm-24h	10.2±1.1	3.6±0.3	0.84±0.01	4.7±0.4	0.96±0.05	12.4±0.6	5.2±0.3	0.78±0.1	2.4±0.2
1ppm-48h	9.6±0.9	3.3±0.3	0.77±0.01	4.9±0.1	0.91±0.04	11.1±0.8	4.8±0.3	0.79±0.2	2.0±0.2
100ppm-24h	10.2±0.9	3.4±0.3	0.85±0.01	5.1±0.3	1.1±0.1	11.0±0.8	5.1±0.3	0.77±0.1	2.4±0.2
100ppm-48h	8.2±0.8	2.6±0.3	0.77±0.02	4.9±0.3	0.98±0.05	9.2±0.8	4.3±0.2	0.74±0.1	2.0±0.2
Significance effects									
EL[y]	NS[x]	NS	NS	NS	NS	***	**	NS	NS
EQ	NS	NS	*	NS	NS	***	*	*	*
TL	***	*	***	NS	NS	***	NS	NS	***
TQ	NS	NS	NS	NS	NS	***	NS	NS	NS
EL*TL	NS	NS	NS	NS	NS	***	NS	NS	NS

[z]Data are mean ± SE of three replications of each treatment.
[y]EL, ethylene linear; EQ, ethylene quadratic; TL, time linear; TQ, time quadratic; EL*TL, ethylene linear by time linear.
[x]NS,*, **, *** Non significant and significant at P≤0.05,0.01 or 0.001, respectively.

Table 3b. Sugar content of cell walls following various ethylene treatments in 'Cresthaven' peach fruits.

Treatment	Ara	Rha	fuc	Xyl	Man	GalA	Gal	GlcA	Glu
	(μmoles/g FW)								
Initial	13.0 ± 0.8[z]	4.5 ± 0.3	0.89 ± 0.03	4.4 ± 0.3	0.89 ± 0.05	20.2 ± 1.0	6.7 ± 0.1	1.1 ± 0.1	2.3 ± 0.1
0ppm-24h	12.7 ± 1.0	4.3 ± 0.3	0.71 ± 0.03	4.3 ± 0.3	0.88 ± 0.03	18.0 ± 0.7	5.2 ± 0.3	1.1 ± 0.2	2.0 ± 0.1
0ppm-48h	12.4 ± 1.1	4.2 ± 0.4	0.72 ± 0.01	4.4 ± 0.3	0.80 ± 0.05	15.3 ± 0.5	4.9 ± 0.4	1.0 ± 0.1	1.7 ± 0.1
1ppm-24h	11.0 ± 1.1	3.8 ± 0.4	0.66 ± 0.01	3.7 ± 0.4	0.69 ± 0.03	12.3 ± 0.3	4.8 ± 0.2	0.94 ± 0.2	1.6 ± 0.1
1ppm-48h	8.7 ± 0.9	2.9 ± 0.3	0.65 ± 0.01	4.0 ± 0.3	0.82 ± 0.03	10.0 ± 0.5	3.9 ± 0.2	0.63 ± 0.1	1.6 ± 0.2
100ppm-24h	11.0 ± 0.8	3.9 ± 0.6	0.65 ± 0.01	4.2 ± 0.3	0.82 ± 0.04	9.7 ± 0.5	4.4 ± 0.1	0.72 ± 0.1	1.7 ± 0.1
100ppm-48h	8.6 ± 0.8	2.8 ± 0.3	0.51 ± 0.02	4.2 ± 0.4	0.71 ± 0.04	5.7 ± 0.4	3.6 ± 0.1	0.64 ± 0.2	1.4 ± 0.1
Significance effects									
EL[y]	NS[x]	NS	***	NS	NS	***	***	NS	NS
EQ	*	NS	*	NS	NS	***	***	NS	NS
TL	***	***	***	NS	**	***	***	*	***
TQ	NS	NS	***	NS	NS	***	NS	NS	NS
EL*TL	NS	NS	***	NS	NS	***	NS	NS	NS

[z]Data are mean ± SE of three replications of each treatment.

[y]EL, ethylene linear; EQ, ethylene quadratic; TL, time linear; TQ, time quadratic; EL*TL, ethylene linear by time linear.

[x]NS,*, **, *** Non significant and significant at $P \leq 0.05, 0.01$ or 0.001, respectively.

Table 4a. Sugar composition of buffer soluble polysaccharides following various ethylene treatments in 'J12-119' peach fruits.

Treatment	Yield (g/100g FW)	Ara	Rha	fuc	Xyl	Man	GalA	Gal	GlcA	Glu
		mole percent								
Initial	0.094 ± 0.002[z]	23.7 ± 1.4	6.2 ± 0.5	1.1 ± 0.2	6.7 ± 0.5	2.1 ± 0.3	30.6 ± 0.3	22.0 ± 2.0	4.1 ± 0.4	4.3 ± 0.3
0ppm-24h	0.100 ± 0.006	23.1 ± 1.4	5.0 ± 0.5	1.3 ± 0.3	7.1 ± 0.7	1.8 ± 0.2	33.3 ± 1.9	20.9 ± 2.4	4.4 ± 0.3	4.3 ± 0.2
0ppm-48h	0.113 ± 0.003	20.6 ± 1.6	5.1 ± 0.6	1.4 ± 0.2	6.2 ± 0.5	1.7 ± 0.1	38.7 ± 2.0	20.9 ± 2.8	3.3 ± 0.1	4.1 ± 0.3
1ppm-24h	0.210 ± 0.003	13.0 ± 1.2	3.8 ± 0.6	0.8 ± 0.3	2.8 ± 0.5	1.3 ± 0.4	60.5 ± 2.6	12.4 ± 2.2	3.9 ± 0.2	2.3 ± 0.4
1ppm-48h	0.227 ± 0.010	13.1 ± 1.2	3.9 ± 0.4	1.1 ± 0.1	2.8 ± 0.5	1.4 ± 0.3	63.2 ± 2.0	10.4 ± 1.8	3.1 ± 0.3	2.1 ± 0.6
100ppm-24h	0.236 ± 0.010	13.5 ± 1.3	4.1 ± 0.4	0.9 ± 0.3	2.2 ± 0.5	0.9 ± 0.2	61.0 ± 1.7	12.2 ± 2.2	3.2 ± 0.3	2.1 ± 0.2
100ppm-48h	0.246 ± 0.012	11.3 ± 1.3	3.9 ± 0.5	1.2 ± 0.5	2.4 ± 0.3	0.7 ± 0.4	65.0 ± 1.7	11.0 ± 2.0	3.4 ± 0.1	1.7 ± 0.3
Significance effects										
EL[y]	***[x]	***	NS	NS	***	NS	***	*	NS	NS
EQ	***	***	NS	NS	***	NS	***	***	NS	NS
TL	***	***	***	NS	***	NS	***	***	NS	NS
TQ	**	***	**	NS	**	NS	**	NS	NS	NS
EL*TL	**	*	NS	NS	*	NS	NS	NS	NS	NS

[z]Data are mean ± SE of three replications of each treatment.

[y]EL, ethylene linear; EQ, ethylene quadratic; TL, time linear; TQ, time quadratic; EL*TL, ethylene linear by time linear.

[x]NS,*, **, *** Non significant and significant at $P \leq 0.05$, 0.01 or 0.001, respectively.

Table 4b. Sugar composition of buffer soluble polysaccharides following various ethylene treatments in 'Cresthaven' peach fruits.

Treatment	Yield (g/100g FW)	Ara	Rha	fuc	Xyl	Man	GalA	Gal	GlcA	Glu
		mole percent								
Initial	0.089 ± 0.005[z]	26.8 ± 1.7	7.4 ± 0.6	1.1 ± 0.1	9.6 ± 0.4	3.2 ± 0.2	21.8 ± 1.9	23.4 ± 1.9	3.4 ± 0.1	5.2 ± 0.3
0ppm-24h	0.134 ± 0.005	21.8 ± 1.6	5.3 ± 0.6	1.2 ± 0.1	8.1 ± 0.6	2.2 ± 0.1	32.5 ± 1.8	21.6 ± 2.7	3.1 ± 0.1	5.1 ± 0.2
0ppm-48h	0.198 ± 0.006	19.6 ± 1.7	5.1 ± 0.5	0.8 ± 0.1	5.4 ± 0.4	1.1 ± 0.1	42.0 ± 1.5	19.1 ± 2.5	4.3 ± 0.3	3.4 ± 0.1
1ppm-24h	0.227 ± 0.009	20.1 ± 1.7	5.2 ± 0.6	0.9 ± 0.3	5.3 ± 0.5	0.7 ± 0.1	45.7 ± 2.2	16.0 ± 1.9	3.3 ± 0.2	2.8 ± 0.1
1ppm-48h	0.233 ± 0.009	17.5 ± 1.9	4.9 ± 0.5	1.4 ± 0.1	4.5 ± 0.4	0.9 ± 0.1	53.4 ± 2.1	12.3 ± 1.9	3.8 ± 0.1	2.3 ± 0.3
100ppm-24h	0.231 ± 0.007	17.2 ± 1.6	5.2 ± 0.8	1.1 ± 0.1	5.1 ± 0.6	1.2 ± 0.1	46.9 ± 2.3	15.4 ± 2.0	5.2 ± 0.5	3.1 ± 0.3
100ppm-48h	0.315 ± 0.010	17.4 ± 1.5	4.9 ± 0.6	0.8 ± 0.1	3.3 ± 0.4	1.4 ± 0.3	55.4 ± 1.4	11.1 ± 1.5	4.1 ± 0.2	2.2 ± 0.2
Significance effects										
EL[y]	***[x]	NS	NS	NS	**	NS	***	NS	NS	NS
EQ	***	NS	NS	NS	**	NS	***	*	NS	NS
TL	***	***	***	NS	***	NS	***	***	NS	NS
TQ	**	**	*	NS	*	NS	***	NS	NS	NS
EL*TL	**	NS	NS	NS	NS	NS	**	NS	NS	NS

[z]Data are mean ± SE of three replications of each treatment.

[y]EL, ethylene linear; EQ, ethylene quadratic; TL, time linear; TQ, time quadratic; EL*TL, ethylene linear by time linear.

[x]NS,*, **, *** Non significant and significant at $P \leq 0.05$, 0.01 or 0.001, respectively.

Table 5a. Sugar composition of buffer soluble polysaccharides following various ethylene treatments on size exclusion chromatography for 'J12-119' peach fruits.

Treatment	Ara	Rha	Fuc	Xyl	Man	GalA	Gal	GlcA	Glu
	mole percent								
Initial (66N)									
Peak 1	30.0±2.2[z]	9.9±0.5	1.2±0.1	6.0±0.3	3.2±0.2	19.2±1.7	20.1±2.2	5.3±1.1	5.3±0.6
Peak 2	13.1±1.4	5.2±0.3	0.8±0.1	2.2±0.1	1.1±0.1	63.3±3.4	8.2±0.8	3.2±0.2	3.2±0.1
Peak 3	28.4±1.8	7.5±0.6	1.1±0.1	8.4±0.6	2.3±0.1	11.5±1.2	26.5±2.2	4.3±0.1	8.4±1.0
1ppm-24h (42N)									
Peak 1	47.4±2.8	6.0±0.5	1.3±0.1	3.1±0.6	2.1±0.1	21.0±2.4	10.9±1.8	3.1±0.6	8.0±0.8
Peak 2	13.6±1.2	3.3±0.1	0.7±0.1	1.2±0.1	1.4±0.1	72.4±2.9	4.4±0.4	2.2±0.1	2.1±0.1
Peak 3	20.1±2.0	6.3±0.6	0.8±0.2	4.4±0.3	0.7±0.1	44.3±2.3	16.8±1.8	2.8±0.1	44.5±0.5
1ppm-48h (15N)									
Peak 1	45.6±3.1	6.2±0.4	1.4±0.1	2.8±0.4	2.2±0.1	20.4±2.6	10.1±1.7	2.0±0.5	8.0±0.8
Peak 2	11.4±1.3	3.4±0.2	1.2±0.2	1.3±0.1	0.9±0.1	74.2±2.1	3.7±0.3	2.3±0.1	1.9±0.1
Peak 3	15.0±1.3	6.5±0.7	1.2±0.1	3.7±0.5	1.4±0.2	52.3±2.4	13.4±1.9	3.2±0.1	4.9±0.6
100ppm-24h (35N)									
Peak 1	47.5±4.2	5.9±0.4	0.7±0.1	3.1±0.3	2.2±0.1	16.2±1.3	11.5±1.4	3.1±0.6	7.4±0.5
Peak 2	13.3±1.0	2.8±0.1	1.3±0.1	1.4±0.2	1.1±0.1	72.0±2.4	4.2±0.5	2.1±0.2	2.4±0.1
Peak 3	17.5±1.4	4.9±0.4	1.1±0.2	3.9±0.4	1.3±0.1	49.4±3.5	15.4±1.7	3.4±0.1	4.1±0.7

100ppm-48h (12N)									
Peak 1	51.3±3.5	4.3±0.8	1.2±0.1	3.0±0.4	2.2±0.1	17.2±1.3	9.9±1.6	2.0±0.5	7.1±0.8
Peak 2	12.9±1.0	3.2±0.1	1.1±0.1	1.3±0.2	1.3±0.1	71.2±3.0	4.1±0.4	2.1±0.2	1.9±0.1
Peak 3	14.5±1.5	6.0±0.6	0.8±0.1	3.4±0.4	0.9±0.1	55.5±2.8	11.5±2.3	2.2±0.1	4.4±0.5
Significance effects for P1									
EL[y]	**[x]	***	NS	**	NS	NS	*	NS	NS
EQ	***	***	NS	***	NS	NS	***	*	**
TL	***	***	NS	***	NS	NS	***	**	*
TQ	*	**	NS	**	NS	NS	NS	NS	NS
EL*TL	*	***	NS	NS	NS	NS	NS	NS	NS
Significance effects For P2									
EL	NS	NS	NS	NS	NS	NS	*	NS	NS
EQ	NS	NS	NS	NS	NS	*	***	NS	NS
TL	NS	NS	NS	NS	NS	*	***	NS	NS
TQ	NS	NS	NS	NS	NS	NS	*	NS	NS
EL*TL	NS	NS	NS	NS	NS	NS	NS	NS	NS
Significance effects for P3									
EL	***	*	NS	***	NS	***	**	NS	*
EQ	***	NS	NS	***	NS	***	***	NS	**
TL	***	NS	NS	***	NS	***	***	NS	**
TQ	NS	NS	NS	**	NS	***	NS	NS	*
EL*TL	*	NS	NS	**	NS	***	*	NS	NS

[z]Data are mean ± SE of three replications of each treatment.

[y]EL, ethylene linear; EQ, ethylene quadratic; TL, time linear; TQ, time quadratic; EL*TL, ethylene linear by time linear.

[x]NS,*, **, *** Non significant and significant at P≤0.05,0.01 or 0.001, respectively.

Table 5b. Sugar composition of buffer soluble polysaccharides following various ethylene treatments on size exclusion chromatography for 'Cresthaven' peach fruits.

Treatment	Ara	Rha	Fuc	Xyl	Man	GalA	Gal	GlcA	Glu
	mole percent								
Initial (67N)									
Peak 1	28.0±2.5[z]	6.1±0.4	1.9±0.1	8.2±0.4	3.4±0.2	19.3±1.9	19.8±2.6	9.3±1.7	4.0±0.4
Peak 2	14.5±0.9	3.1±0.1	1.3±0.1	3.3±0.2	2.1±0.2	60.4±3.4	7.3±1.3	7.0±0.4	3.2±0.1
Peak 3	24.2±1.7	7.0±0.8	2.1±0.2	9.4±0.4	2.2±0.1	11.2±1.8	30.1±3.1	5.7±0.2	8.1±0.9
1ppm-24h (43N)									
Peak 1	27.4±2.3	6.0±0.8	1.8±0.1	5.9±0.5	3.3±0.1	20.1±2.3	20.2±2.3	9.3±1.7	6.5±1.1
Peak 2	13.4±1.3	3.3±0.1	1.3±0.1	2.1±0.1	0.7±0.1	68.5±2.3	6.0±0.9	6.4±0.1	3.1±0.2
Peak 3	20.0±2.1	5.3±0.5	2.2±0.1	6.8±0.6	0.8±0.2	34.1±1.3	18.5±3.0	4.2±0.3	7.9±0.7
1ppm-48h (27N)									
Peak 1	29.0±2.1	6.2±0.8	1.8±0.1	4.9±0.6	3.4±0.1	18.0±1.4	20.2±1.9	5.1±1.0	12.4±1.6
Peak 2	9.5±1.1	2.9±0.2	1.4±0.1	1.3±0.1	1.2±0.2	70.2±2.9	3.8±0.7	6.1±0.3	5.4±0.3
Peak 3	18.3±2.3	5.2±0.6	1.1±0.1	4.9±0.5	1.2±0.1	43.2±2.3	14.2±1.8	3.9±0.2	7.4±1.1
100ppm-24h (47N)									
Peak 1	27.1±1.9	8.2±0.8	2.0±0.1	6.4±0.3	2.7±0.1	19.4±2.2	20.4±1.9	6.2±1.0	6.3±0.8
Peak 2	9.2±0.9	3.1±0.1	1.1±0.1	2.2±0.2	1.3±0.1	69.0±3.9	5.2±0.7	7.3±0.4	2.1±0.1
Peak 3	18.1±0.5	4.3±0.6	2.2±0.1	7.0±0.4	1.1±0.2	35.4±1.3	17.5±2.0	6.4±0.6	8.4±0.8

100ppm-48h (15N)									
Peak 1	30.5±2.3	8.5±0.7	2±0.3	5.9±0.5	3±0.3	19.6±2.1	16.3±1.5	5.0±0.8	10.3±0.8
Peak 2	13.3±0.8	4.2±0.3	1.1±0.1	1.2±0.5	1±0.1	68.0±3.8	4.1±0.6	5.3±0.4	3.3±0.4
Peak 3	15.7±1.6	5.3±0.6	1.3±0.1	3.7±0.6	1±0.1	52.5±2.3	11.0±1.4	4.1±0.1	6.0±0.6
Significance effects for P1									
EL[y]	NS[x]	**	NS	NS	NS	NS	NS	NS	NS
EQ	NS	NS	NS	***	NS	NS	NS	NS	***
TL	NS	NS	NS	***	NS	NS	NS	*	***
TQ	NS	NS	NS	NS	NS	NS	NS	NS	NS
EL*TL	NS	NS	NS	NS	NS	NS	NS	NS	NS
Significance effects for P2									
EL	NS	NS	NS	NS	NS	NS	NS	NS	NS
EQ	*	NS	NS	NS	NS	*	NS	NS	NS
TL	*	NS	NS	NS	NS	*	*	NS	NS
TQ	NS	NS	NS	NS	NS	NS	NS	NS	NS
EL*TL	NS	NS	NS	NS	NS	NS	NS	NS	NS
Significance effects for P3									
EL	*	NS	NS	***	NS	***	**	NS	NS
EQ	*	*	NS	***	NS	***	***	NS	NS
TL	**	*	NS	***	NS	***	***	NS	NS
TQ	NS	NS	NS	NS	NS	*	NS	NS	NS
EL*TL	NS	NS	NS	***	NS	***	*	NS	NS

[z]Data are mean ± SE of three replications of each treatment.

[y]EL, ethylene linear; EQ, ethylene quadratic; TL, time linear; TQ, time quadratic; EL*TL, ethylene linear by time linear.

[x]NS,*, **, *** Non significant and significant at P≤0.05,0.01 or 0.001, respectively.

Table 6a. Sugar composition of imidazole soluble extracts following various ethylene treatments for 'J12-119' peach fruits.

Treatment	Yield (g/100g FW)	Ara	Rha	fuc	Xyl	Man	GalA	Gal	GlcA	Glu
		mole percent								
Initial	0.125 ± 0.009[z]	9.6 ± 1.4	3.0 ± 0.3	0.3 ± 0.2	1.9 ± 0.3	1.9 ± 0.2	70.1 ± 4.5	4.0 ± 0.4	4.1 ± 0.3	3.9 ± 0.3
0ppm-24h	0.127 ± 0.006	10.4 ± 1.5	3.1 ± 0.4	0.4 ± 0.1	3.2 ± 0.6	2.0 ± 0.3	66.1 ± 4.3	7.5 ± 0.6	3.2 ± 0.3	4.5 ± 0.3
0ppm-48h	0.110 ± 0.011	10.3 ± 1.6	2.9 ± 0.3	0.6 ± 0.1	3.2 ± 0.5	2.0 ± 0.2	66.1 ± 4.4	6.8 ± 0.5	2.5 ± 0.4	5.4 ± 0.7
1ppm-24h	0.094 ± 0.008	14.9 ± 1.4	4.8 ± 0.4	0.5 ± 0.2	2.3 ± 0.5	3.3 ± 0.4	60.2 ± 4.1	5.1 ± 0.5	3.8 ± 0.5	4.2 ± 0.4
1ppm-48h	0.079 ± 0.008	21.5 ± 2.1	6.3 ± 0.5	0.8 ± 0.2	5.1 ± 0.6	3.1 ± 0.3	47.2 ± 3.6	7.4 ± 0.7	2.1 ± 0.3	7.0 ± 0.5
100ppm-24h	0.091 ± 0.006	15.2 ± 1.9	5.1 ± 0.6	0.4 ± 0.1	2.8 ± 0.5	2.1 ± 0.6	61.1 ± 3.7	5.9 ± 0.5	4.3 ± 0.4	3.8 ± 0.4
100ppm-48h	0.078 ± 0.009	20.1 ± 2.2	6.0 ± 0.4	1.1 ± 0.2	6.0 ± 0.7	4.0 ± 0.5	45.4 ± 3.8	7.9 ± 0.5	2.1 ± 0.4	7.5 ± 0.4
Significance effects										
EL[y]	*[x]	NS	NS	NS	NS	NS	NS	NS	NS	NS
EQ	**	***	***	NS	NS	*	*	NS	NS	NS
TL	***	***	***	NS	***	***	***	***	***	***
TQ	NS	NS	NS	NS	NS	NS	NS	NS	*	**
EL*TL	NS	NS	Ns	NS	*	*	NS	NS	NS	NS

[z]Data are mean ± SE of three replications of each treatment.

[y]EL, ethylene linear; EQ, ethylene quadratic; TL, time linear; TQ, time quadratic; EL*TL, ethylene linear by time linear.

[x]NS,*, **, *** Non significant and significant at P≤ 0.05, 0.01 or 0.001, respectively.

Table 6b. Sugar composition of imidazole soluble extracts following various ethylene treatments for 'Cresthaven' peach fruits.

Treatment	Yield (g/100g FW)	Ara	Rha	fuc	Xyl	Man	GalA	Gal	GlcA	Glu
		mole percent								
Initial	0.108 ± 0.006[z]	9.1 ± 1.4	2.9 ± 0.3	1.1 ± 0.2	2.0 ± 0.4	1.4 ± 0.2	68.8 ± 2.7	5.3 ± 0.4	6.3 ± 0.3	3.4 ± 0.3
0ppm-24h	0.102 ± 0.009	10.3 ± 1.6	4.0 ± 0.5	0.4 ± 0.1	2.2 ± 0.3	2.3 ± 0.3	66.0 ± 3.6	6.0 ± 0.6	3.4 ± 0.2	4.2 ± 0.3
0ppm-48h	0.093 ± 0.010	13.3 ± 1.4	3.6 ± 0.7	1.2 ± 0.1	3.1 ± 0.4	2.2 ± 0.3	61.6 ± 3.8	5.7 ± 0.8	4.4 ± 0.3	5.4 ± 0.3
1ppm-24h	0.088 ± 0.006	16.1 ± 1.6	5.1 ± 0.7	1.4 ± 0.2	2.9 ± 0.4	2.1 ± 0.4	57.2 ± 3.7	7.0 ± 0.6	5.0 ± 0.5	4.1 ± 0.3
1ppm-48h	0.079 ± 0.009	20.1 ± 2.2	6.0 ± 0.8	0.8 ± 0.2	3.5 ± 0.5	3.1 ± 0.5	48.2 ± 3.2	9.4 ± 1.0	3.3 ± 0.3	6.2 ± 0.7
100ppm-24h	0.076 ± 0.005	15.3 ± 1.7	4.4 ± 0.5	1.1 ± 0.3	2.1 ± 0.3	1.0 ± 0.1	59.3 ± 5.4	7.1 ± 0.6	5.1 ± 0.4	4.0 ± 0.3
100ppm-48h	0.058 ± 0.006	20.4 ± 2.1	6.0 ± 0.8	1.3 ± 0.1	5.3 ± 0.5	4.2 ± 0.7	46.1 ± 3.2	8.1 ± 0.6	2.1 ± 0.3	7.3 ± 0.5
Significance effects										
EL[y]	*[x]	NS	NS	NS	NS	NS	NS	NS	NS	NS
EQ	NS	**	*	NS	NS	NS	*	**	NS	NS
TL	***	***	***	NS	***	***	***	***	***	***
TQ	NS	NS	NS	NS	*	*	NS	NS	NS	**
EL*TL	*	NS	NS	NS	NS	*	NS	NS	**	*

[z]Data are mean ± SE of three replications of each treatment.
[y]EL, ethylene linear; EQ, ethylene quadratic; TL, time linear; TQ, time quadratic; EL*TL, ethylene linear by time linear.
[x]NS,*, **, *** Non significant and significant at P≤ 0.05, 0.01 or 0.001, respectively.

Table7a. Sugar composition of imidazole soluble extracts following various ethylene treatments on size exclusion chromatography for 'J12-119' peach fruits.

Treatment	Ara	Rha	Fuc	Xyl	Man	GalA	Gal	GlcA	Glu
	mole percent								
Initial (66N)									
Peak 1	39.0±2.2[z]	4.2±0.7	0.8±0.1	2.3±0.3	0.6±0.1	42.2±3.0	6.2±0.6	1.9±0.2	4.3±0.2
Peak 2	14.1±1.0	3.2±0.2	1.1±0.1	1.0±0.2	0.6±0.1	71.8±3.4	4.4±0.8	1.6±0.1	1.8±0.1
1ppm-24h (42N)									
Peak 1	45.8±2.1	6.3±0.6	1.3±0.1	2±0.1	0.8±0.1	34.4±2.2	4.3±0.5	2.3±0.1	4.4±0.3
Peak 2	18.5±1.7	4.4±0.1	0.7±0.1	1.3±0.2	1.1±0.1	64.4±2.0	4.1±0.7	2.0±0.1	2.2±0.1
1ppm-48h (15N)									
Peak 1	57.7±2.2	3.4±0.6	0.6±0.2	2.0±0.1	1.2±0.1	24.1±1.1	4.9±0.6	1.1±0.1	5.1±0.1
Peak 2	20.8±1.9	4.8±0.2	1.2±0.1	4.0±0.4	2.3±0.1	53.3±2.5	7.0±1.0	1.9±0.1	5.4±0.1
100ppm-24h (35N)									
Peak 1	45.9±3.0	7.5±0.8	1.1±0.1	2.2±0.1	1.4±0.1	27.8±3.4	8.1±1.6	1.7±0.2	3.2±0.1
Peak 2	17.8±1.9	5.1±0.2	1.3±0.1	1.7±0.3	1.1±0.2	64.6±4.3	4.7±0.6	2.2±0.1	2.1±0.1
100ppm-48h (12N)									
Peak 1	62.1±3.4	3.2±0.3	0.7±0.2	1.7±0.1	1.2±0.2	18.5±1.7	7.0±1.0	1.4±0.1	4.0±0.3
Peak 2	24.0±1.5	5.4±0.1	1.2±0.1	4.3±0.4	1.9±0.1	48.1±2.1	8.2±1.0	2.1±0.1	5.3±0.1

Significance effects for P1									
EL	**[x]	NS	NS	NS	NS	***	*	NS	NS
EQ	***	NS	NS	NS	NS	***	NS	NS	NS
TL	***	NS	NS	NS	NS	***	NS	NS	NS
TQ	NS	***	NS	NS	NS	NS	NS	NS	NS
EL*TL	**	NS	NS	NS	NS	**	NS	NS	NS
Significance effects for P2									
EL	*	NS	NS	***	NS	*	NS	NS	NS
EQ	**	NS	NS	***	NS	**	NS	NS	NS
TL	***	NS	NS	***	NS	***	**	NS	NS
TQ	NS	NS	NS	**	NS	NS	NS	NS	NS
EL*TL	*	NS	NS	***	NS	*	NS	NS	NS

[z]Data are mean ± SE of three replications of each treatment.

[y]EL, ethylene linear; EQ, ethylene quadratic; TL, time linear; TQ, time quadratic; EL*TL, ethylene linear by time linear.

[x]NS,*, **, *** Non significant and significant at $P \leq 0.05, 0.01$ or 0.001, respectively.

Table 7b. Sugar composition of imidazole soluble extracts following various ethylene treatments on size exclusion chromatography for 'Cresthaven' peach fruits.

Treatment	Ara	Rha	Fuc	Xyl	Man	GalA	Gal	GlcA	Glu
	mole percent								
Initial (67N)									
Peak 1	30.5±2.0[z]	6.2±0.4	1.3±0.1	1.3±0.1	0.8±0.1	47.0±3.3	9.1±1.4	1.6±0.1	3.1±0.1
Peak 2	13.0±1.5	2.7±0.3	1.1±0.1	0.9±0.2	1.4±0.1	71.0±3.8	5.0±1.2	2.1±0.3	2.3±0.1
1ppm-24h (43N)									
Peak 1	40.5±2.6	6.1±0.5	1.1±0.1	1.1±0.3	1.3±0.1	38.4±2.5	7.4±1.6	1.4±0.1	2.7±0.4
Peak 2	16.7±1.7	4.3±0.4	0.7±0.1	1.7±0.2	0.7±0.1	66.4±2.6	5.0±0.7	2.0±0.1	2.1±0.1
1ppm-48h (27N)									
Peak 1	42.0±2.3	2.2±0.3	0.7±0.2	3.4±0.1	0.6±0.2	30.4±3.4	4.2±0.6	1.3±0.1	16.2±0.6
Peak 2	14.3±1.5	2.2±0.1	1.2±0.1	1.7±0.3	1.2±0.1	66.6±3.5	4.2±0.7	2.2±0.1	6.3±0.3
100ppm-24h (47N)									
Peak 1	43.3±1.7	7.3±0.6	1.1±0.1	2.0±0.1	1.1±0.1	36.5±2.0	7.2±1.1	1.8±0.1	2.0±0.1
Peak 2	14.6±1.7	4.3±0.3	1.3±0.1	1.3±0.2	1.3±0.1	68.0±3.5	4.2±0.7	2.1±0.2	3.3±0.1
100ppm-48h (15N)									
Peak 1	47.7±3.3	3.3±0.3	0.6±0.2	2.1±0.3	0.7±0.2	26.4±2.9	7.0±1.2	1.1±0.1	9.1±0.5
Peak 2	22.9±2.6	5.4±0.1	1.2±0.1	4.4±0.6	3.2±0.1	41.6±3.2	9.3±1.0	2.4±0.1	9.3±0.3

Significance effects for P1									
EL[y]	***[x]	NS	NS	NS	NS	*	NS	NS	NS
EQ	***	**	NS	NS	NS	**	*	NS	NS
TL	***	***	NS	NS	NS	***	*	NS	NS
TQ	NS	***	NS	NS	NS	NS	NS	NS	NS
EL*TL	**	*	NS	NS	NS	*	NS	NS	NS
Significance effects for P2									
EL	*	NS	NS	***	NS	**	NS	NS	NS
EQ	NS	NS	NS	NS	NS	NS	NS	NS	NS
TL	*	NS	NS	***	NS	***	NS	NS	NS
TQ	NS	NS	NS	**	NS	NS	NS	NS	NS
EL*TL	*	NS	NS	***	NS	***	*	NS	NS

[z]Data are mean ± SE of three replications of each treatment.

[y]EL, ethylene linear; EQ, ethylene quadratic; TL, time linear; TQ, time quadratic; EL*TL, ethylene linear by time linear.

[x]NS,*, **, *** Non significant and significant at $P \leq 0.05, 0.01$ or 0.001, respectively.

Table 8a. Sugar composition of Na_2CO_3-cold soluble extracts following various ethylene treatments for 'J12-119' peach fruits.

Treatment	Yield (g/100g FW)	Ara	Rha	fuc	Xyl	Man	GalA	Gal	GlcA	Glu
		mole percent								
Initial	0.195±0.013[z]	11.1±1.1	5.0±0.6	0.4±0.1	1.2±0.3	1.3±0.1	70.3±5.1	6.4±0.2	4.3±0.3	2.2±0.1
0ppm-24h	0.190±0.011	9.2±1.3	5.3±0.8	0.4±0.2	1.4±0.3	1.4±0.1	70.1±4.9	6.2±0.2	4.0±0.2	2.1±0.1
0ppm-48h	0.188±0.010	16.3±1.1	6.1±0.8	0.3±0.2	0.9±0.5	1.1±0.1	70.3±4.6	5.9±0.1	2.3±0.3	1.3±0.1
1ppm-24h	0.184±0.012	11.4±1.0	8.2±0.9	0.3±0.3	0.7±0.3	0.9±0.2	68.8±3.7	5.7±0.1	4.1±0.2	1.8±0.1
1ppm-48h	0.169±0.007	32.2±2.4	9.2±0.9	0.5±0.2	2.2±0.2	0.9±0.1	45.0±3.9	7.3±0.2	2.1±0.3	0.9±0.2
100ppm-24h	0.178±0.009	17.3±1.8	7.9±1.1	0.4±0.1	2.4±0.2	0.7±0.1	56.3±3.5	6.8±0.3	4.3±0.7	2.2±0.1
100ppm-48h	0.152±0.011	30.1±3.5	8.7±1.2	0.3±0.1	1.8±0.1	1.3±0.2	46.2±4.5	5.7±0.1	2.2±0.2	1.7±0.1
Significance effects										
EL[y]	NS[x]	**	NS	NS	NS	NS	*	NS	NS	NS
EQ	NS	***	**	NS	NS	NS	*	NS	NS	NS
TL	*	***	***	NS	NS	NS	***	NS	***	NS
TQ	NS	***	NS	NS	NS	NS	NS	NS	***	NS
EL*TL	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[z]Data are mean ± SE of three replications of each treatment.

[y]EL, ethylene linear; EQ, ethylene quadratic; TL, time linear; TQ, time quadratic; EL*TL, ethylene linear by time linear.

[x]NS,*, **, *** Non significant and significant at $P \leq 0.05$, 0.01 or 0.001, respectively.

Table 8b. Sugar composition of Na_2CO_3-cold soluble extracts following various ethylene treatments for 'Cresthaven' peach fruits.

Treatment	Yield (g/100g FW)	Ara	Rha	fuc	Xyl	Man	GalA	Gal	GlcA	Glu
		mole percent								
Initial	0.201 ± 0.010[z]	11.2 ± 1.6	4.8 ± 0.7	0.3 ± 0.2	1.2 ± 0.3	0.7 ± 0.3	69.5 ± 3.9	6.3 ± 0.2	5.1 ± 0.4	2.3 ± 0.1
0ppm-24h	0.196 ± 0.011	15.9 ± 1.2	6.1 ± 0.7	0.2 ± 0.2	1.1 ± 0.3	1.1 ± 0.2	64.3 ± 4.4	7.1 ± 0.5	4.0 ± .3	2.3 ± 0.2
0ppm-48h	0.181 ± 0.010	17.3 ± 1.4	6.1 ± 0.8	0.4 ± 0.1	0.8 ± 0.4	1.2 ± 0.2	64.3 ± 4.3	6.8 ± 0.3	2.8 ± 0.4	1.2 ± 0.2
1ppm-24h	0.179 ± 0.010	16.2 ± 1.5	5.8 ± 1.0	0.5 ± 0.3	0.7 ± 0.1	1.1 ± 0.1	60.2 ± 4.2	7.2 ± 0.5	3.8 ± 0.6	2.1 ± 0.3
1ppm-48h	0.169 ± 0.009	25.8 ± 2.3	10.0 ± 1.3	0.3 ± 0.1	2.3 ± 0.3	1.5 ± 0.3	51.1 ± 4.1	7.1 ± 0.2	2.3 ± 0.3	0.7 ± 0.1
100ppm-24h	0.163 ± 0.011	20.9 ± 1.6	7.9 ± 0.9	0.4 ± 0.1	1.2 ± 0.2	0.8 ± 0.2	55.5 ± 3.8	5.8 ± 0.5	3.3 ± 0.4	1.8 ± 0.1
100ppm-48h	0.152 ± 0.007	31.2 ± 3.2	11.1 ± 1.9	0.2 ± 0.1	1.8 ± 0.3	0.7 ± 0.1	45.2 ± 4.1	8.1 ± 0.1	2.1 ± 0.2	1.8 ± 0.1
Significance effects										
EL[y]	*[x]	***	*	NS	NS	NS	*	NS	NS	NS
EQ	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
TL	**	***	***	NS	NS	NS	***	NS	***	NS
TQ	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
EL*TL	NS	*	NS	NS	NS	NS	NS	NS	NS	NS

[z]Data are mean ± SE of three replications of each treatment.

[y]EL, ethylene linear; EQ, ethylene quadratic; TL, time linear; TQ, time quadratic; EL*TL, ethylene linear by time linear.

[x]NS,*, **, *** Non significant and significant at $P \leq 0.05$, 0.01 or 0.001, respectively.

Table 9a. Sugar composition of Na_2CO_3-warm soluble extracts following various ethylene treatments for 'J12-119' peach fruits.

Treatment	Yield (g/100g FW)	Ara	Rha	fuc	Xyl	Man	GalA	Gal	GlcA	Glu
		mole percent								
Initial	0.048 ± 0.004[z]	34.6 ± 1.7	11.1 ± 1.3	0.4 ± 0.1	2.2 ± 0.1	1.4 ± 0.1	38.9 ± 3.0	9.0 ± 0.8	1.9 ± 0.2	1.9 ± 0.2
0ppm-24h	0.039 ± 0.004	33.3 ± 1.6	11.1 ± 1.4	0.5 ± 0.1	2.3 ± 0.1	1.3 ± 0.1	41.1 ± 2.1	98.5 ± 0.9	3.0 ± 0.2	1.3 ± 0.1
0ppm-48h	0.035 ± 0.005	35.0 ± 1.7	12.2 ± 0.7	0.3 ± 0.1	2.4 ± 0.1	0.8 ± 0.1	40.1 ± 2.8	7.5 ± 0.7	1.3 ± 0.2	3.3 ± 0.5
1ppm-24h	0.037 ± 0.004	39.0 ± 2.8	10.1 ± 1.2	0.4 ± 0.1	2.0 ± 0.1	0.7 ± 0.1	33.1 ± 2.0	9.1 ± 1.0	2.9 ± 0.2	2.0 ± 0.2
1ppm-48h	0.029 ± 0.005	39.2 ± 2.5	13.0 ± 1.2	0.3 ± 0.2	1.8 ± 0.1	1.3 ± 0.1	24.7 ± 1.9	12.0 ± 0.9	1.9 ± 0.1	3.0 ± 0.2
100ppm-24h	0.023 ± 0.004	39.4 ± 3.1	10.2 ± 1.2	0.4 ± 0.2	2.2 ± 0.2	1.2 ± 0.2	30.9 ± 3.2	10.0 ± 1.2	3.0 ± 0.1	2.2 ± 0.3
100ppm-48h	0.025 ± 0.003	40.2 ± 2.3	12.6 ± 1.5	0.3 ± 0.1	3.2 ± 0.1	1.4 ± 0.2	27.3 ± 4.0	12.2 ± 1.3	1.2 ± 0.1	1.9 ± 0.2
Significance effects										
EL[y]	*[x]	NS	NS	NS	NS	NS	NS	NS	NS	NS
EQ	NS	NS	NS	NS	NS	NS	**	*	NS	NS
TL	***	*	NS	NS	NS	NS	***	*	**	***
TQ	NS	NS	NS	NS	NS	NS	NS	NS	***	*
EL*TL	NS	NS	NS	NS	NS	NS	NS	NS	NS	**

[z]Data are mean ± SE of three replications of each treatment.

[y]EL, ethylene linear; EQ, ethylene quadratic; TL, time linear; TQ, time quadratic; EL*TL, ethylene linear by time linear.

[x]NS,*, **, *** Non significant and significant at $P \leq 0.05$, 0.01 or 0.001, respectively.

Table 9b. Sugar composition of Na_2CO_3-warm soluble extracts following various ethylene treatments for 'Cresthaven' peach fruits.

Treatment	Yield (g/100g FW)	Ara	Rha	fuc	Xyl	Man	GalA	Gal	GlcA	Glu
		mole percent								
Initial	0.075 ± 0.007[z]	31.2 ± 2.2	10.0 ± 1.2	1.1 ± 0.2	2.1 ± 0.3	1.4 ± 0.1	38.2 ± 1.3	13.3 ± 1.2	2.0 ± 0.2	1.9 ± 0.2
0ppm-24h	0.066 ± 0.008	37.0 ± 3.2	12.3 ± 1.1	1.3 ± 0.3	1.8 ± 0.2	1.3 ± 0.1	32.5 ± 2.2	10.6 ± 1.4	1.9 ± 0.2	2.2 ± 0.3
0ppm-48h	0.074 ± 0.006	34.4 ± 1.8	15.1 ± 1.3	1.4 ± 0.2	1.7 ± 0.1	0.8 ± 0.1	33.0 ± 2.1	12.0 ± 1.6	2.0 ± 0.2	3.9 ± 0.2
1ppm-24h	0.058 ± 0.006	38.0 ± 2.6	11.0 ± 1.3	0.8 ± 0.3	1.3 ± 0.4	0.7 ± 0.1	31.1 ± 2.5	13.6 ± 1.4	2.2 ± 0.2	1.9 ± 0.2
1ppm-48h	0.042 ± 0.007	40.1 ± 2.6	14.9 ± 1.3	1.1 ± 0.1	1.4 ± 0.3	1.3 ± 0.1	22.9 ± 2.6	14.2 ± 1.2	1.3 ± 0.3	2.0 ± 0.2
100ppm-24h	0.052 ± 0.004	39.9 ± 2.4	13.1 ± 1.1	0.9 ± 0.3	0.9 ± 0.2	1.2 ± 0.2	30.2 ± 2.3	11.0 ± 0.9	2.2 ± 0.3	1.9 ± 0.2
100ppm-48h	0.048 ± 0.004	42.4 ± 2.4	15.8 ± 1.0	1.2 ± 0.5	0.7 ± 0.4	1.4 ± 0.2	20.2 ± 2.6	14.2 ± 1.5	1.4 ± 0.1	4.1 ± 0.4
Significance effects										
EL[y]	NS[x]	NS	NS	NS	NS	NS	*	NS	NS	NS
EQ	NS	NS	NS	NS	NS	NS	*	NS	NS	***
TL	***	***	***	NS	NS	NS	***	NS	**	***
TQ	NS	NS	NS	NS	NS	NS	NS	NS	*	***
EL*TL	NS	NS	NS	NS	NS	NS	**	NS	NS	*

[z]Data are mean ± SE of three replications of each treatment.

[y]EL, ethylene linear; EQ, ethylene quadratic; TL, time linear; TQ, time quadratic; EL*TL, ethylene linear by time linear.

[x]NS,*, **, *** Non significant and significant at $P \leq 0.05$, 0.01 or 0.001, respectively.

Table10a. Sugar composition of Na_2CO_3-cold extracts following various ethylene treatments on size exclusion chromatography for 'J12-119' peach fruits.

Treatment	Ara	Rha	Fuc	Xyl	Man	GalA	Gal	GlcA	Glu
	mole percent								
Initial (66N)									
Peak 1	45.5 ± 1.4[z]	9.0 ± 1.0	1.3 ± 0.1	2.3 ± 0.4	0.8 ± 0.1	27.0 ± 1.6	8.3 ± 1.0	1.8 ± 0.1	2.1 ± 0.1
Peak 2	14.0 ± 1.4	4.5 ± 0.6	1.1 ± 0.1	1.4 ± 0.1	1.1 ± 0.1	70.7 ± 2.1	6.4 ± 0.6	2.1 ± 0.1	0.6 ± 0.1
1ppm-24h (42N)									
Peak 1	45.3 ± 1.1	8.7 ± 1.3	1.3 ± 0.2	3.7 ± 0.6	1.4 ± 0.1	24.0 ± 1.6	10.9 ± 1.3	2.0 ± 0.2	3.1 ± 0.1
Peak 2	18.3 ± 1.6	3.8 ± 0.5	0.9 ± 0.1	0.7 ± 0.1	0.7 ± 0.1	63.9 ± 1.0	4.0 ± 0.5	2.2 ± 0.1	2.4 ± 0.1
1ppm-48h (15N)									
Peak 1	39.3 ± 1.6	15.4 ± 1.1	0.6 ± 0.2	4.1 ± 0.8	0.9 ± 0.2	22.0 ± 1.6	14.4 ± 0.9	1.8 ± 0.1	2.1 ± 0.1
Peak 2	20.4 ± 2.3	8.8 ± 1.2	1.2 ± 0.1	0.8 ± 0.1	1.2 ± 0.1	55.9 ± 1.7	6.0 ± 0.4	2.1 ± 0.1	0.9 ± 0.1
100ppm-24h (35N)									
Peak 1	41.9 ± 1.8	14.6 ± 1.5	1.1 ± 0.1	4.0 ± 0.6	1.3 ± 0.1	20.8 ± 1.7	12.8 ± 1.1	2.4 ± 0.2	2.2 ± 0.1
Peak 2	18.1 ± 1.8	7.6 ± 0.6	1.4 ± 0.1	1.3 ± 0.1	1.3 ± 0.1	61.7 ± 1.8	7.3 ± 1.1	1.8 ± 0.1	0.7 ± 0.2
100ppm-48h (12N)									
Peak 1	38.1 ± 2.3	14.8 ± 1.6	0.7 ± 0.2	4.5 ± 0.5	1.1 ± 0.2	22.2 ± 2.2	14.0 ± 1.4	3.1 ± 0.1	2.2 ± 0.1

Peak 2	20.3 ± 2.4	9.5 ± 1.6	1.2 ± 0.1	1.2 ± 0.1	1.2 ± 0.1	57.3 ± 1.7	7.0 ± 0.7	2.3 ± 0.1	1.4 ± 0.1
Significance effects for P1									
EL[y]	*[x]	**	NS	NS	NS	NS	*	NS	NS
EQ	NS	NS	NS	*	NS	NS	**	NS	NS
TL	**	***	NS	**	NS	*	***	NS	NS
TQ	NS	NS	NS	NS	NS	NS	NS	NS	NS
EL*TL	NS	NS	NS	NS	NS	NS	NS	NS	NS
Significance effects for P2									
EL	NS	**	NS	NS	NS	**	*	NS	NS
EQ	*	NS	NS	NS	NS	***	NS	NS	NS
TL	**	***	NS	NS	NS	***	NS	NS	NS
TQ	NS	NS	NS	NS	NS	NS	NS	NS	NS
EL*TL	NS	NS	NS	NS	NS	NS	NS	NS	NS

[z]Data are mean ± SE of three replications of each treatment.

[y]EL, ethylene linear; EQ, ethylene quadratic; TL, time linear; TQ, time quadratic; EL*TL, ethylene linear by time linear.

[x]NS,*, **, *** Non significant and significant at $P \leq 0.05, 0.01$ or 0.001, respectively.

Table 10b. Sugar composition of Na2CO3-cold extracts following various ethylene treatments on size exclusion chromatography for 'Cresthaven' peach fruits.

Treatment	Ara	Rha	Fuc	Xyl	Man	GalA	Gal	GlcA	Glu
	mole percent								
Initial (67N)									
Peak 1	50.1±2.4[z]	7.9±0.5	1.2±0.1	1.3±0.2	1.3±0.1	28.5±2.1	6.4±0.8	1.0±0.1	2.7±0.3
Peak 2	13.3±1.7	4.4±0.7	0.7±0.1	1.4±0.1	1.1±0.2	70.1±3.1	7.3±1.1	1.9±0.1	1.1±0.2
1ppm-24h (43N)									
Peak 1	46.3±2.9	10.4±1.1	1.3±0.2	2.3±0.2	1.0±0.2	22.2±1.8	11.3±1.1	1.4±0.1	3.3±0.1
Peak 2	17.2±1.8	6.9±0.8	0.9±0.1	0.6±0.1	0.9±0.1	63.9±1.4	7.2±0.7	1.7±0.1	1.2±0.1
1ppm-48h (27N)									
Peak 1	46.9±2.3	14.1±1.5	0.9±0.2	2.0±0.3	0.6±0.2	21.1±1.7	12.1±1.3	1.3±0.1	2.7±0.3
Peak 2	23.6±0.7	9.9±1.3	1.2±0.1	0.7±0.1	0.8±0.1	50.3±2.2	6.9±0.5	2.1±0.2	2.3±0.1
100ppm-24h (47N)									
Peak 1	50.1±3.6	11.1±1.6	1.1±0.1	1.3±0.1	1.1±0.1	23.2±1.6	8.1±0.8	1.4±0.1	3.1±0.1
Peak 2	17.7±0.9	6.8±0.8	0.8±0.1	1.1±0.1	1.4±0.1	61.2±2.7	7.0±0.6	2.1±0.1	1.8±0.1
100ppm-48h (15N)									
Peak 1	47.6±2.9	13.5±1.7	0.7±0.2	2.3±0.3	0.6±0.2	16.5±0.6	14.2±1.3	2.1±0.1	2.4±0.1

Peak 2	26.8 ± 3.1	11.9 ± 1.7	1.2 ± 0.1	1.2 ± 0.3	1.1 ± 0.1	46.9 ± 2.0	8.7 ± 1.1	2.3 ± 0.1	1.2 ± 0.1
Significance effects for P1									
EL[y]	NS[x]	**	NS	NS	NS	*	*	NS	NS
EQ	NS	***	NS	*	NS	**	***	NS	NS
TL	NS	***	NS	*	NS	***	***	NS	NS
TQ	NS	NS	NS	NS	NS	NS	NS	NS	NS
EL*TL	NS	*	NS	NS	NS	*	**	NS	NS
Significance effects for P2									
EL	*	**	NS	NS	NS	**	NS	NS	NS
EQ	**	**	NS	NS	NS	***	NS	NS	NS
TL	***	***	NS	NS	NS	***	NS	NS	NS
TQ	NS	NS	NS	NS	NS	NS	NS	NS	NS
EL*TL	*	**	NS	NS	NS	**	NS	NS	NS

[z]Data are mean ± SE of three replications of each treatment.

[y]EL, ethylene linear; EQ, ethylene quadratic; TL, time linear; TQ, time quadratic; EL*TL, ethylene linear by time linear.

[x]NS,*, **, *** Non significant and significant at $P \leq 0.05, 0.01$ or 0.001, respectively.

Table11a. Sugar composition of Na_2CO_3-warm extracts following various ethylene treatments on size exclusion chromatography for 'J12-119' peach fruits.

Treatment	Ara	Rha	Fuc	Xyl	Man	GalA	Gal	GlcA	Glu
	mole percent								
Initial (66N)									
Peak 1	50.2±2.3[z]	7.6±0.5	0.7±0.1	2.2±0.1	0.8±0.1	22.3±1.7	9.1±0.7	3.3±0.1	2.2±0.1
Peak 2	42.3±1.9	6.3±0.8	1.1±0.1	2.0±0.1	1.1±0.1	32.0±1.5	8.4±0.6	1.9±0.1	2.1±0.1
1ppm-24h (42N)									
Peak 1	43.3±1.6	12.2±1.0	1.3±0.1	1.9±0.1	1.1±0.1	27.1±0.6	11.2±1.1	1.3±0.1	2.0±0.1
Peak 2	36.3±1.8	9.3±0.5	0.9±0.1	1.1±0.1	0.7±0.1	37.3±1.1	10.1±0.8	1.4±0.1	1±0.1
1ppm-48h (15N)									
Peak 1	42.4±1.8	11.0±0.4	0.6±0.2	3.3±0.3	0.9±0.2	22.9±1.8	13.6±0.9	0.6±0.1	3.4±0.2
Peak 2	38.6±1.4	7.5±0.5	1.1±0.1	2.4±0.1	1.2±0.1	32.8±3.5	10.4±0.9	2.1±0.1	3.3±0.3
100ppm-24h (35N)									
Peak 1	40.7±2.2	16.5±1.4	1.1±0.1	1.6±0.1	1.1±0.1	23.6±1.9	14.3±1.5	1.3±0.1	1.8±0.1
Peak 2	35.8±1.9	11.8±1.2	1.2±0.1	1.3±0.2	1.3±0.1	34.7±2.0	12.3±0.4	1.0±0.1	1.7±0.1
100ppm-48h (12N)									
Peak 1	50.7±2.0	7.2±0.4	0.8±0.1	4.3±0.1	0.7±0.2	14.9±1.0	12.1±1.1	2.2±0.1	2.2±0.1
Peak 2	43.2±1.7	8.0±0.9	1.2±0.1	3.2±0.1	1.2±0.1	27.4±2.5	9.9±0.4	1.2±0.1	4.3±0.2

Significance effects for P1									
EL[y]	NS [x]	**	NS	NS	NS	*	*	NS	NS
EQ	*	***	NS	NS	NS	NS	*	NS	NS
TL	NS	NS	NS	NS	NS	NS	**	NS	NS
TQ	*	***	NS	NS	NS	*	NS	NS	NS
EL*TL	NS	NS	NS	NS	NS	*	NS	NS	NS
Significance effects for P2									
EL	NS	**	NS	NS	NS	NS	NS	NS	NS
EQ	*	*	NS	NS	NS	NS	NS	NS	NS
TL	NS	NS	NS	NS	NS	NS	NS	NS	NS
TQ	*	***	NS	NS	NS	*	NS	NS	NS
EL*TL	NS	NS	NS	NS	NS	NS	NS	NS	NS

[z]Data are mean ± SE of three replications of each treatment.

[y]EL, ethylene linear; EQ, ethylene quadratic; TL, time linear; TQ, time quadratic; EL*TL, ethylene linear by time linear.

[x]NS,*, **, *** Non significant and significant at $P \leq 0.05, 0.01$ or 0.001, respectively.

Table 11b. Sugar composition of Na2CO3-warm extracts following various ethylene treatments on size exclusion chromatography for 'Cresthaven' peach fruits.

Treatment	Ara	Rha	Fuc	Xyl	Man	GalA	Gal	GlcA	Glu
	mole percent								
Initial (67N)									
Peak 1	40.7 ± 1.3[z]	12.4 ± 1.6	1.2 ± 0.1	1.0 ± 0.1	1.3 ± 0.1	24.2 ± 2.1	17.4 ± 1.5	1.3 ± 0.1	1.8 ± 0.1
Peak 2	36.1 ± 1.6	8.5 ± 0.8	0.7 ± 0.1	1.2 ± 0.1	1.1 ± 0.2	38.2 ± 1.4	10.7 ± 0.6	1.1 ± 0.1	2.1 ± 0.2
1ppm-24h (43N)									
Peak 1	40.4 ± 1.6	13.4 ± 1.4	1.4 ± 0.2	0.8 ± 0.2	1.3 ± 0.2	23.3 ± 1.3	17.2 ± 1.9	1.3 ± 0.2	2.0 ± 0.2
Peak 2	37.1 ± 2.1	11.0 ± 1.5	0.9 ± 0.3	1.3 ± 0.1	0.9 ± 0.1	30.0 ± 2.7	14.2 ± 0.5	0.9 ± 0.1	1.6 ± 0.1
1ppm-48h (27N)									
Peak 1	46.2 ± 2.6	14.3 ± 1.3	0.7 ± 0.2	1.6 ± 0.1	0.6 ± 0.2	17.5 ± 0.7	14.9 ± 1.1	0.6 ± 0.2	1.9 ± 0.1
Peak 2	45.3 ± 1.1	9.1 ± 0.9	1.2 ± 0.1	2.1 ± 0.1	1.4 ± 0.1	26.3 ± 1.9	11.4 ± 0.4	1.2 ± 0.1	2.1 ± 0.1
100ppm-24h (47N)									
Peak 1	45.2 ± 1.6	13.1 ± 0.2	1.2 ± 0.1	1.7 ± 0.2	1.1 ± 0.1	19.4 ± 1.0	15.3 ± 1.2	1.1 ± 0.1	2.0 ± 0.2
Peak 2	40.8 ± 1.8	11.4 ± 1.1	1.4 ± 0.1	2.2 ± 0.1	1.0 ± 0.1	27.1 ± 1.3	12.1 ± 1.0	1.4 ± 0.1	1.8 ± 0.1
100ppm-48h (15N)									
Peak 1	38.4 ± 1.8	17.3 ± 1.3	0.9 ± 0.2	1.8 ± 0.4	0.7 ± 0.2	19.0 ± 1.7	18.1 ± 1.8	0.7 ± 0.2	2.1 ± 0.1

Peak 2	38.1 ± 1.8	14.1 ± 0.8	1.2 ± 0.1	2.1 ± 0.1	1.3 ± 0.1	26.1 ± 1.2	15.2 ± 0.9	1.2 ± 0.1	1.9 ± 0.1
Significance effects for P1									
EL[y]	NS[x]	NS	NS	NS	NS	NS	NS	NS	NS
EQ	NS	NS	NS	NS	NS	NS	NS	NS	NS
TL	NS	NS	NS	NS	NS	*	NS	NS	NS
TQ	NS	NS	NS	NS	NS	NS	NS	NS	NS
EL*TL	NS	NS	NS	NS	NS	NS	NS	NS	NS
Significance effects for P2									
EL	NS	**	NS	NS	NS	**	NS	NS	NS
EQ	*	NS	NS	NS	NS	***	NS	NS	NS
TL	*	*	NS	NS	NS	***	NS	NS	NS
TQ	NS	NS	NS	NS	NS	NS	NS	NS	NS
EL*TL	NS	**	NS	NS	NS	*	NS	NS	NS

[z]Data are mean ± SE of three replications of each treatment.

[y]EL, ethylene linear; EQ, ethylene quadratic; TL, time linear; TQ, time quadratic; EL*TL, ethylene linear by time linear.

[x]NS,*, **, *** Non significant and significant at $P \leq 0.05, 0.01$ or 0.001, respectively.

Table 12a. Sugar composition of 1 M KOH-cold soluble extracts following various ethylene treatments in 'J12-119' peach fruits.

Treatment	Yield (g/100g FW)	Ara	Rha	fuc	Xyl	Man	GalA	Gal	GlcA	Glu
		mole percent								
Initial	0.089 ± 0.009[z]	8.3 ± 0.3	2.2 ± 0.3	5.3 ± 0.5	34.0 ± 2.0	4.3 ± 0.3	5.2 ± 0.1	13.3 ± 0.7	1.3 ± 0.1	25.2 ± 2.0
0ppm-24h	0.091 ± 0.004	8.1 ± 0.3	3.2 ± 0.1	4.9 ± 0.1	34.1 ± 2.0	4.3 ± 0.1	5.4 ± 0.3	12.8 ± 0.9	1.2 ± 0.3	25.3 ± 1.8
0ppm-48h	0.108 ± 0.007	8.4 ± 0.1	2.1 ± 0.2	6.2 ± 0.1	38.6 ± 2.4	3.9 ± 0.1	4.3 ± 0.1	13.1 ± 0.4	0.4 ± 0.2	25.3 ± 1.8
1ppm-24h	0.116 ± 0.008	6.3 ± 0.1	2.4 ± 0.4	6.4 ± 0.2	37.1 ± 2.7	3.7 ± 0.4	3.1 ± 0.3	14.4 ± 0.3	1.3 ± 0.1	25.9 ± 2.5
1ppm-48h	0.112 ± 0.006	7.4 ± 0.2	1.8 ± 0.1	5.2 ± 0.3	38.3 ± 2.0	4.3 ± 0.2	2.7 ± 0.2	14.1 ± 0.8	0.4 ± 0.1	26.6 ± 3.2
100ppm-24h	0.109 ± 0.010	7.1 ± 0.1	1.9 ± 0.2	5.8 ± 0.1	37.5 ± 2.4	4.3 ± 0.1	2.9 ± 0.3	13.8 ± 1.1	0.9 ± 0.1	26.1 ± 1.8
100ppm-48h	0.116 ± 0.007	6.4 ± 0.3	2.1 ± 0.1	6.2 ± 0.4	37.1 ± 3.2	3.8 ± 0.1	3.1 ± 0.1	13.9 ± 0.6	0.4 ± 0.2	27.0 ± 3.0
Significance effects										
EL[y]	NS[x]	NS	NS	NS	NS	NS	NS	NS	NS	NS
EQ	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
TL	**	NS	NS	NS	*	NS	NS	NS	NS	NS
TQ	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
EL*TL	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[z]Data are mean ± SE of three replications of each treatment.

[y]EL, ethylene linear; EQ, ethylene quadratic; TL, time linear; TQ, time quadratic; EL*TL, ethylene linear by time linear.

[x]NS,*, **, *** Non significant and significant at $P \leq 0.05$, 0.01 or 0.001, respectively.

Table 12b. Sugar composition of 1 M KOH-cold soluble extracts following various ethylene treatments in 'Cresthaven' peach fruits.

Treatment	Yield (g/100g FW)	Ara	Rha	fuc	Xyl	Man	GalA	Gal	GlcA	Glu
		mole percent								
Initial	0.084 ± 0.009[z]	8.4 ± 0.7	2.2 ± 0.3	6.2 ± 0.6	35.1 ± 4.2	4.3 ± 0.2	4.1 ± 0..1	14.4 ± 1.1	1.0 ± 0.1	26.1 ± 2.7
0ppm-24h	0.083 ± 0.005	7.1 ± 0.8	2.1 ± 0.1	5.4 ± 0.7	34.0 ± 3.4	4.1 ± 0.3	4.4 ± 0.3	14.3 ± 0.5	1.3 ± 0.1	26.1 ± 2.2
0ppm-48h	0.098 ± 0.007	6.4 ± 0.2	3.4 ± 0.5	4.8 ± 0.2	37.5 ± 3.5	4.3 ± 0.3	3.3 ± 0.1	14.1 ± 0.4	0.8 ± 0.1	27.9 ± 3.2
1ppm-24h	0.106 ± 0.007	5.8 ± 0.5	1.9 ± 0.2	6.3 ± 0.3	37.1 ± 3.4	3.8 ± 0.1	3.9 ± 0.3	13.7 ± 0.7	0.7 ± 0.2	26.2 ± 2.7
1ppm-48h	0.116 ± 0.004	7.2 ± 0.4	2.3 ± 0.2	6.1 ± 0.4	34.9 ± 3.1	3.8 ± 0.5	3.1 ± 0.3	13.9 ± 1.2	1.3 ± 0.1	27.1 ± 3.0
100ppm-24h	0.110 ± 0.005	7.4 ± 0.7	2.3 ± 0.1	5.9 ± 0.1	36.1 ± 2.3	3.9 ± 0.1	3.2 ± 0.3	14.4 ± 1.0	1.2 ± 0.2	28.2 ± 3.9
100ppm-48h	0.112 ± 0.009	6.8 ± 0.2	2.1 ± 0.1	7.2 ± 0.2	38.3 ± 2.3	5.2 ± 0.2	3.4 ± 0.1	14.1 ± 0.7	1.4 ± 0.2	26.3 ± 2.9
Significance effects										
EL[y]	NS[x]	NS	NS	NS	NS	NS	NS	NS	NS	NS
EQ	*	NS	NS	NS	NS	NS	NS	NS	NS	NS
TL	***	NS	NS	NS	NS	NS	NS	NS	NS	NS
TQ	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
EL*TL	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[z]Data are mean ± SE of three replications of each treatment.

[y]EL, ethylene linear; EQ, ethylene quadratic; TL, time linear; TQ, time quadratic; EL*TL, ethylene linear by time linear.

[x]NS,*, **, *** Non significant and significant at $P \leq 0.05$, 0.01 or 0.001, respectively.

Table 13a. Sugar composition of 1 M KOH-warm soluble extracts following various ethylene treatments in 'J12-119' peach fruits.

Treatment	Yield (g/100g FW)	Ara	Rha	fuc	Xyl	Man	GalA	Gal	GlcA	Glu
		mole percent								
Initial	0.033 ± 0.008[z]	33.1 ± 2.6	10.3 ± 1.4	1.2 ± 0.2	10.0 ± 1.0	4.2 ± 0.1	17.2 ± 1.7	11.0 ± 1.3	2.2 ± 0.1	10.0 ± 0.9
0ppm-24h	0.028 ± 0.004	32.3 ± 2.7	10.1 ± 0.4	2.3 ± 0.2	12.2 ± 1.6	3.9 ± 0.4	14.1 ± 2.0	11.4 ± 1.7	2.3 ± 0.1	11.3 ± 1.4
0ppm-48h	0.027 ± 0.005	33.2 ± 2.7	9.2 ± 0.6	1.3 ± 0.1	10.6 ± 1.5	3.7 ± 0.3	15.1 ± 1.4	13.0 ± 1.2	1.1 ± 0.1	12.4 ± 1.3
1ppm-24h	0.038 ± 0.006	31.0 ± 3.4	8.8 ± 0.4	1.8 ± 0.1	12.5 ± 1.3	5.3 ± 0.6	14.4 ± 1.6	10.9 ± 1.9	2.2 ± 0.1	12.3 ± 1.3
1ppm-48h	0.038 ± 0.005	31.1 ± 3.1	8.9 ± 0.7	1.8 ± 0.2	12.2 ± 1.5	4.2 ± 0.2	13.3 ± 1.7	12.5 ± 1.3	0.7 ± 0.2	13.0 ± 1.2
100ppm-24h	0.035 ± 0.006	32.3 ± 2.9	9.2 ± 0.3	1.9 ± 0.2	13.0 ± 1.9	3.7 ± 0.1	13.8 ± 1.3	12.2 ± 1.7	1.8 ± 0.1	10.3 ± 1.4
100ppm-48h	0.040 ± 0.005	28.9 ± 2.4	10.3 ± 0.5	1.8 ± 0.1	12.7 ± 1.4	4.4 ± 0.1	13.1 ± 1.7	12.2 ± 1.7	1.3 ± 0.1	13.1 ± 1.4
Significance effects										
EL[y]	NS[x]	NS	NS	NS	NS	NS	NS	NS	NS	NS
EQ	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
TL	NS	NS	NS	NS	NS	NS	*	NS	NS	**
TQ	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
EL*TL	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[z]Data are mean ± SE of three replications of each treatment.

[y]EL, ethylene linear; EQ, ethylene quadratic; TL, time linear; TQ, time quadratic; EL*TL, ethylene linear by time linear.

[x]NS,*, **, *** Non significant and significant at $P \leq 0.05$, 0.01 or 0.001, respectively.

Table 13b. Sugar composition of 1 M KOH-warm soluble extracts following various ethylene treatments in 'Cresthaven' peach fruits.

Treatment	Yield (g/100g FW)	Ara	Rha	fuc	Xyl	Man	GalA	Gal	GlcA	Glu
		mole percent								
Initial	0.035 ± 0.004[z]	36.4 ± 2.7	9.4 ± 1.1	1.3 ± 0.2	8.3 ± 1.2	1.7 ± 0.3	17.3 ± 1.4	14.7 ± 1.1	2.3 ± 0.1	8.3 ± 0.6
0ppm-24h	0.031 ± 0.005	35.1 ± 2.3	10.1 ± 0.5	1.1 ± 0.3	10.0 ± 0.9	3.4 ± 0.2	14.1 ± 1.4	13.0 ± 1.5	1.1 ± 0.2	10.3 ± 1.1
0ppm-48h	0.037 ± 0.004	35.3 ± 2.4	9.9 ± 0.3	1.1 ± 0.1	9.2 ± 1.3	2.8 ± 0.3	15.9 ± 1.5	12.3 ± 1.2	2.2 ± 0.3	10.1 ± 1.1
1ppm-24h	0.035 ± 0.004	34.0 ± 2.4	9.6 ± 0.8	0.6 ± 0.1	10.2 ± 1.1	3.3 ± 0.1	14.0 ± 1.6	13.0 ± 1.3	1.4 ± 0.1	10.3 ± 1.6
1ppm-48h	0.040 ± 0.004	29.3 ± 2.6	8.3 ± 0.5	2.3 ± 0.2	13.1 ± 1.3	3.6 ± 0.4	12.2 ± 1.4	14.2 ± 1.4	0.8 ± 0.1	11.2 ± 1.0
100ppm-24h	0.032 ± 0.004	35.0 ± 3.0	10.1 ± 0.3	1.1 ± 0.1	10.0 ± 1.6	4.2 ± 0.6	15.3 ± 1.6	11.4 ± 1.0	1.7 ± 0.1	10.0 ± 1.4
100ppm-48h	0.036 ± 0.006	29.1 ± 3.0	8.4 ± 0.4	2.1 ± 0.5	13.3 ± 1.4	5.4 ± 0.2	12.2 ± 1.2	14.2 ± 1.3	1.1 ± 0.1	14.1 ± 1.2
Significance effects										
EL[y]	NS[x]	NS	Ns	NS	NS	NS	NS	NS	NS	NS
EQ	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
TL	NS	*	***	NS	NS	NS	**	NS	NS	***
TQ	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
EL*TL	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[z]Data are mean ± SE of three replications of each treatment.

[y]EL, ethylene linear; EQ, ethylene quadratic; TL, time linear; TQ, time quadratic; EL*TL, ethylene linear by time linear.

[x]NS,*, **, *** Non significant and significant at $P \leq 0.05$, 0.01 or 0.001, respectively.

Table14a. Sugar composition of 1 M KOH-cold soluble extracts following various ethylene treatments on size exclusion chromatography for 'J12-119' peach fruits.

Treatment	Ara	Rha	Fuc	Xyl	Man	GalA	Gal	GlcA	Glu
	mole percent								
Initial (66N)									
Peak 1	32.4±1.8[z]	3.2±0.2	4.2±0.4	20.5±1.1	0.9±0.1	12.1±0.8	11.9±1.2	1.2±0.1	12.2±0.9
Peak 2	11.2±1.0	1.2±0.1	8.4±0.1	34.4±1.2	1.1±0.1	1.9±0.1	13.7±1.0	0.8±0.1	27.4±1.2
Peak 3	9.4±0.7	0.6±0.2	3.1±0.1	40.2±1.9	8.0±0.1	1.0±0.1	12.2±0.8	1.1±0.1	22.2±0.8
1ppm-24h (42N)									
Peak 1	29.9±2.6	8.2±0.9	2.2±0.5	20.5±1.1	0.7±0.1	15.0±1.4	12.1±1.1	1.3±0.1	9.2±1.0
Peak 2	10.1±0.8	1.3±0.1	7.3±0.4	33.7±2.1	1.3±0.1	4.2±0.2	15.4±0.5	0.7±0.1	25.1±0.9
Peak 3	9.9±0.5	0.7±0.1	4.1±0.1	41.1±2.4	8.1±0.6	1.1±0.1	13.1±0.9	1.1±0.2	21.4±1.3
1ppm-48h (15N)									
Peak 1	46.2±2.1	5.8±0.6	2.0±0.4	13.8±1.2	0.9±0.1	7.7±0.7	10.5±1.3	1.2±0.1	11.8±1.1
Peak 2	15.9±1.5	1.1±0.1	7.4±0.5	32.2±1.8	1.1±0.1	3.3±0.1	12.7±0.4	1.2±0.2	25.8±1.7
Peak 3	12.4±0.8	0.8±0.2	3.9±0.1	39.7±2.0	7.4±0.1	1.4±0.1	12.0±0.6	1.2±0.1	22.0±0.9
100ppm-24h (35N)									
Peak 1	29.3±1.6	8.0±0.8	2.0±0.4	22.0±2.3	0.7±0.2	11.2±1.5	15.3±1.3	1.4±0.1	8.1±1.0
Peak 2	13.2±0.8	2.2±0.1	6.8±0.2	33.1±1.4	1.1±0.1	3.8±0.1	14.1±1.3	0.8±0.1	24.4±0.8
Peak 3	10.1±0.3	1.4±0.1	4.1±0.2	40.4±1.5	8.3±0.1	2.1±0.1	12.3±0.8	1.1±0.2	21.3±1.1

100ppm-48h (12N)									
Peak 1	47.1±2.1	4.4±0.3	1.1±0.2	11.6±1.4	0.9±0.1	6.4±0.5	9.0±0.7	1.2±0.1	20.2±2.0
Peak 2	18.2±2.1	1±0.1	7.3±0.6	32.1±1.2	1.4±0.1	3.1±0.1	12.1±0.7	1.1±0.2	24.9±0.8
Peak 3	14.3±0.9	1±0.1	4.4±0.3	37.3±1.1	7.3±0.5	1.1±0.1	11.6±1.0	0.9±0.1	21.0±1.2
Significance effects for P1									
EL[y]	NS[x]	*	**	NS	NS	**	NS	NS	*
EQ	*	***	***	NS	NS	NS	NS	NS	NS
TL	***	**	***	***	NS	***	NS	NS	*
TQ	***	***	NS	**	NS	**	*	NS	***
EL*TL	*	NS	**	*	NS	*	NS	NS	***
Significance effects for P2									
EL	*	NS	NS	NS	NS	NS	NS	NS	NS
EQ	NS	NS	NS	NS	NS	NS	NS	NS	NS
TL	**	NS	NS	NS	NS	NS	NS	NS	NS
TQ	NS	NS	NS	NS	NS	NS	NS	NS	NS
EL*TL	*	NS	NS	NS	NS	NS	NS	NS	NS
Significance effects for P3									
EL	NS	NS	NS	NS	NS	NS	NS	NS	NS
EQ	NS	NS	NS	NS	NS	NS	NS	NS	NS
TL	NS	NS	NS	NS	NS	NS	NS	NS	NS
TQ	NS	NS	NS	NS	NS	NS	NS	NS	NS
EL*TL	NS	NS	NS	NS	NS	NS	NS	NS	NS

[z]Data are mean ± SE of three replications of each treatment.

[y]EL, ethylene linear; EQ, ethylene quadratic; TL, time linear; TQ, time quadratic; EL*TL, ethylene linear by time linear.

[x]NS,*, **, *** Non significant and significant at $P \leq 0.05, 0.01$ or 0.001, respectively.

Table 14b. Sugar composition of 1 M KOH-cold soluble extracts following various ethylene treatments on size exclusion chromatography for 'Cresthaven' peach fruits.

Treatment	Ara	Rha	Fuc	Xyl	Man	GalA	Gal	GlcA	Glu
	mole percent								
Initial (67N)									
Peak 1	28.2±1.8[z]	10.4±1.3	2.2±0.2	20.2±1.6	1.2±0.1	11.0±1.3	17.1±1.9	1.4±0.1	8.6±1.0
Peak 2	14.7±0.7	1.2±0.2	7.3±0.3	33±2.4	0.8±0.1	1.7±0.1	15.1±1.0	0.8±0.3	25.1±3.0
Peak 3	10.4±1.2	1.4±0.1	4.4±0.3	38±4.1	8.4±0.6	1.3±0.1	13.4±0.5	1.1±0.1	22.0±1.4
1ppm-24h (43N)									
Peak 1	32.4±2.5	9.2±0.9	0.8±0.1	24.1±0.8	1.3±0.1	13.3±1.2	13.3±1.5	1.3±0.1	5.6±0.7
Peak 2	11.4±1.7	0.7±0.3	7.1±0.2	33±1.5	0.7±0.1	4.2±0.1	14.2±0.4	1.4±0.1	27.4±1.5
Peak 3	8.6±0.5	1.2±0.1	4.3±0.7	39±1.9	6.8±0.2	1.1±0.1	13.0±1.0	0.8±0.2	22.3±0.9
1ppm-48h (27N)									
Peak 1	40.2±2.5	10.1±0.8	1.0±0.1	13.7±1.4	1.2±0.1	12.1±1.5	14.0±1.4	1.4±0.1	6.3±0.9
Peak 2	15.2±1.0	2.1±0.2	7.1±0.2	32±2.3	1.2±0.2	2.8±0.1	12.9±0.4	0.7±0.2	25.3±1.3
Peak 3	11.3±0.6	1.3±0.1	4.2±0.3	38±2.1	6.3±0.3	2.4±0.1	13.3±0.9	1.2±0.1	21.6±2.1
100ppm-24h (47N)									
Peak 1	42.0±1.7	6.0±1.0	1.9±0.1	16.2±1.0	1.4±0.1	9.4±1.2	11.2±1.1	0.7±0.1	12.3±2.2
Peak 2	11.1±1.4	1.2±0.1	8.0±1.2	36±3.2	0.8±0.1	2.2±0.1	14.1±1.4	1.3±0.1	26.1±1.7
Peak 3	9.3±0.4	1.0±0.1	3.7±0.2	39±4.6	7.1±0.2	1.3±0.3	13.4±0.5	1.3±0.2	22.3±3.1

100ppm-48 (15N)									
Peak 1	55.0±2.1	5.9±0.6	0.9±0.1	6.7±1.0	1.2±0.1	8.1±0.8	10.1±1.3	1.2±0.1	9.0±1.1
Peak 2	18.2±1.9	1.4±0.1	7.4±0.6	32.2±3.2	1.1±0.2	2.7±0.3	13.3±0.8	1.1±0.1	22.7±1.3
Peak 3	11.3±0.6	1.3±0.2	3.7±0.2	37.6±2.6	6.3±0.9	1.3±0.3	13.0±0.5	1.0±0.1	22.3±0.8
Significance effects for P1									
EL[y]	***[x]	**	NS	***	NS	*	*	NS	*
EQ	**	NS	***	NS	NS	NS	NS	NS	NS
TL	***	NS	***	***	NS	NS	*	NS	NS
TQ	NS	NS	NS	**	NS	NS	NS	NS	NS
EL*TL	***	*	*	***	NS	NS	NS	NS	NS
Significance effects for P2									
EL	NS	NS	NS	NS	NS	NS	NS	NS	NS
EQ	NS	NS	NS	NS	NS	NS	NS	NS	NS
TL	NS	NS	NS	NS	NS	NS	NS	NS	NS
TQ	***	NS	NS	NS	NS	NS	NS	NS	NS
EL*TL	NS	NS	NS	NS	NS	NS	NS	NS	NS
Significance effects for P3									
EL	NS	NS	NS	NS	NS	NS	NS	NS	NS
EQ	NS	NS	NS	NS	NS	NS	NS	NS	NS
TL	NS	NS	NS	NS	NS	NS	NS	NS	NS
TQ	NS	NS	NS	NS	NS	NS	NS	NS	NS
EL*TL	NS	NS	NS	NS	NS	NS	NS	NS	NS

[z]Data are mean ± SE of three replications of each treatment.

[y]EL, ethylene linear; EQ, ethylene quadratic; TL, time linear; TQ, time quadratic; EL*TL, ethylene linear by time linear.

[x]NS,*, **, *** Non significant and significant at P≤0.05,0.01 or 0.001, respectively.

Table15a. Sugar composition of 1 M KOH-warm soluble extracts following various ethylene treatments on size exclusion chromatography for 'J12-119' peach fruits.

Treatment	Ara	Rha	Fuc	Xyl	Man	GalA	Gal	GlcA	Glu
	mole percent								
Initial (66N)									
Peak 1	72.2 ± 3.3[z]	2.2 ± 0.4	1.3 ± 0.1	3.1 ± 0.3	3.2 ± 0.2	4.2 ± 0.3	5.9 ± 0.2	3.3 ± 0.3	4.7 ± 0.4
Peak 2	35.1 ± 1.5	7.0 ± 1.0	3.2 ± 0.1	13.7 ± 1.6	1.1 ± 0.1	14.2 ± 1.2	12.2 ± 0.9	2.4 ± 0.1	11.2 ± 0.3
Peak 3	23.1 ± 1.4	5.8 ± 0.1	1.7 ± 0.1	14.1 ± 1.4	9.4 ± 0.8	11.1 ± 0.8	14.2 ± 1.0	2.1 ± 0.1	14.7 ± 0.8
1ppm-24h (42N)									
Peak 1	69.8 ± 2.2	2.1 ± 0.2	1.2 ± 0.2	6.1 ± 0.3	2.8 ± 0.1	3.9 ± 0.6	6.3 ± 0.4	0.8 ± 0.1	8.2 ± 0.2
Peak 2	32.6 ± 1.4	4.2 ± 0.5	4.4 ± 0.1	18.3 ± 1.7	1.0 ± 0.1	9.1 ± 1.1	12.0 ± 0.3	1.2 ± 0.1	15.0 ± 0.7
Peak 3	22.3 ± 1.1	4.3 ± 0.2	2.1 ± 0.1	18.3 ± 2.0	11.2 ± 0.9	6.0 ± 0.5	14.7 ± 0.2	2.0 ± 0.1	17.2 ± 1.4
1ppm-48h (15N)									
Peak 1	72.1 ± 2.3	2.1 ± 0.2	1.0 ± 0.1	5.4 ± 0.3	1.6 ± 0.1	3.5 ± 0.3	7.1 ± 0.4	1.4 ± 0.1	7.1 ± 0.8
Peak 2	33.2 ± 1.2	4.9 ± 0.5	3.9 ± 0.1	19.3 ± 1.3	1.8 ± 0.1	8.2 ± 1.0	12.3 ± 0.6	1.1 ± 03	15.3 ± 0.8
Peak 3	23.7 ± 0.8	5.1 ± 0.1	2.1 ± 0.2	19.4 ± 1.9	8.7 ± 0.1	7.0 ± 0.6	13.6 ± 0.9	07 ± 0.2	16.8 ± 1.3
100ppm-24h (35N)									
Peak 1	71.1 ± 1.5	2.0 ± 0.3	1.2 ± 0.1	4.4 ± 0.1	2.2 ± 0.1	3.2 ± 0.3	7.3 ± 0.6	2.8 ± 0.1	6.1 ± 0.3
Peak 2	34.3 ± 1.8	3.7 ± 0.5	4.3 ± 0.1	19.2 ± 2.3	1.4 ± 0.1	6.0 ± 0.4	13.2 ± 1.1	2.1 ± 0.1	15.4 ± 0.8
Peak 3	23.1 ± 1.6	5.2 ± 0.3	2.1 ± 0.1	17.7 ± 2.6	11.2 ± 0.5	5.7 ± 0.5	14.8 ± 0.7	2.2 ± 0.1	17.1 ± 0.9

100ppm-48h (12N)									
Peak 1	74.3 ± 1.8	2.1 ± 0.4	1.2 ± 0.1	3.1 ± 0.1	2.2 ±	3.1 ± 0.5	6.2 ± 0.4	1 ± 0.1	7.4 ± 0.8
Peak 2	33.2 ± 2.2	4.7 ± 0.9	4.4 ± 0.3	19.0 ± 2.7	0.7 ±	9.7 ± 0.9	12.3 ± 1.2	1 ± 0.2	14.7 ± 0.4
Peak 3	24.4 ± 2.1	5.2 ± 0.3	2.2 ± 0.2	17.6 ± 1.2	10.7 ±	7.4 ± 0.3	14.4 ± 0.4	1 ± 0.1	17.1 ± 0.8
Significance effects for P1									
EL[y]	NS[x]	NS	NS	NS	NS	NS	NS	NS	NS
EQ	NS	NS	NS	NS	NS	NS	NS	NS	NS
TL	NS	NS	NS	NS	NS	NS	NS	NS	NS
TQ	NS	NS	NS	NS	NS	NS	NS	NS	NS
EL*TL	NS	NS	NS	NS	NS	NS	NS	NS	NS
Significance effects for P2									
EL	NS	NS	NS	NS	NS	**	NS	NS	NS
EQ	NS	*	NS	*	NS	***	NS	NS	NS
TL	NS	*	NS	*	NS	***	NS	NS	NS
TQ	NS	*	NS	NS	NS	**	NS	NS	NS
EL*TL	NS	NS	NS	NS	NS	NS	NS	NS	NS
Significance effects for P3									
EL	NS	NS	NS	NS	NS	**	NS	NS	NS
EQ	NS	NS	NS	*	NS	***	NS	NS	NS
TL	NS	NS	NS	*	NS	***	NS	NS	NS
TQ	NS	NS	NS	NS	NS	***	NS	NS	NS
EL*TL	NS	NS	NS	NS	NS	NS	NS	NS	NS

[z]Data are mean ± SE of three replications of each treatment.

[y]EL, ethylene linear; EQ, ethylene quadratic; TL, time linear; TQ, time quadratic; EL*TL, ethylene linear by time linear.

[x]NS,*, **, *** Non significant and significant at $P \leq 0.05, 0.01$ or 0.001, respectively.

Table 15b. Sugar composition of 1 M KOH-warm soluble extracts following various ethylene treatments on size exclusion chromatography for 'Cresthaven' peach fruits.

Treatment	Ara	Rha	Fuc	Xyl	Man	GalA	Gal	GlcA	Glu
	mole percent								
Initial (67N)									
Peak 1	70.0±3.1[z]	4.9±0.5	1.3±0.1	4.2±0.3	1.3±0.1	7.0±0.8	6.1±0.5	1.2±0.3	4.8±0.2
Peak 2	32.2±1.2	8.3±0.7	1.9±0.4	12.3±1.0	0.8±0.1	18.0±1.6	14.4±2.1	0.7±0.1	9.2±0.6
Peak 3	27.3±3.1	4.9±0.1	1.2±0.1	10.2±1.2	10.3±0.9	11.6±1.4	15.4±1.5	1.1±0.1	14.2±1.5
1ppm-24h (43N)									
Peak 1	69.9±4.1	2.9±0.4	1.3±0.3	8.1±0.5	1.1±0.1	4.2±0.4	5.1±0.3	1.3±0.1	7.4±0.6
Peak 2	42.0±2.7	7.9±1.1	1.7±0.1	10.0±1.0	0.7±0.1	13.2±0.8	12.7±1.3	0.7±0.1	8.1±0.4
Peak 3	28.0±2.4	5.2±0.2	2.1±0.1	12.3±0.7	7.1±0.5	14.0±1.8	15.3±2.0	1.2±0.2	14.2±1.2
1ppm-48h (27N)									
Peak 1	78.1±3.9	3.4±0.5	1.4±0.1	3.3±0.4	0.6±0.1	0.9±0.1	3.6±0.1	1.2±0.1	5.7±0.5
Peak 2	39.0±1.5	7.1±1.0	3.1±0.2	18.1±1.9	1.2±0.2	6.1±0.5	13.1±0.6	1.1±0.2	12.2±0.9
Peak 3	26.8±1.9	6.8±0.3	2.2±0.1	16.2±1.9	8.2±0.9	5.2±0.4	17.3±1.8	1.2±0.1	15.1±0.5
100ppm-24h (47N)									
Peak 1	72.5±4.3	4.0±0.5	1.1±0.1	6.2±0.2	1.1±0.1	4.2±0.7	3.8±0.5	1.4±0.1	3.9±0.3
Peak 2	34.0±2.5	9.2±1.0	1.8±0.1	13.3±1.4	0.8±0.3	18.0±1.6	12.3±1.2	0.8±0.1	8.4±0.4
Peak 3	22.4±1.6	7.1±0.6	2.4±0.1	13.5±1.0	8.1±0.6	13.0±1.4	15.0±0.9	1.4±0.2	14.2±1.1

100ppm-48h (15N)									
Peak 1	85.1±2.4	0.6±0.1	0.9±0.1	3.3±0.4	1.2±0.1	0.6±0.1	3.7±0.1	1.2±0.1	3.4±0.3
Peak 2	41.6±2.0	6.1±0.5	3.1±0.2	16.9±1.4	1.1±0.2	6.2±0.6	12.3±1.1	1.1±0.2	11.2±0.8
Peak 3	28.1±1.2	5.3±0.3	2.2±0.1	17.1±1.4	.9.4±1.3	4.1±0.6	14.7±0.9	1.4±0.1	16.9±0.9
Significance effects for P1									
EL[y]	*[x]	**	NS	NS	NS	**	NS	NS	NS
EQ	NS	**	NS	NS	NS	***	NS	NS	NS
TL	**	***	NS	NS	NS	***	NS	NS	NS
TQ	NS	NS	NS	NS	NS	NS	NS	NS	NS
EL*TL	*	***	NS	NS	NS	*	NS	NS	NS
Significance effects for P2									
EL	NS	NS	NS	*	NS	NS	NS	NS	NS
EQ	***	NS	NS	NS	NS	***	NS	NS	NS
TL	**	NS	NS	*	NS	***	NS	NS	NS
TQ	NS	NS	NS	*	NS	*	NS	NS	NS
EL*TL	NS	NS	NS	NS	NS	*	NS	NS	NS
Significance effects for P3									
EL	NS	NS	NS	**	NS	NS	NS	NS	NS
EQ	NS	NS	NS	NS	NS	NS	NS	NS	NS
TL	NS	NS	NS	**	NS	***	NS	NS	NS
TQ	NS	NS	NS	NS	NS	**	NS	NS	NS
EL*TL	NS	NS	NS	NS	NS	NS	NS	NS	NS

[z]Data are mean ± SE of three replications of each treatment.

[y]EL, ethylene linear; EQ, ethylene quadratic; TL, time linear; TQ, time quadratic; EL*TL, ethylene linear by time linear.

[x]NS,*, **, *** Non significant and significant at P≤0.05,0.01 or 0.001, respectively.

Table 16a. Sugar composition of 4 M KOH-$NaBH_4$ soluble extracts following various ethylene treatments for 'J12-119' peach fruits.

Treatment	Yield (g/100g FW)	Ara	Rha	fuc	Xyl	Man	GalA	Gal	GlcA	Glu
		mole percent								
Initial	0.146 ± 0.006[z]	25.8 ± 1.5	12.3 ± 1.0	3.2 ± 0.3	11.0 ± 0.7	5.2 ± 0.12	14.8 ± 1.2	11.8 ± 1.0	1.2 ± 0.1	15.0 ± 1.1
0ppm-24h	0.142 ± 0.005	26.2 ± 2.1	12.4 ± 1.0	3.2 ± 0.1	12.0 ± 1.0	4.8 ± 0.2	15.4 ± 0.8	12.2 ± 1.1	1.1 ± 0.1	14.2 ± 1.2
0ppm-48h	0.143 ± 0.007	27.2 ± 2.5	9.9 ± 1.2	2.3 ± 0.1	11.2 ± 1.0	5.1 ± 0.4	16.2 ± 1.0	10.9 ± 1.1	1.3 ± 0.1	14.1 ± 1.1
1ppm-24h	0.146 ± 0.008	24.9 ± 1.9	11.3 ± 1.4	4.1 ± 0.1	13.3 ± 0.5	3.8 ± 0.3	13.1 ± 1.3	11.3 ± 1.2	1.1 ± 0.3	14.1 ± 1.2
1ppm-48h	0.169 ± 0.008	23.3 ± 1.4	8.9 ± 0.8	4.3 ± 0.3	15.1 ± 0.9	5.3 ± 0.1	10.0 ± 0.9	10.1 ± 1.1	2.4 ± 0.1	19.3 ± 1.4
100ppm-24h	0.163 ± 0.007	24.1 ± 1.6	9.9 ± 0.7	3.3 ± 0.1	12.3 ± 0.8	5.3 ± 0.1	12.2 ± 1.4	13.2 ± 1.4	2.1 ± 0.3	16.2 ± 1.3
100ppm-48h	0.184 ± 0.004	20.1 ± 1.4	7.3 ± 0.8	2.9 ± 0.1	17.4 ± 1.0	6.4 ± 0.1	10.3 ± 1.0	12.3 ± 1.4	0.8 ± 0.1	23.3 ± 1.8
Significance effects										
EL[y]	**[x]	*	NS	NS	*	NS	*	NS	NS	**
EQ	NS	NS	NS	NS	*	NS	**	NS	NS	NS
TL	**	NS	***	NS	***	NS	**	NS	NS	***
TQ	NS	NS	NS	NS	NS	NS	NS	NS	NS	*
EL*TL	NS	NS	NS	NS	**	NS	NS	NS	NS	**

[z]Data are mean ± SE of three replications of each treatment.

[y]EL, ethylene linear; EQ, ethylene quadratic; TL, time linear; TQ, time quadratic; EL*TL, ethylene linear by time linear.

[x]NS,*, **, *** Non significant and significant at $P \leq 0.05$, 0.01 or 0.001, respectively.

Table 16b. Sugar composition of 4 M KOH-$NaBH_4$ soluble extract following various ethylene treatments for 'Cresthaven' peach fruits.

Treatment	Yield (g/100g FW)	Ara	Rha	fuc	Xyl	Man	GalA	Gal	GlcA	Glu
		mole percent								
Initial	0.151 ± 0.008[z]	30.0 ± 1.6	8.2 ± 0.9	3.2 ± 0.4	11.0 ± 1.1	4.3 ± 0.4	12.9 ± 1.5	15.2 ± 1.2	2.2 ± 0.3	15.1 ± 1.4
0ppm-24h	0.160 ± 0.007	29.1 ± 1.7	8.3 ± 1.0	2.1 ± 0.3	11.3 ± 1.1	5.2 ± 0.3	13.9 ± 1.0	14.1 ± 0.8	1.3 ± 0.3	15.1 ± 1.3
0ppm-48h	0.161 ± 0.009	29.2 ± 2.0	8.3 ± 1.0	3.4 ± 0.1	13.0 ± 0.9	5.1 ± 0.1	14.1 ± 1.1	13.1 ± 1.1	0.4 ± 0.1	17.3 ± 1.0
1ppm-24h	0.168 ± 0.008	27.3 ± 2.4	8.1 ± 1.0	2.2 ± 0.1	12.5 ± 0.8	4.9 ± 0.2	13.2 ± 1.2	13.9 ± 1.2	2.4 ± 0.1	19.5 ± 1.2
1ppm-48h	0.185 ± 0.007	24.0 ± 1.9	8.8 ± 1.2	1.9 ± 0.1	13.2 ± 1.1	4.2 ± 0.1	11.3 ± 1.0	10.9 ± 1.2	0.3 ± 0.1	24.2 ± 1.3
100ppm-24h	0.174 ± 0.005	27.2 ± 1.8	8.1 ± 0.9	1.8 ± 0.2	13.1 ± 1.2	5.9 ± 0.4	11.2 ± 1.2	12.4 ± 1.0	1.3 ± 0.1	22.2 ± 1.6
100ppm-48h	0.178 ± 0.008	25.4 ± 2.1	10.0 ± 1.2	2.2 ± 0.1	15.5 ± 1.0	4.4 ± 0.1	9.0 ± 1.0	11.2 ± 0.7	0.3 ± 0.1	24.3 ± 1.3
Significance effects										
EL[y]	NS[x]	NS	NS	NS	NS	NS	*	NS	NS	**
EQ	NS	NS	NS	NS	NS	NS	NS	NS	NS	**
TL	**	*	NS	NS	**	NS	NS	***	NS	***
TQ	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
EL*TL	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[z]Data are mean ± SE of three replications of each treatment.
[y]EL, ethylene linear; EQ, ethylene quadratic; TL, time linear; TQ, time quadratic; EL*TL, ethylene linear by time linear.
[x]NS,*, **, *** Non significant and significant at $P \leq 0.05$, 0.01 or 0.001, respectively.

Table17a Sugar composition of 4 M KOH-NaBH4 soluble extracts following various ethylene treatments on size exclusion chromatography for 'J12-119' peach fruits.

Treatment	Ara	Rha	Fuc	Xyl	Man	GalA	Gal	GlcA	Glu
	mole percent								
Initial (66N)									
Peak 1	62.4±2.8[z]	5.3±1.2	0.6±0.1	4.4±0.3	0.9±0.1	8.2±1.1	8.2±0.8	3.4±0.1	6.4±0.2
Peak 2	29.8±2.2	9.3±0.2	3.1±0.1	13.1±0.4	1.2±0.1	15.1±0.7	13.3±1.4	1.1±0.1	13.3±0.8
Peak 3	25.0±2.1	3.1±0.1	0.7±0.1	8.3±0.6	13.7±1.2	10.2±1.0	16.3±0.7	1.3±0.1	18.6±1.6
1ppm-24h (42N)									
Peak 1	63.3±1.6	5.1±0.7	1.3±0.1	3.9±0.2	1.4±0.1	8.8±0.8	11.3±1.0	1.0±0.1	4.4±0.1
Peak 2	30.3±3.1	8.8±0.7	3.1±0.2	15.1±0.7	1.1±0.1	15.4±0.4	14.1±1.3	0.9±0.1	13.2±0.7
Peak 3	25.3±1.0	4.1±0.1	1.4±0.1	8.4±0.4	14.2±0.8	10.2±0.7	15.7±1.4	1.1±0.1	19.2±0.8
1ppm-48h (15N)									
Peak 1	67.2±1.3	3.2±0.2	1.0±0.1	3.3±0.1	2.8±0.1	5.9±0.4	7.0±0.3	1.8±0.1	6.9±0.4
Peak 2	34.7±2.3	6.9±0.1	3.1±0.1	13.2±1.0	1.4±0.1	12.3±1.0	12.4±1.5	2.4±0.1	12.0±0.2
Peak 3	35.4±2.7	2.7±0.3	0.6±0.1	8.1±0.4	11.2±0.9	7.3±0.7	13.2±0.6	1.1±0.1	17.1±1.1
100ppm-24h (35N)									
Peak 1	65.3±2.3	6.3±0.9	1.3±0.1	2.6±0.2	1.3±0.1	7.2±0.8	7.9±0.5	3.4±0.1	5.2±0.4
Peak 2	29.5±2.9	8.3±0.3	3.4±0.2	14.1±1.2	0.7±0.1	13.2±0.9	14.1±0.6	1.2±0.1	14.4±0.7
Peak 3	24.1±2.5	4.4±0.1	2.1±0.1	10.4±1.5	12.3±0.4	9.6±1.0	16.4±0.6	1.2±0.1	20.2±1.3

100ppm-48h (12N)									
Peak 1	80.6±2.1	3.4±0.5	1.1±0.1	3.0±0.1	1.2±0.1	3.1±0.2	4.4±0.4	1.2±0.1	4.2±0.1
Peak 2	35.0±2.5	7.1±0.4	2.8±0.1	15.9±1.0	0.8±0.1	11.2±0.5	12.3±1.0	1.4±0.2	13.4±0.7
Peak 3	35.2±1.1	3.2±0.1	2.1±0.1	10.4±0.9	12.2±0.7	6.4±0.5	13.7±.12	1.1±0.1	18.1±1.1
Significance effects for P1									
EL[y]	**[x]	NS	NS	NS	NS	*	**	NS	NS
EQ	NS	NS	NS	NS	NS	NS	NS	NS	NS
TL	**	NS	NS	NS	NS	**	*	NS	NS
TQ	NS	NS	NS	NS	NS	NS	**	NS	NS
EL*TL	**	NS	NS	NS	NS	*	*	NS	NS
Significance effects for P2									
EL	NS	NS	NS	NS	NS	NS	NS	NS	NS
EQ	NS	NS	NS	NS	NS	NS	NS	NS	NS
TL	NS	NS	NS	NS	NS	NS	NS	NS	NS
TQ	NS	NS	NS	NS	NS	NS	NS	NS	NS
EL*TL	NS	NS	NS	NS	NS	NS	NS	NS	NS
Significance effects for P3									
EL	NS	NS	NS	NS	NS	NS	NS	NS	NS
EQ	*	NS	NS	NS	NS	NS	NS	NS	NS
TL	***	NS	NS	NS	NS	**	NS	NS	NS
TQ	*	NS	NS	NS	NS	NS	NS	NS	NS
EL*TL	NS	NS	NS	NS	NS	NS	NS	NS	NS

[z]Data are mean ± SE of three replications of each treatment.

[y]EL, ethylene linear; EQ, ethylene quadratic; TL, time linear; TQ, time quadratic; EL*TL, ethylene linear by time linear.

[x]NS,*, **, *** Non significant and significant at P≤0.05,0.01 or 0.001, respectively.

Table17b. Sugar composition of 4 M KOH-$NaBH_4$ soluble extracts following various ethylene treatments on size exclusion chromayography for 'Cresthaven' peach fruits.

Treatment	Ara	Rha	Fuc	Xyl	Man	GalA	Gal	GlcA	Glu
	mole percent								
Initial (67N)									
Peak 1	52.5 ± 2.3[z]	9.0 ± 0.5	0.9 ± 0.3	2.9 ± 0.2	0.9 ± 0.1	12.1 ± 2.1	14.2 ± 0.7	0.8 ± 0.1	4.7 ± 0.7
Peak 2	27.9 ± 2.2	9.7 ± 0.8	1.8 ± 0.1	12.4 ± 1.4	1.2 ± 0.1	14.2 ± 1.3	18.3 ± 1.4	0.7 ± 0.1	12.1 ± 0.7
Peak 3	27.3 ± 2.0	4.1 ± 0.3	1.2 ± 0.1	9.2 ± 0.5	13.2 ± 1.1	7.2 ± 1.0	16.2 ± 0.9	1.3 ± 0.3	18.4 ± 1.6
1ppm-24h (43N)									
Peak 1	62.3 ± 2.9	8.4 ± 1.4	1.4 ± 0.1	3.6 ± 0.3	1.6 ± 0.1	9.5 ± 1.4	9.2 ± 0.8	1.1 ± 0.1	5.7 ± 0.6
Peak 2	35.2 ± 2.3	9.2 ± 0.3	2.3 ± 0.1	11.4 ± 1.1	0.6 ± 0.2	13.1 ± 0.8	14.3 ± 1.4	1.7 ± 0.1	10.4 ± 1.2
Peak 3	25.3 ± 2.3	4.4 ± 0.1	1.7 ± 0.1	11.2 ± 0.8	9.3 ± 0.6	9.1 ± 0.9	17.3 ± 0.8	2.2 ± 0.1	18.1 ± 0.3
1ppm-48h (27N)									
Peak 1	66.3 ± 2.1	4.1 ± 0.9	0.7 ± 0.1	4.2 ± 0.3	0.8 ± 0.1	6.3 ± 0.3	7.1 ± 0.7	4.1 ± 0.3	5.2 ± 0.3
Peak 2	36.2 ± 0.9	5.3 ± 0.6	4.4 ± 0.2	11.3 ± 0.9	1.3 ± 0.1	12.4 ± 0.8	12.2 ± 1.0	3.4 ± 0.1	13.4 ± .07
Peak 3	29.4 ± 1.6	1.8 ± 0.1	3.1 ± 0.3	10.0 ± 0.1	11.2 ± 0.3	5.3 ± 0.6	16.3 ± 1.4	1.3 ± 0.1	19.1 ± 0.8
100ppm-24h (47N)									
Peak 1	62.2 ± 1.6	6.3 ± 0.5	1.2 ± 0.1	2.7 ± 0.2	1.9 ± 0.3	9.5 ± 0.9	10.2 ± 0.8	1.9 ± 0.1	5.4 ± 0.4
Peak 2	29.3 ± 2.2	10.4 ± 1.4	2.8 ± 0.1	13.1 ± 0.1	1.3 ± 0.2	14.6 ± 0.9	14.2 ± 1.0	2.3 ± 0.1	11.2 ± 1.3
Peak 3	29.4 ± 2.5	3.2 ± 0.3	2.3 ± 0.1	9.2 ± 0.5	11.0 ± 1.2	7.4 ± 0.3	15.3 ± 1.1	2.2 ± 0.1	19.3 ± 0.7

100ppm-48h (15N)									
Peak 1	65.5 ± 1.8	5.2 ± 0.4	1.2 ± 0.1	5.4 ± 0.4	0.6 ± 0.1	6.0 ± 0.7	10.4 ± 1.3	1.8 ± 0.2	5.3 ± 0.3
Peak 2	37.8 ± 1.4	9.2 ± 0.6	0.8 ± 0.1	10.3 ± 0.9	1.2 ± 0.1	15.1 ± 0.8	13.2 ± 1.0	3.1 ± 0.2	8.4 ± 1.3
Peak 3	30.1 ± 2.7	4.1 ± 0.3	1.1 ± 0.1	9.7 ± 1.3	9.4 ± 0.7	8.2 ± 0.3	14.2 ± 0.8	2.3 ± 0.2	17.7 ± 1.5
Significance effects for P1									
EL[y]	*[x]	*	NS	NS	NS	NS	NS	NS	NS
EQ	***	**	NS	NS	NS	NS	***	NS	NS
TL	***	***	NS	NS	NS	**	***	NS	NS
TQ	NS	NS	NS	NS	NS	NS	NS	NS	NS
EL*TL	NS	NS	NS	NS	NS	NS	NS	NS	NS
Significance effects for P2									
EL	NS	NS	NS	NS	NS	NS	NS	NS	NS
EQ	**	NS	NS	NS	NS	NS	**	NS	NS
TL	**	NS	NS	NS	NS	NS	**	NS	NS
TQ	NS	NS	NS	NS	NS	NS	NS	NS	NS
EL*TL	NS	NS	NS	NS	NS	NS	NS	NS	NS
Significance effects for P3									
EL	NS	NS	NS	NS	NS	NS	NS	NS	NS
EQ	NS	NS	NS	NS	NS	NS	NS	NS	NS
TL	NS	NS	NS	NS	NS	NS	NS	NS	NS
TQ	NS	NS	NS	NS	NS	NS	NS	NS	NS
EL*TL	NS	NS	NS	NS	NS	NS	NS	NS	NS

[z]Data are mean ± SE of three replications of each treatment.

[y]EL, ethylene linear; EQ, ethylene quadratic; TL, time linear; TQ, time quadratic; EL*TL, ethylene linear by time linear.

[x]NS,*, **, *** Non significant and significant at $P \leq 0.05, 0.01$ or 0.001, respectively.

Table 18a. Sugar composition of 4MKOH-Boric acid soluble extracts following various ethylene treatments in 'J12-119' peach fruits.

Treatment	Yield (g/100g FW)	Ara	Rha	fuc	Xyl	Man	GalA	Gal	GlcA	Glu
		mole percent								
Initial	0.061 ± 0.005[z]	39.2 ± 1.8	11.2 ± 0.4	1.3 ± 0.1	4.3 ± 0.3	4.8 ± 0.6	20.3 ± 1.7	12.3 ± 0.5	2.2 ± 0.1	7.4 ± 0.6
0ppm-24h	0.059 ± 0.004	37.1 ± 1.7	12.3 ± 0.6	1.1 ± 0.1	4.1 ± 0.2	5.3 ± 0.5	20.7 ± 1.5	13.4 ± 0.9	2.2 ± 0.3	6.1 ± 0.3
0ppm-48h	0.064 ± 0.006	36.8 ± 1.4	10.9 ± 0.3	0.8 ± 0.1	3.8 ± 0.2	5.2 ± 0.6	17.7 ± 1.4	14.1 ± 0.5	2.4 ± 0.2	6.8 ± 0.4
1ppm-24h	0.060 ± 0.005	37.3 ± 1.7	11.4 ± 0.7	0.9 ± 0.1	4.1 ± 0.3	6.0 ± 0.6	19.2 ± 1.5	12.9 ± 0.6	2.1 ± 0.3	7.9 ± 0.1
1ppm-48h	0.062 ± 0.005	32.9 ± 1.7	10.7 ± 0.3	0.8 ± 0.2	4.4 ± 0.1	7.1 ± 0.6	18.1 ± 1.8	14.7 ± 1.1	1.1 ± 0.2	8.2 ± 0.2
100ppm-24h	0.058 ± 0.005	38.3 ± 1.5	12.7 ± 0.7	1.2 ± 0.1	3.9 ± 0.1	5.6 ± 0.8	15.2 ± 1.1	13.2 ± 0.7	1.8 ± 0.2	8.4 ± 0.5
100ppm-48h	0.071 ± 0.006	32.1 ± 2.0	10.1 ± 0.2	1.2 ± 0.1	5.2 ± 0.2	8.9 ± 0.7	16.2 ± 1.1	14.4 ± 0.9	1.7 ± 0.1	10.1 ± 0.9
Significance effects										
EL[y]	NS	NS	NS	NS	NS	*	NS	NS	NS	NS
EQ	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
TL	NS	***[x]	NS	NS	NS	***	NS	NS	NS	NS
TQ	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
EL*TL	NS	NS	NS	NS	NS	*	NS	NS	NS	NS

[z]Data are mean ± SE of three replications of each treatment.

[y]EL, ethylene linear; EQ, ethylene quadratic; TL, time linear; TQ, time quadratic; EL*TL, ethylene linear by time linear.

[x]NS,*, **, *** Non significant and significant at P≤ 0.05, 0.01 or 0.001, respectively.

Table 18b. Sugar composition of 4 M KOH-Boric acid soluble extracts following various ethylene treatments for 'Cresthaven' peach fruits.

Treatment	Yield (g/100g FW)	Ara	Rha	fuc	Xyl	Man	GalA	Gal	GlcA	Glu
		mole percent								
Initial	0.067 ± 0.009[z]	39.2 ± 1.9	11 ± 0.6	1.4 ± 0.3	4.2 ± 0.3	4.9 ± 0.6	16.9 ± 1.4	17.2 ± 1.2	1.3 ± 0.2	7 ± 0.4
0ppm-24h	0.064 ± 0.006	39.0 ± 1.6	11 ± 0.3	1.1 ± 0.1	4.1 ± 0.3	5.3 ± 0.6	18.3 ± 1.5	15.8 ± 1.3	1.1 ± 0.3	7 ± 0.3
0ppm-48h	0.059 ± 0.008	40.7 ± 1.9	12 ± 1.1	0.8 ± 0.1	3.3 ± 0.1	4.8 ± 0.5	17.1 ± 1.2	15.2 ± 0.7	1.1 ± 0.1	5 ± 0.5
1ppm-24h	0.063 ± 0.004	37.2 ± 1.8	11 ± 0.3	0.7 ± 0.1	4.4 ± 0.6	5.1 ± 0.8	16.0 ± 1.0	16.4 ± 0.7	0.6 ± 0.1	8 ± 0.1
1ppm-48h	0.068 ± 0.008	41.8 ± 1.4	11 ± 0.2	1.3 ± 0.1	2.7 ± 0.3	5.1 ± 0.8	14.2 ± 0.9	13.2 ± 0.9	2.3 ± 0.2	7 ± 0.2
100ppm-24h	0.071 ± 0.008	38.1 ± 1.7	11 ± 0.8	1.2 ± 0.2	3.2 ± 0.7	5.3 ± 0.6	17.3 ± 0.8	16.1 ± 0.3	1.1 ± 0.1	7 ± 0.5
100ppm-48h	0.070 ± 0.009	41.8 ± 1.7	11 ± 0.5	1.4 ± 0.2	2.6 ± 0.1	5.1 ± 0.5	14.8 ± 0.9	14.7 ± 0.5	2.1 ± 0.5	6 ± 0.1
Significance effects										
EL[y]	NS[x]	NS	NS	NS	NS	NS	NS	NS	NS	NS
EQ	NS	NS	NS	NS	NS	NS	*	NS	NS	NS
TL	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
TQ	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
EL*TL	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[z]Data are mean ± SE of three replications of each treatment.

[y]EL, ethylene linear; EQ, ethylene quadratic; TL, time linear; TQ, time quadratic; EL*TL, ethylene linear by time linear.

[x]NS,*, **, *** Non significant and significant at $P \leq 0.05$, 0.01 or 0.001, respectively.

Table19a. Sugar composition of 4 M KOH-Boric soluble extracts following various ethylene treatments on size exclusion chromatography for 'J12-119' peach fruits.

Treatment	Ara	Rha	Fuc	Xyl	Man	GalA	Gal	GlcA	Glu
	mole percent								
Initial (66N)									
Peak 1	50.4 ± 2.1[z]	10.3 ± 1.0	1.2 ± 0.1	2.6 ± 0.1	1.2 ± 0.1	14.3 ± 1.1	12.4 ± 1.6	1.7 ± 0.1	5.0 ± 0.6
Peak 2	40.1 ± 2.3	9.1 ± 0.1	3.2 ± 0.1	6.3 ± 0.7	1.2 ± 0.1	20.5 ± 1.7	13.2 ± 1.1	2.7 ± 0.1	4.4 ± 1.1
Peak 3	34.3 ± 1.7	6.4 ± 0.3	1.1 ± 0.1	3.1 ± 0.1	12.3 ± 0.8	13.4 ± 1.2	14.2 ± 0.9	2.1 ± 0.1	11.4 ± 1.2
1ppm-24h (42N)									
Peak 1	64.3 ± 1.6	9.1 ± 1.3	1.3 ± 0.1	2.3 ± 0.1	1.3 ± 0.1	7.0 ± 1.0	9.0 ± 1.3	1.3 ± 0.1	3.4 ± 0.7
Peak 2	43.3 ± 2.3	13.3 ± 0.6	0.8 ± 0.1	4.7 ± 0.2	0.8 ± 0.1	18.3 ± 1.6	13.2 ± 1.7	1.4 ± 0.1	4.3 ± 1.2
Peak 3	36.3 ± 2.2	6.9 ± 0.2	1.1 ± 0.2	3.0 ± 0.1	13.8 ± 1.5	10.5 ± 1.2	15.1 ± 1.3	0.8 ± 0.1	10.7 ± 1.1
1ppm-48h (15N)									
Peak 1	73.0 ± 3.1	2.9 ± 0.6	1.2 ± 0.1	2.1 ± 0.1	1.2 ± 0.1	5.4 ± 1.1	5.3 ± 0.6	4.1 ± 0.4	5.4 ± 1.1
Peak 2	46.2 ± 2.3	11.2 ± 0.8	0.9 ± 0.2	6.8 ± 0.2	0.9 ± 0.2	12.4 ± 1.2	14.4 ± 1.7	2.0 ± 0.1	7.3 ± 1.2
Peak 3	32.4 ± 2.3	5.0 ± 0.1	1.2 ± 0.1	3.2 ± 0.1	20.1 ± 1.8	5.5 ± 0.9	14 ± 0.5	2.3 ± 0.2	15.5 ± 1.1
100ppm-24h (35N)									
Peak 1	65.3 ± 3.2	8.6 ± 1.1	1.3 ± 0.1	2.1 ± 0.1	1.3 ± 0.1	6.4 ± 0.6	9.3 ± 1.2	0.6 ± 0.1	7.4 ± 1.2
Peak 2	47.1 ± 2.3	11.1 ± 0.4	0.8 ± 0.1	5.4 ± 0.1	0.8 ± 0.1	15.5 ± 1.2	12.5 ± 1.1	1.4 ± 0.1	5.5 ± 1.1
Peak 3	37.3 ± 2.6	7.4 ± 0.2	1.1 ± 0.2	3.2 ± 0.1	15 ± 0.4	18.3 ± 2.3	15.4 ± 0.6	1.3 ± 0.1	11.5 ± 1.1

100ppm-48h (12N)									
Peak 1	84.2±3.8	0.6±0.1	1.2±0.1	2.2±0.1	2±0.1	2.5±0.5	3.5±0.5	1.2±0.1	7.3±0.6
Peak 2	46.2±3.3	7.6±0.3	2.2±0.2	11.3±0.4	2±0.2	5.5±0.8	14.7±1.1	0.6±0.1	10.5±1.1
Peak 3	30.2±2.7	5.3±0.3	0.9±0.1	3.1±0.1	24±2.2	2.9±0.4	14.7±0.7	1.0±0.1	16.4±1.8
Significance effects for P1									
EL[y]	***[x]	**	NS	NS	NS	***	*	NS	**
EQ	***	**	NS	NS	NS	***	**	NS	NS
TL	***	***	NS	NS	NS	***	***	NS	NS
TQ	NS	*	NS	NS	NS	*	NS	NS	NS
EL*TL	***	**	NS	NS	NS	***	*	NS	NS
Significance effects for P2									
EL	NS	NS	NS	NS	NS	***	NS	NS	*
EQ	NS	NS	NS	NS	NS	*	NS	NS	NS
TL	*	NS	NS	NS	NS	***	NS	NS	**
TQ	NS	NS	NS	NS	NS	NS	NS	NS	NS
EL*TL	NS	NS	NS	NS	NS	***	NS	NS	*
Significance effects for P3									
EL	NS	NS	NS	NS	NS	NS	NS	NS	NS
EQ	NS	NS	NS	NS	NS	**	NS	NS	NS
TL	NS	NS	NS	NS	NS	***	NS	NS	**
TQ	NS	NS	NS	NS	NS	***	NS	NS	NS
EL*TL	NS	NS	NS	NS	NS	**	NS	NS	NS

[z]Data are mean ± SE of three replications of each treatment.

[y]EL, ethylene linear; EQ, ethylene quadratic; TL, time linear; TQ, time quadratic; EL*TL, ethylene linear by time linear.

[x]NS,*, **, *** Non significant and significant at P≤0.05,0.01 or 0.001, respectively.

Table 19b. Sugar composition of 4 M KOH-Boric soluble extracts following various ethylene treatments on size exclusion chromatography for 'Cresthaven' peach fruits.

Treatment	Ara	Rha	Fuc	Xyl	Man	GalA	Gal	GlcA	Glu
	mole percent								
Initial (67N)									
Peak 1	55.4±1.9[z]	9.2±0.5	1.2±0.1	2.3±0.1	1.2±0.1	10.3±1.2	13.3±1.3	4.3±0.3	4.3±0.6
Peak 2	40.2±3.9	8.8±0.3	0.8±0.2	4.2±0.3	0.9±0.3	19.4±2.4	18.2±1.5	3.2±0.1	4.3±0.7
Peak 3	38.3±2.9	6.1±0.5	1.1±0.1	2.2±0.1	12.3±0.9	9.2±1.2	19±1.6	1.8±0.2	9.3±0.6
1ppm-24h (43N)									
Peak 1	65.4±2.4	8.3±0.8	1.4±0.1	3.2±0.2	1.3±0.1	8.4±0.9	10.9±1.0	1.1±0.1	2.3±0.4
Peak 2	46.0±2.6	13.3±0.9	0.7±0.1	2.9±01	0.7±0.1	15.3±1.4	16.4±1.0	1.4±0.1	2.6±0.5
Peak 3	39.7±3.5	6.3±0.3	1.1±0.2	2.4±0.1	13.1±1.2	8.0±0.8	17±1.1	0.6±0.1	9.5±1.2
1ppm-48h (27N									
Peak 1	79.4±2.1	2.4±0.4	1.1±0.1	2.1±0.2	1.2±0.1	2.2±0.6	5.2±0.6	1.2±0.1	7.1±1.6
Peak 2	54.2±2.1	10.7±0.7	0.6±0.2	2.3±0.3	1.2±0.2	5.1±0.6	13.0±1.0	0.9±0.1	6.2±1.0
Peak 3	34.3±2.0	7.4±0.6	1.2±0.1	3.1±0.1	19.2±1.6	3.3±0.5	15±0.9	0.9±0.1	14.2±1.7
100ppm-24h (47N)									
Peak 1	82.9±2.2	3.4±0.5	1.2±0.1	1.8±0.1	1.4±0.1	3.0±0.4	4.2±0.7	1.3±0.1	3.3±0.8
Peak 2	61.4±2.9	9.2±0.4	0.8±0.1	3.3±0.2	0.8±0.1	10.3±1.5	9.5±0.9	1.1±0.3	4.2±0.9
Peak 3	38.4±2.8	5.3±0.3	1.1±0.2	2.2±0.1	16.1±0.8	7.7±0.6	15±1.3	1.1±0.1	12.4±1.2

100ppm-48h (15N)									
Peak 1	74.0±3.1	1.2±0.1	1.2±0.1	2.0±0.3	1.9±0.1	2.4±0.9	4.3±0.6	4.4±0.2	9.3±1.2
Peak 2	55.1±1.5	7.8±0.6	1.1±0.2	6.3±0.2	1.1±0.2	6.1±0.7	11.3±1.0	2.1±0.1	7.1±1.0
Peak 3	32.4±2.3	6.3±0.9	0.7±0.1	2.7±0.1	20.8±2.1	2.3±0.4	15±0.6	1.3±0.1	15.5±2.0
Significance effects for P1									
EL[y]	***[x]	***	NS	NS	NS	***	***	NS	NS
EQ	***	***	NS	NS	NS	***	***	NS	NS
TL	***	***	NS	NS	NS	***	***	NS	**
TQ	**	NS	NS	NS	NS	NS	NS	NS	**
EL*TL	NS	***	NS	NS	NS	*	*	NS	*
Significance effects for P2									
EL	***	NS	NS	NS	NS	**	***	NS	NS
EQ	*	NS	NS	NS	NS	***	*	NS	NS
TL	**	NS	NS	NS	NS	***	***	NS	*
TQ	NS	NS	NS	NS	NS	NS	NS	NS	NS
EL*TL	NS	NS	NS	NS	NS	NS	NS	NS	NS
Significance effects for P3									
EL	NS	NS	NS	NS	NS	*	NS	NS	*
EQ	NS	NS	NS	NS	NS	**	NS	NS	NS
TL	NS	NS	NS	NS	NS	***	NS	NS	***
TQ	NS	NS	NS	NS	NS	NS	NS	NS	NS
EL*TL	NS	NS	NS	NS	NS	*	NS	NS	NS

[z]Data are mean ± SE of three replications of each treatment.

[y]EL, ethylene linear; EQ, ethylene quadratic; TL, time linear; TQ, time quadratic; EL*TL, ethylene linear by time linear.

[x]NS,*, **, *** Non significant and significant at P≤0.05,0.01 or 0.001, respectively.

Table 20a. Sugar composition of extraction residues for 'J12-119' peach fruits

Treatment	Yield (g/100g FW)	Ara	Rha	fuc	Xyl	Man	GalA	Gal	GlcA	Glu
		mole percent								
Initial	0.273±0.10	29.1±2.2	7.3±0.8	0.7±0.2	8.3±1.1	1.1±0.2	10.4±2.0	15.3±1.2	1.2±0.3	27.0±3.0
0ppm-24h	0.268±0.09	29.4±2.8	8.1±1.3	1.2±0.1	8.3±1.5	1.4±0.1	10.5±2.4	14.2±1.4	0.7±0.1	23.8±6.3
0ppm-48h	0.286±0.01	29.3±3.2	7.9±0.6	0.8±0.1	9.1±1.6	3.2±0.5	7.3±1.5	14.2±2.0	1.3±0.1	29.4±2.8
1ppm-24h	0.318±0.006	28.1±2.4	8.4±0.5	1.1±0.3	9.2±1.9	1.8±0.1	10.4±2.6	13.8±2.0	0.9±0.1	26.0±2.7
1ppm-48h	0.327±0.006	25.1±2.9	8.0±0.6	0.3±0.1	13.1±1.4	3.3±0.2	4.5±0.4	12.2±2.1	0.8±0.1	30.0±4.1
100ppm-24h	0.315±0.004	25.1±2.3	7.7±0.5	1.2±0.1	8.4±2.1	2.4±0.1	9.1±1.6	16.0±1.6	1.3±0.1	30.2±3.5
100ppm-48h	0.346±0.005	25.0±2.4	8.4±0.4	0.4±0.1	10.8±0.9	3.4±0.1	8.4±2.1	13.1±2.0	1.1±0.1	31.2±2.1
Significance effects										
EL[y]	**[x]	NS	NS	NS	NS	NS	NS	NS	NS	NS
EQ	***	NS	NS	NS	NS	NS	NS	NS	NS	NS
TL	***	NS	NS	NS	*	NS	*	NS	NS	NS
TQ	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
EL*TL	*	NS	NS	NS	NS	NS	NS	NS	NS	NS

[z]Data are mean ± SE of three replications of each treatment.
[y]EL, ethylene linear; EQ, ethylene quadratic; TL, time linear; TQ, time quadratic; EL*TL, ethylene linear by time linear.
[x]NS,*, **, *** Non significant and significant at P≤0.05,0.01 or 0.001, respectively.

Table 20b. Sugar composition of extraction residues for 'Cresthaven' peach fruits

Treatment	Yield (g/100g FW)	Ara	Rha	fuc	Xyl	Man	GalA	Gal	GlcA	Glu
		mole percent								
Initial	0.262±0.009	26.1±1.9	8.2±0.4	1.0±0.2	6.3±1.1	1.1±0.2	9.5±0.6	16.3±2.0	1.4±0.1	30.6±3.4
0ppm-24h	0.275±0.010	25.2±3.8	6.7±0.9	0.9±0.1	6.2±1.6	1.3±0.1	9.1±0.4	16.3±1.9	0.9±0.1	32.9±3.1
0ppm-48h	0.281±0.006	28.0±3.0	8.4±0.3	1.2±0.1	8.8±2.0	2.4±0.3	5.2±1.3	8.3±2.0	1.1±0.2	35.4±3.2
1ppm-24h	0.302±0.011	25.0±3.7	7.2±0.5	0.4±0.1	6.1±1.4	0.8±0.1	8.8±2.0	15.4±1.7	0.9±0.1	35.4±3.9
1ppm-48h	0.326±0.006	26.1±2.6	7.1±0.3	0.4±0.1	10.5±1.7	0.9±0.1	5.5±1.2	8.3±1.4	1.3±0.1	37.4±2.7
100ppm-24h	0.331±0.009	27.9±3.6	7.4±0.7	0.3±0.1	8.0±2.1	0.7±0.1	8.8±2.5	10.4±2.4	1.2±0.3	36.4±2.1
100ppm-48h	0.335±0.011	26.0±2.7	7.0±1.0	0.4±0.1	10.2±2.0	1.9±0.1	5.6±1.4	8.8±1.5	1.1±0.1	37.3±2.1
Significance effects										
EL[y]	***[x]	NS	NS	NS	NS	NS	NS	NS	NS	NS
EQ	**	NS	NS	NS	NS	NS	NS	NS	NS	NS
TL	***	NS	NS	NS	*	NS	**	***	NS	*
TQ	*	NS	NS	NS	NS	NS	NS	NS	NS	NS
EL*TL	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

[z]Data are mean ± SE of three replications of each treatment.
[y]EL, ethylene linear; EQ, ethylene quadratic; TL, time linear; TQ, time quadratic; EL*TL, ethylene linear by time linear.
[x]NS,*, **, *** Non significant and significant at $P \leq 0.05, 0.01$ or 0.001, respectively.

FIGURE LEGENDS

Figure Page

16a. Toyopearl HW65S apparent molecular size profiles of buffer soluble polysaccharide for 'J12-119' peach fruits following various ethylene treatments for 0 h, 24 h or 48 h. The X-axis represents time in minutes and the Y-axis represents refractive index detector relative response. P1, P2 and P3 represent peak 1, peak 2 and peak 3. Arrows at the top of figure represents the elution positions (from left to right) of pullulan standards of molecular mass 853 kD, 380 kD, 100 kD, 48 kD, 23 kD, and 12 kD.....154

16b. Toyopearl HW65S apparent molecular size profiles of buffer soluble polysaccharide for 'Cresthaven' peach fruits following various ethylene treatments for 0 h, 24 h or 48 h. The X-axis represents time in minutes and the Y-axis represents refractive index detector relative response. P1, P2 and P3 represent peak 1, peak 2 and peak 3. Arrows at the top of figure represents the elution positions (from left to right) of pullulan standards of molecular mass 853 kD, 380 kD, 100 kD, 48 kD, 23 kD, and 12 kD.....155

17a. Toyopearl HW65S apparent molecular size profiles of imidazole soluble extracts for 'J12-119' peach fruits following various ethylene treatments for 0 h, 24 h or 48 h. The X-axis represents time in minutes and the Y-axis represents refractive index detector relative response. P1 and P2 represent peak 1 and peak 2. Arrows at the top of figure represents the elution positions (from left to right) of pullulan standards of molecular mass 853 kD, 380 kD, 100 kD, 48 kD, 23 kD, and 12 kD.....156

17b. Toyopearl HW65S apparent molecular size profiles of imidazole soluble extracts for 'Cresthaven' peach fruits following various ethylene treatments for 0 h, 24 h or 48 h. The X-axis represents time in minutes and the Y-axis represents refractive index detector relative response. P1 and P2 represent peak 1 and peak 2. Arrows at the top of figure represents the elution positions (from left to right) of pullulan standards of molecular mass 853 kD, 380 kD, 100 kD, 48 kD, 23 kD, and 12 kD.....157

18a. Toyopearl HW65S apparent molecular size profiles of Na_2CO_3-cold soluble extracts for 'J12-119' peach fruits following various ethylene treatments for 0 h, 24 h or 48 h. The X-axis represents time in minutes and the Y-axis represents refractive index detector relative response. P1 and P2 represent peak 1 and peak 2. Arrows at the top of figure represents the

elution positions (from left to right) of pullulan standards of molecular mass 853 kD, 380 kD, 100 kD, 48 kD, 23 kD, and 12 kD.....158

18b. Toyopearl HW65S apparent molecular size profiles of Na_2CO_3-cold soluble extracts for 'Cresthaven' peach fruits following various ethylene treatments for 0 h, 24 h or 48 h. The X-axis represents time in minutes and the Y-axis represents refractive index detector relative response. P1 and P2 represent peak 1 and peak 2. Arrows at the top of figure represents the elution positions (from left to right) of pullulan standards of molecular mass 853 kD, 380 kD, 100 kD, 48 kD, 23 kD, and 12 kD.....159

19a. Toyopearl HW65S apparent molecular size profiles of Na_2CO_3-warm soluble extracts for 'J12-119' peach fruits following various ethylene treatments for 0 h, 24 h or 48 h. The X-axis represents time in minutes and the Y-axis represents refractive index detector relative response. P1 and P2 represent peak 1 and peak 2. Arrows at the top of figure represents the elution positions (from left to right) of pullulan standards of molecular mass 853 kD, 380 kD, 100 kD, 48 kD, 23 kD, and 12 kD.....160

19b. Toyopearl HW65S apparent molecular size profiles of Na_2CO_3-warm soluble extracts for 'Cresthaven' peach fruits following various ethylene treatments for 0 h, 24 h or 48 h. The X-axis represents time in minutes and the Y-axis represents refractive index detector relative response. P1 and P2 represent peak 1 and peak 2. Arrows at the top of figure represents the elution positions (from left to right) of pullulan standards of molecular mass of 853 kD, 380 kD, 100 kD, 48 kD, 23 kD, and 12 kD.....161

20a. Toyopearl HW65S apparent molecular size profiles of 1 M KOH-cold soluble extracts for 'J12-119' peach fruits following various ethylene treatments for 0 h, 24 h or 48 h. The X-axis represents time in minutes and the Y-axis represents refractive index detector relative response. P1, P2 and P3 represent peak 1, peak 2 and peak 3. Arrows at the top of figure represents the elution positions (from left to right) of pullulan standards of molecular mass 853 kD, 380 kD, 100 kD, 48 kD, 23 kD, and 12 kD.....162

20b. Toyopearl HW65S apparent molecular size profiles of 1 M KOH-cold soluble extracts for 'Cresthaven' peach fruits following various ethylene treatments for 0 h, 24 h or 48 h. The X-axis represents time in minutes and the Y-axis represents refractive index detector relative response. P1, P2 and P3 represent peak 1, peak 2 and peak 3. Arrows at the top of figure represents the elution positions (from left to right) of pullulan standards of molecular mass 853 kD,

380 kD, 100 kD, 48 kD, 23 kD, and 12 kD.....163

21a. Toyopearl HW65S apparent molecular size profiles of 1 M KOH-warm soluble extracts for 'J12-119' peach fruits following various ethylene treatments for 0 h, 24 h or 48 h. The X-axis represents time in minutes and the Y-axis represents refractive index detector relative response. P1, P2 and P3 represent peak 1, peak 2 and peak 3. Arrows at the top of figure represents the elution positions (from left to right) of pullulan standards of molecular mass 853 kD, 380 kD, 100 kD, 48 kD, 23 kD, and 12 kD.....164

21b. Toyopearl HW65S apparent molecular size profiles of 1 M KOH-warm soluble extracts for 'Cresthaven' peach fruits following various ethylene treatments for 0 h, 24 h or 48 h. The X-axis represents time in minutes and the Y-axis represents refractive index detector relative response. P1, P2 and P3 represent peak 1, peak 2 and peak 3. Arrows at the top of figure represents the elution positions (from left to right) of pullulan standards of molecular mass 853 kD, 380 kD, 100 kD, 48 kD, 23 kD, and 12 kD.....165

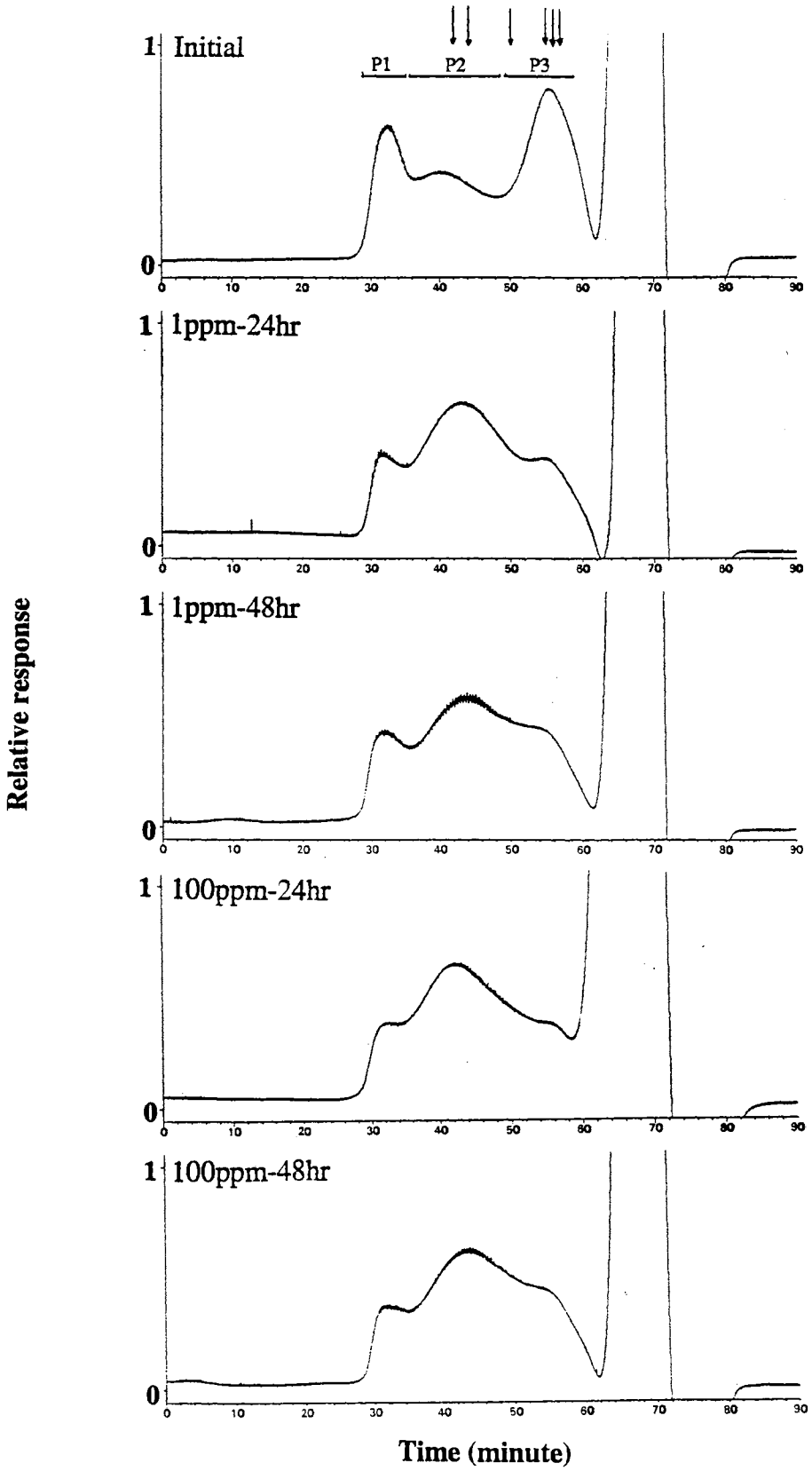
22a. Toyopearl HW65S apparent molecular size profiles of 4 M KOH-$NaBH_4$ soluble extracts for 'J12-119' peach fruits following various ethylene treatments for 0 h, 24 h or 48 h. The X-axis represents time in minutes and the Y-axis represents refractive index detector relative response. P1, P2 and P3 represent peak 1, peak 2 and peak 3. Arrows at the top of figure represents the elution positions (from left to right) of pullulan standards of molecular mass 853 kD, 380 kD, 100 kD, 48 kD, 23 kD, and 12 kD.....166

22b. Toyopearl HW65S apparent molecular size profiles of 4 M KOH-$NaBH_4$ soluble extracts for 'Cresthaven' peach fruits following various ethylene treatments for 0 h, 24 h or 48 h. The X-axis represents time in minutes and the Y-axis represents refractive index detector relative response. P1, P2 and P3 represent peak 1, peak 2 and peak 3. Arrows at the top of figure represents the elution positions (from left to right) of pullulan standards of molecular mass 853 kD, 380 kD, 100 kD, 48 kD, 23 kD, and 12 kD.....167

23a. Toyopearl HW65S apparent molecular size profiles of 4 M KOH-Boric acid soluble extracts for 'J12-119' peach fruits following various ethylene treatments for 0 h, 24 h or 48 h. The X-axis represents time in minutes and the Y-axis represents refractive index detector relative response. P1, P2 and P3 represent peak 1, peak 2 and peak 3. Arrows at the top of figure represents the elution positions (from left to right) of pullulan standards of molecular mass 853 kD, 380 kD, 100 kD, 48 kD, 23 kD, and 12 kD.....168

23b. Toyopearl HW65S apparent molecular size profiles of 4 M KOH-Boric acid soluble extracts for 'Cresthaven' peach fruits following various ethylene treatments for 0 h, 24 h or 48 h. The X-axis represents time in minutes and the Y-axis represents refractive index detector relative response. P1, P2 and P3 represent peak 1, peak 2 and peak 3. Arrows at the top of figure represents the elution positions (from left to right) of pullulan standards of molecular mass 853 kD, 380 kD, 100 kD, 48 kD, 23 kD, and 12 kD.....169

Figure 16a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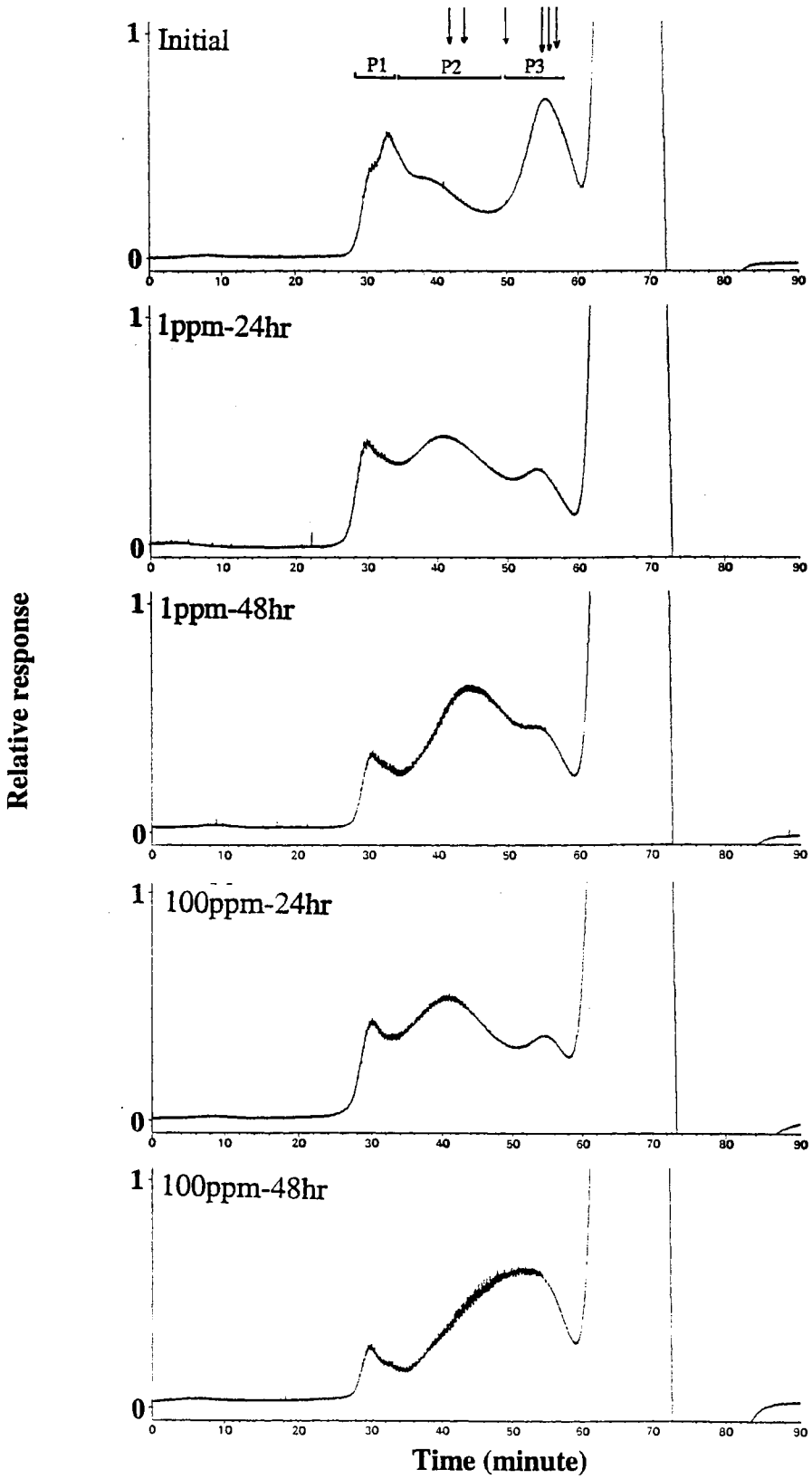
Relative response
Time (minute)

Figure 16b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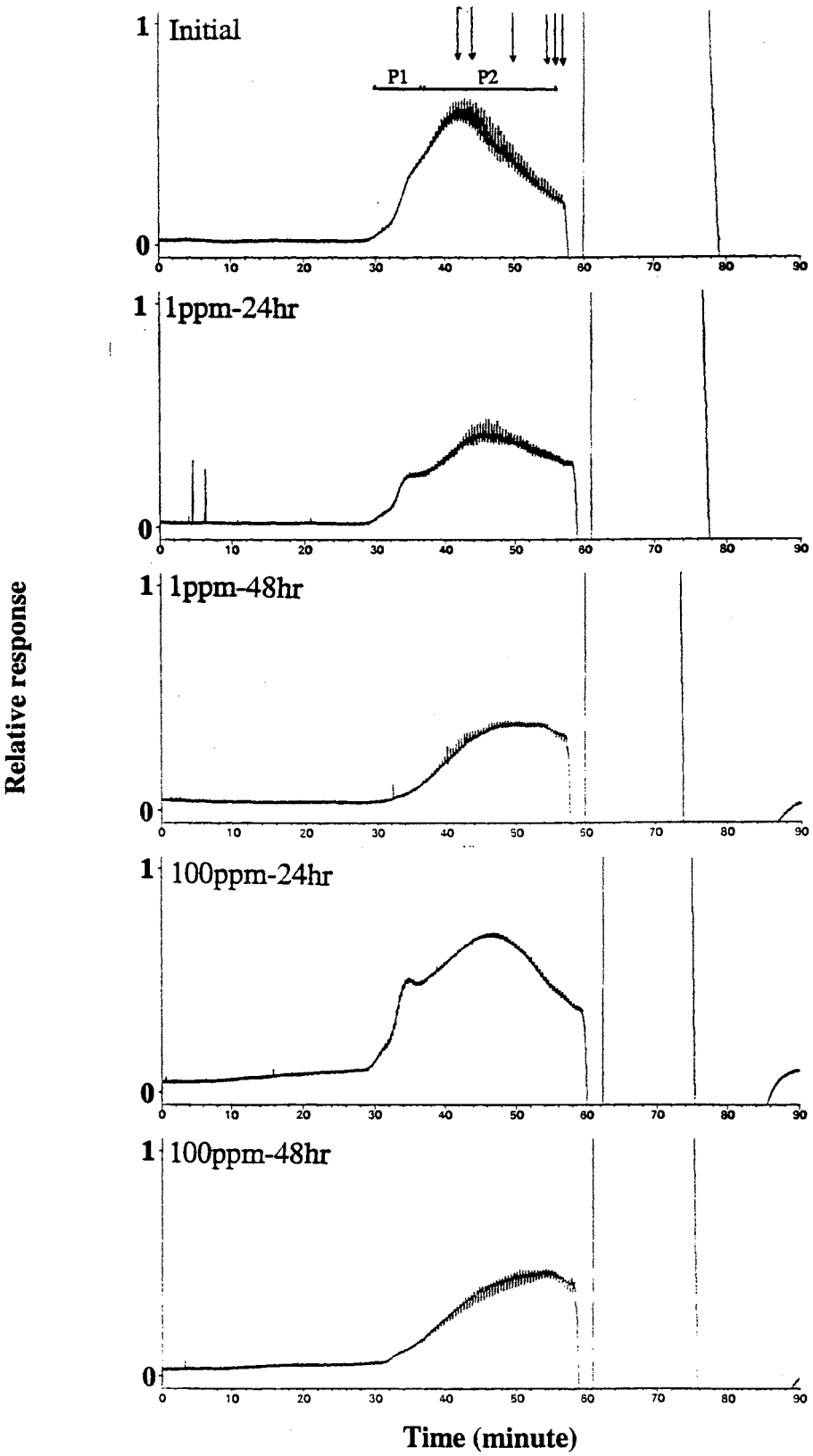
Relative response
Time (minute)

Figure 17a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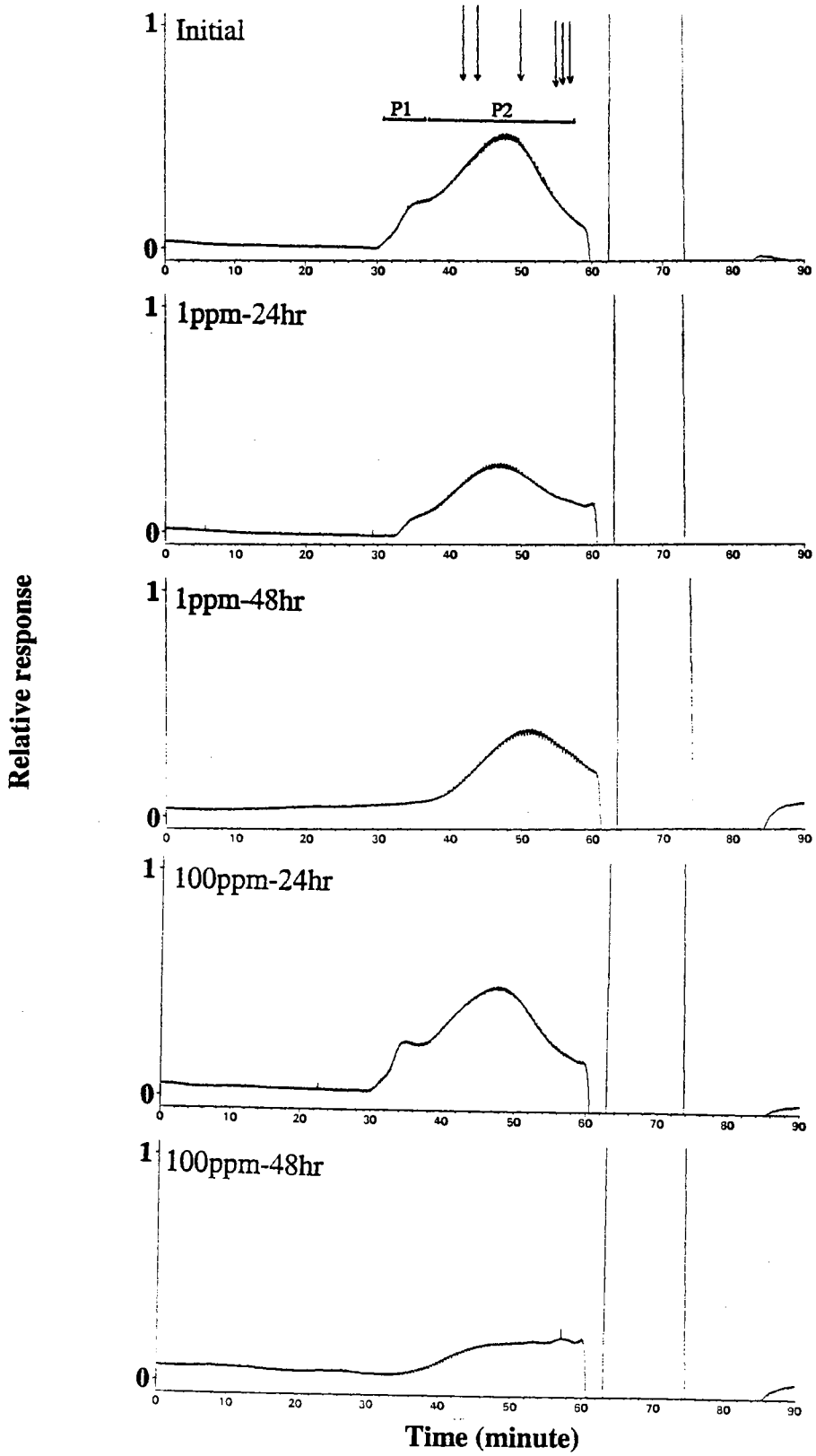
Relative response
Time (minute)

Figure 17b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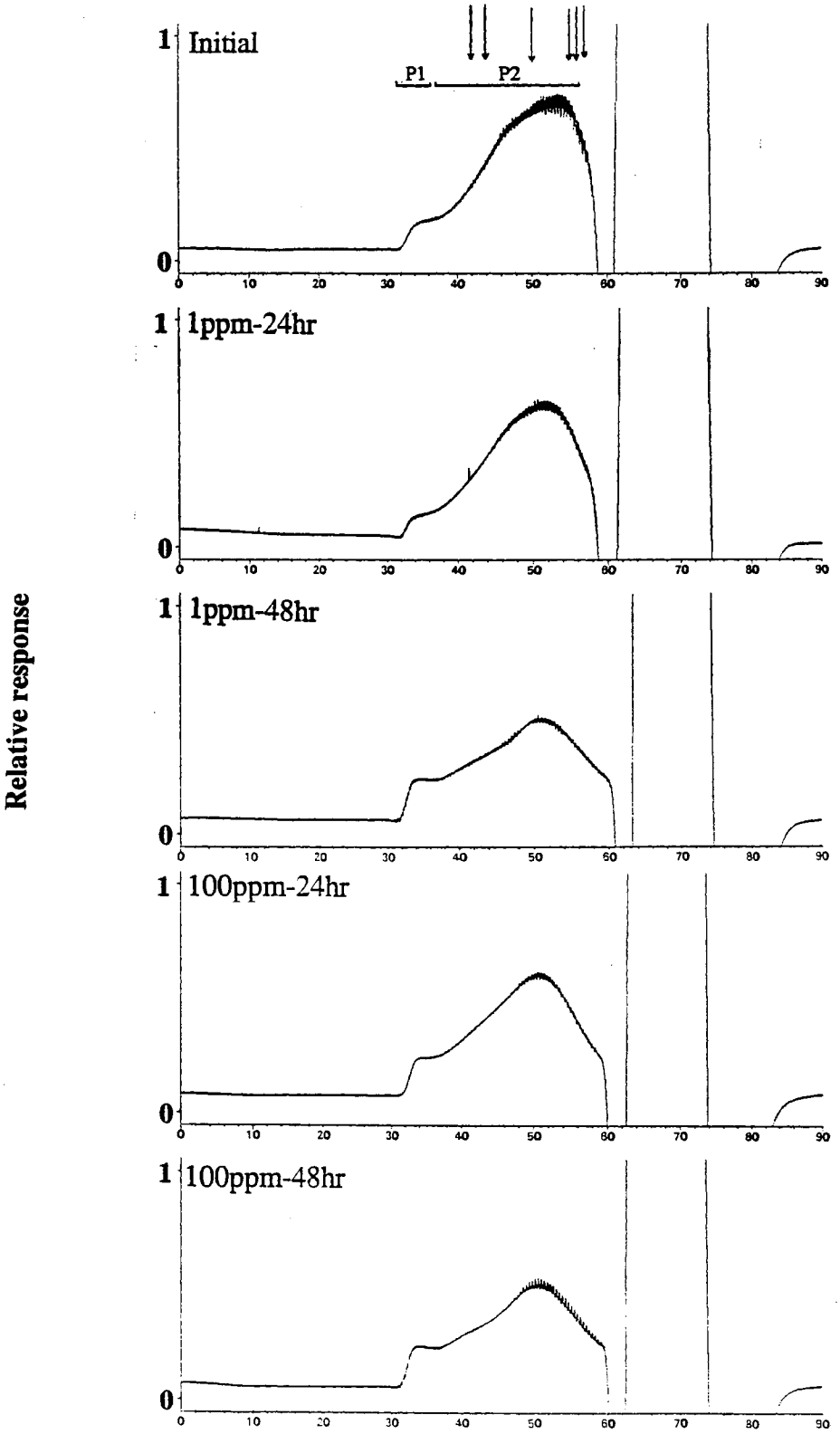
Relative response
Time (minute)

Figure 18a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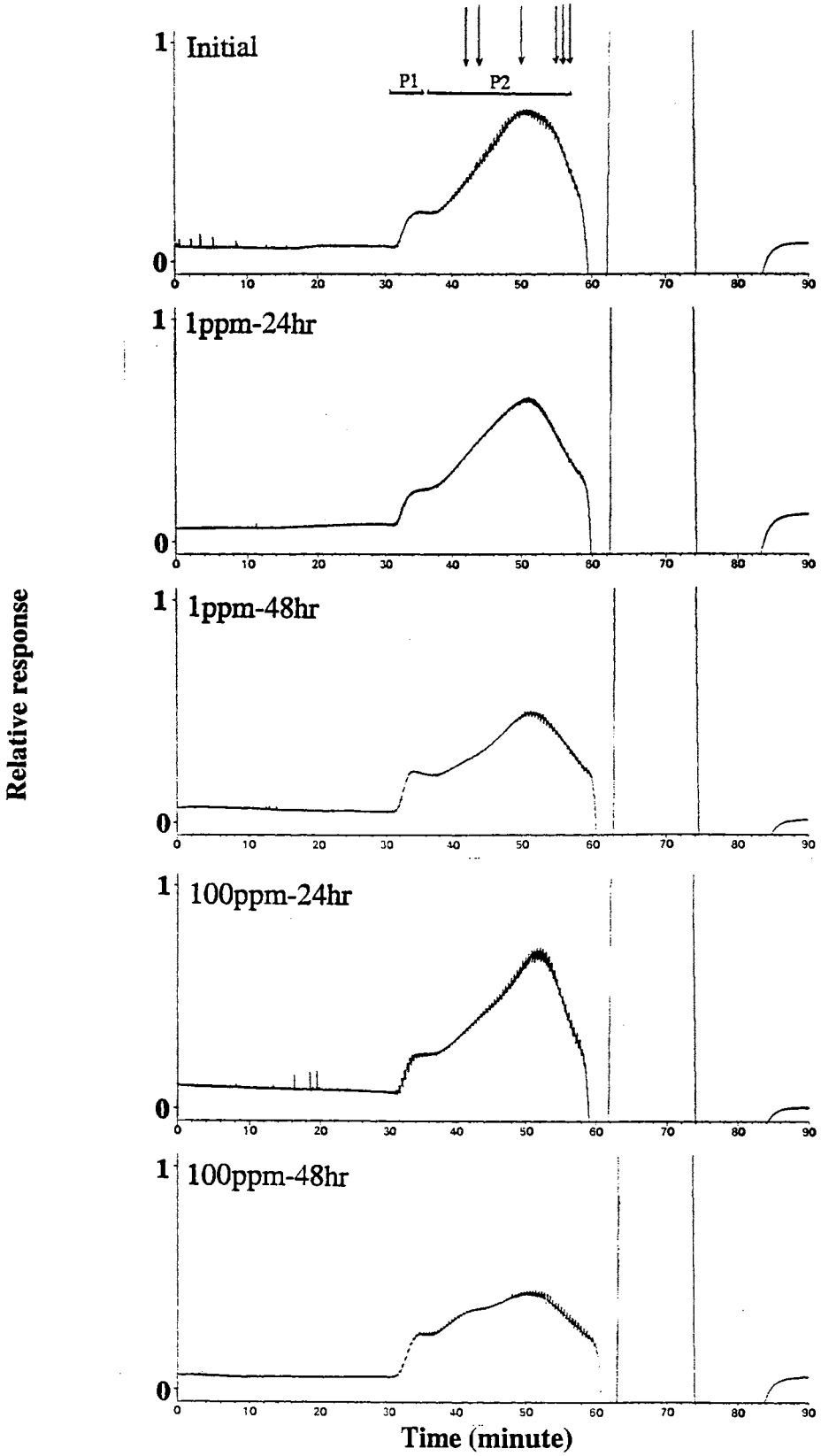
Relative response
Time (minute)

Figure 18b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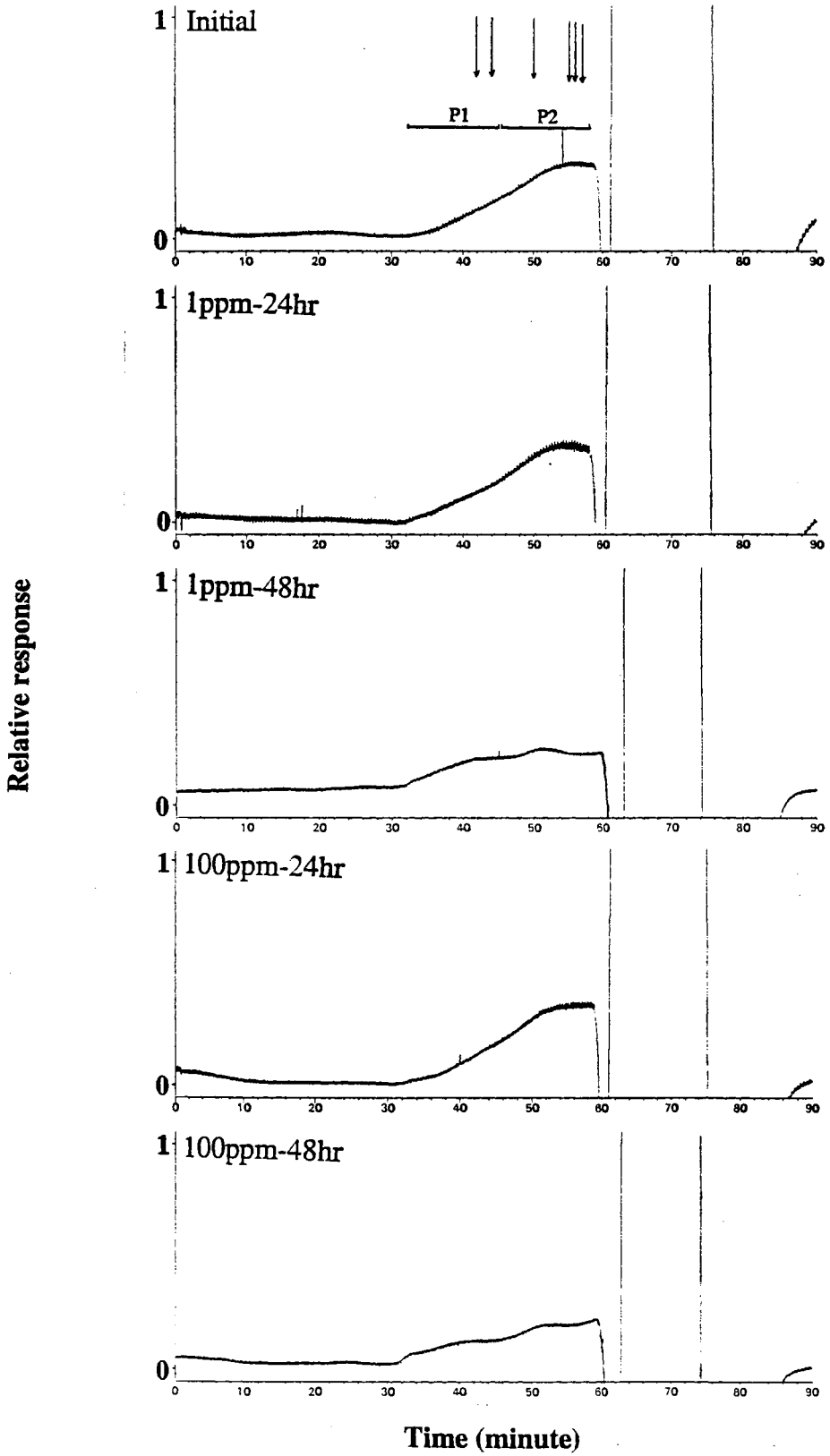
Relative response
Time (minute)

Figure 19a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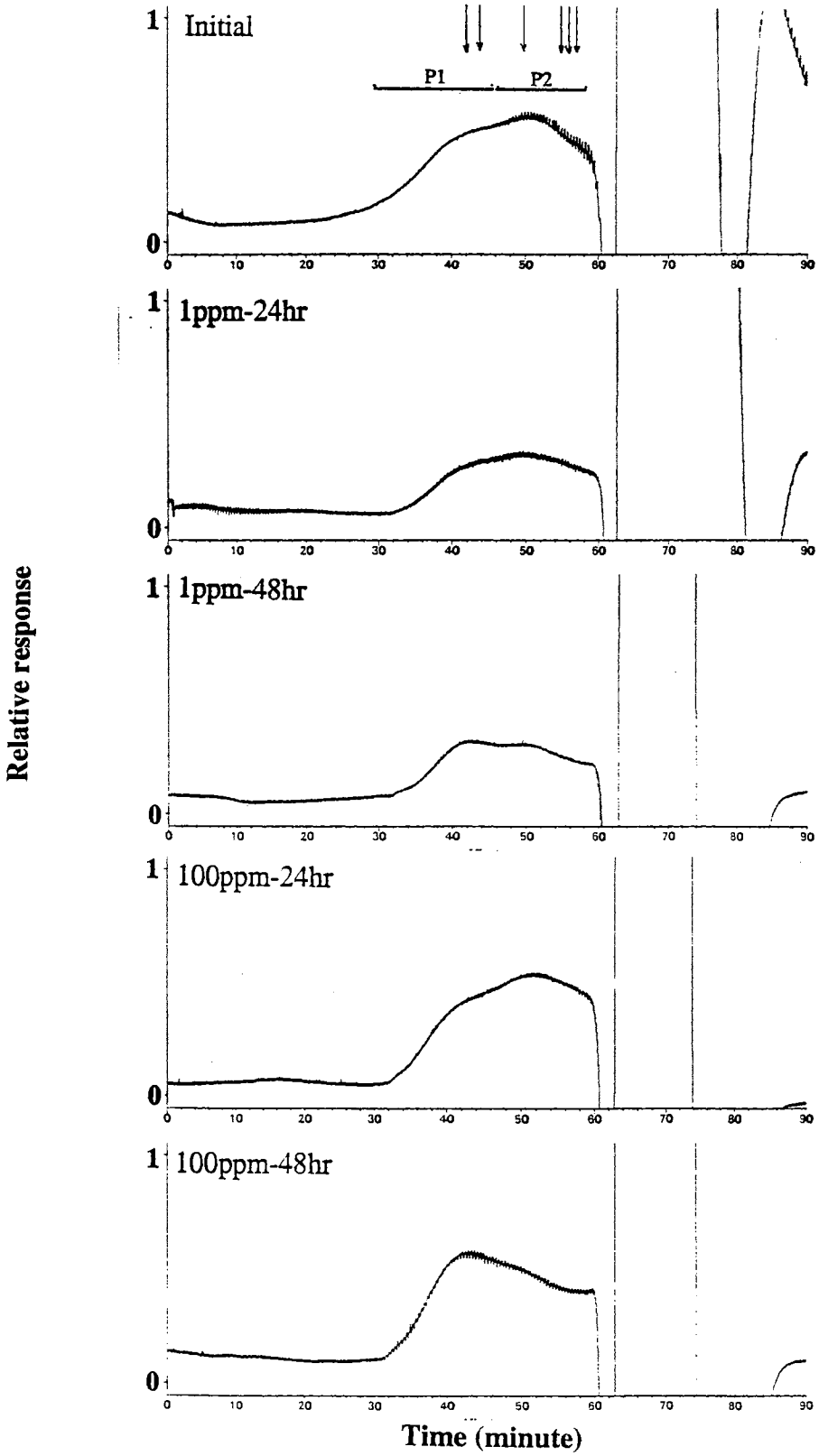
Relative response
Time (minute)

Figure 19b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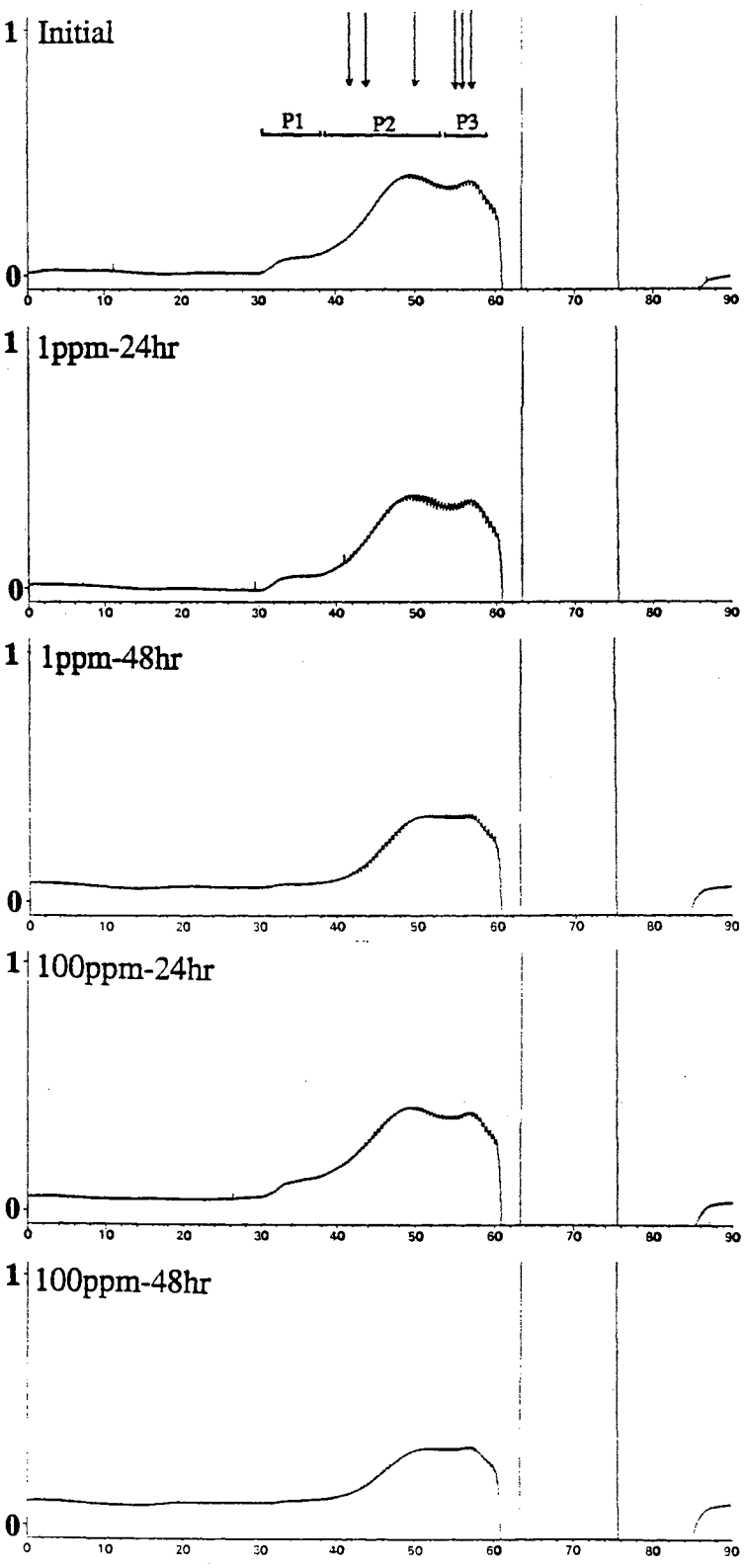
Relative response
Time (minute)

Figure 20a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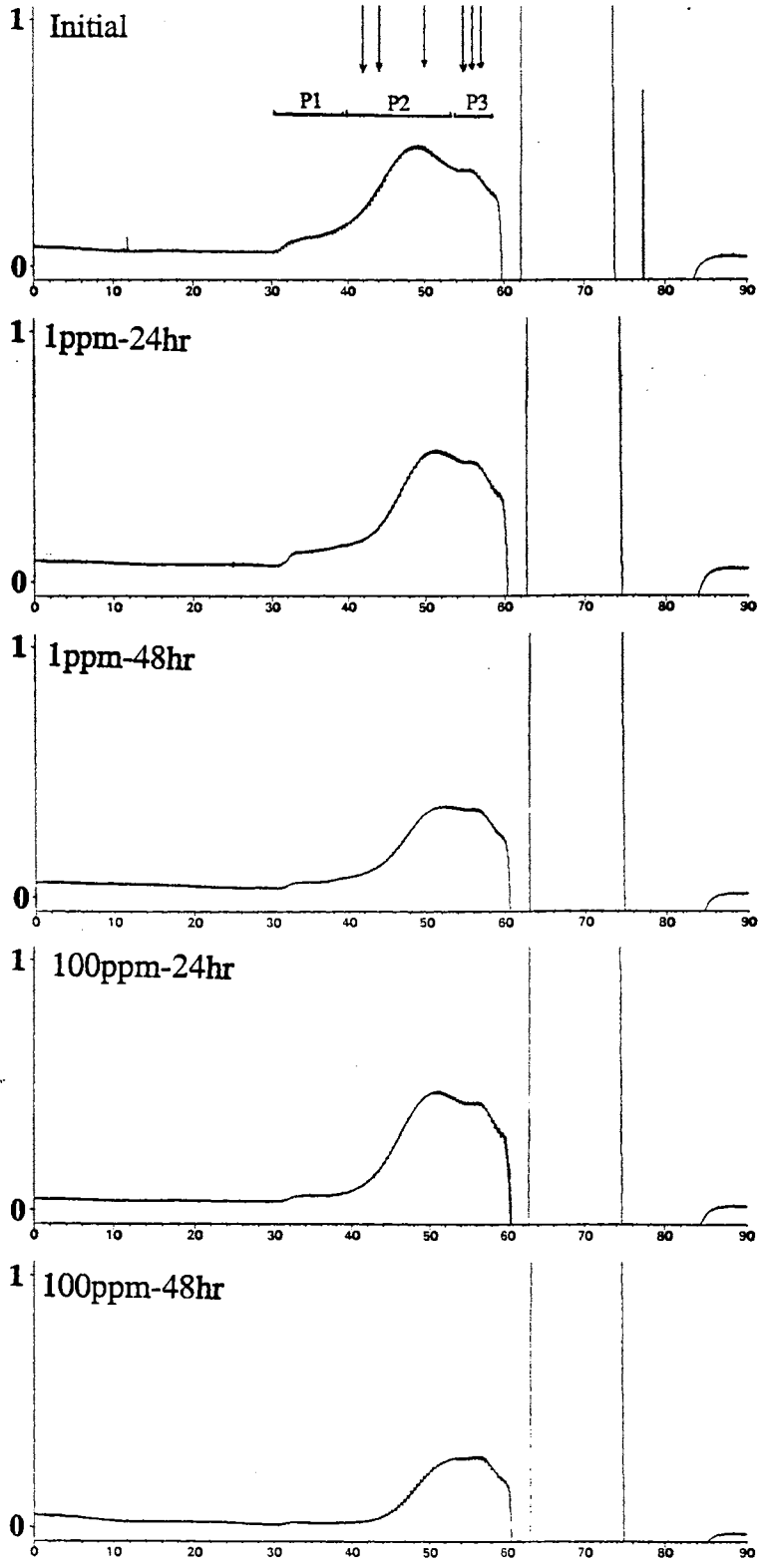
Relative response
Time (minute)

Figure 20b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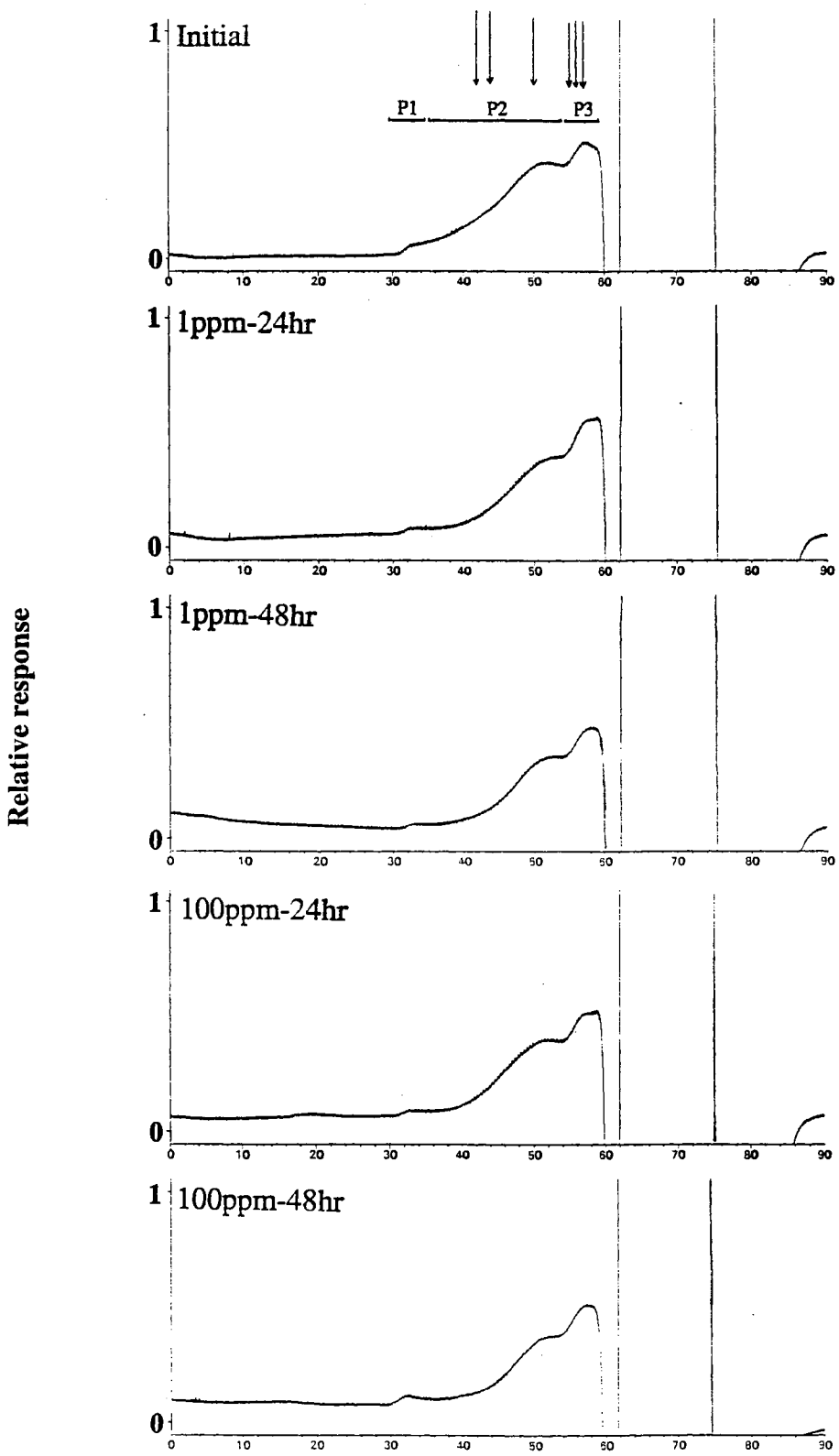
Relative response
Time (minute)

Figure 21a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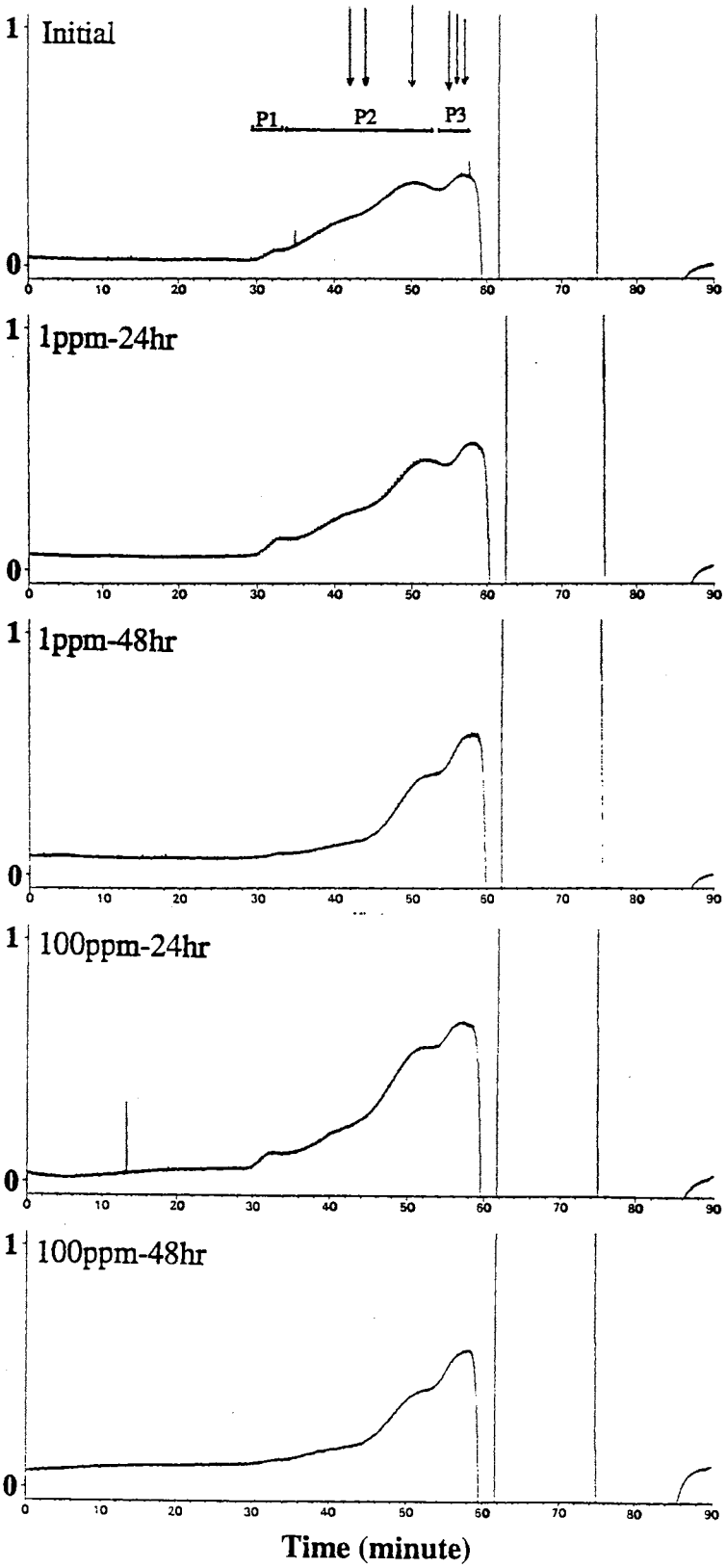
Relative response
Time (minute)

Figure 21b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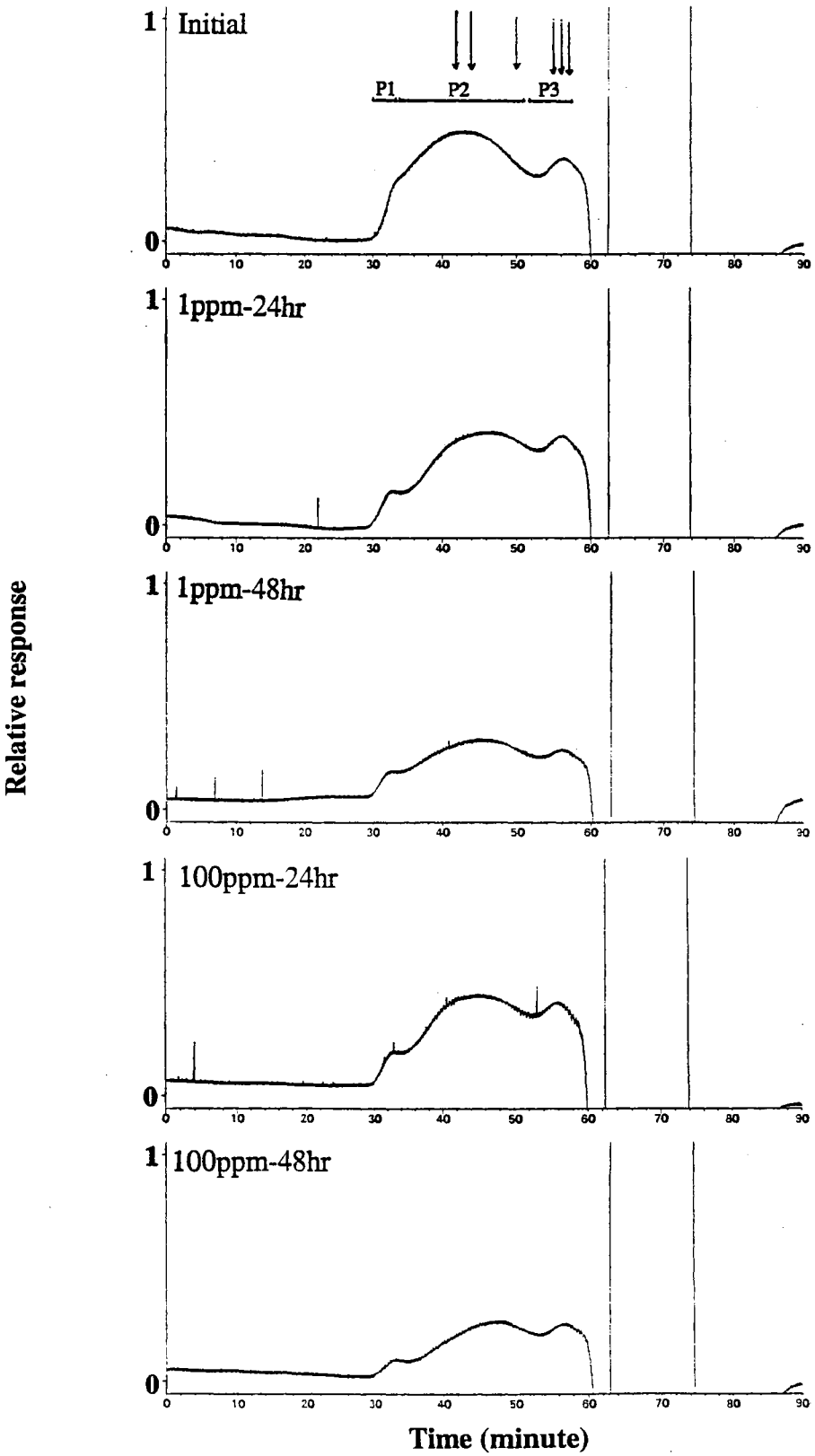
Relative response
Time (minute)

Figure 22a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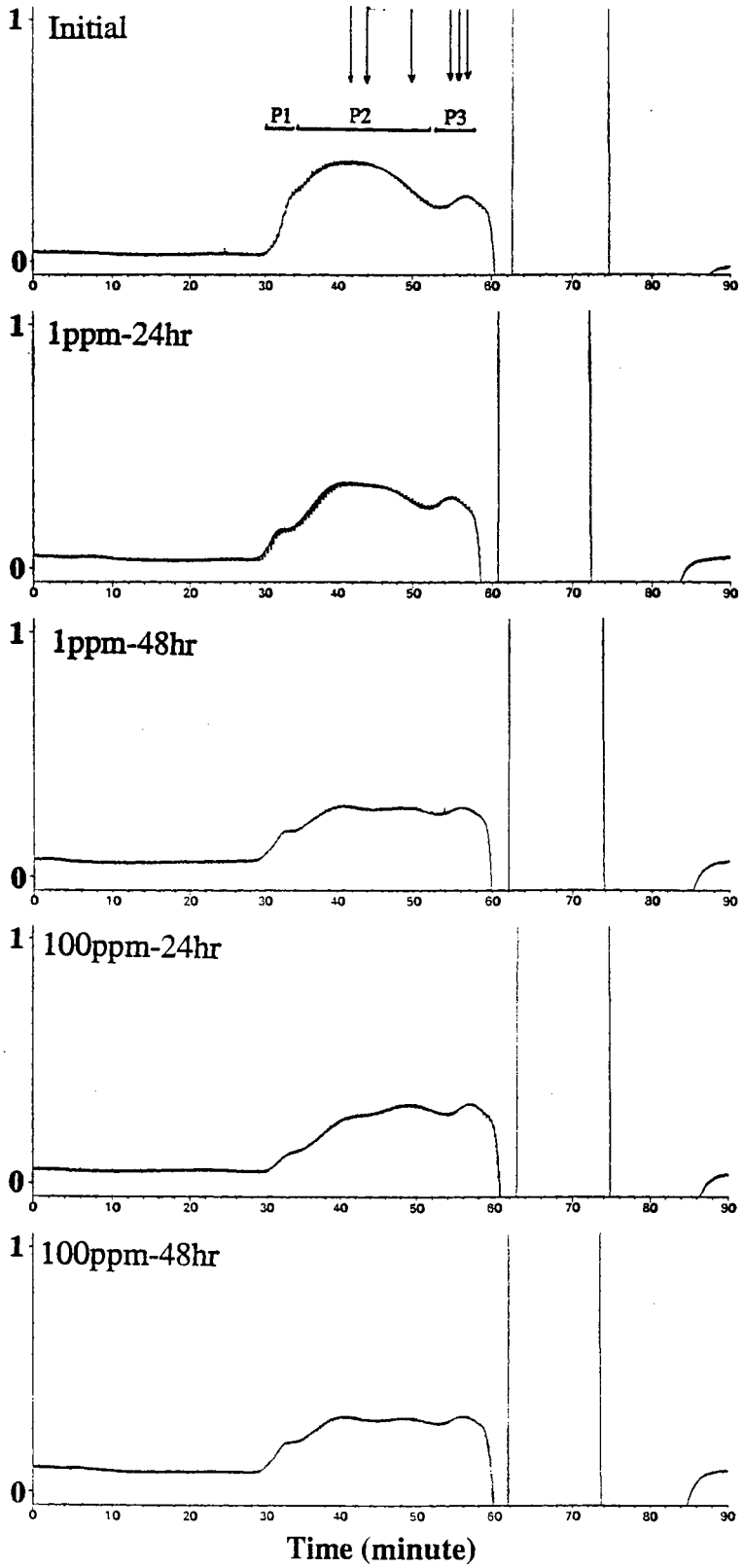
Relative response
Time (minute)

Figure 22b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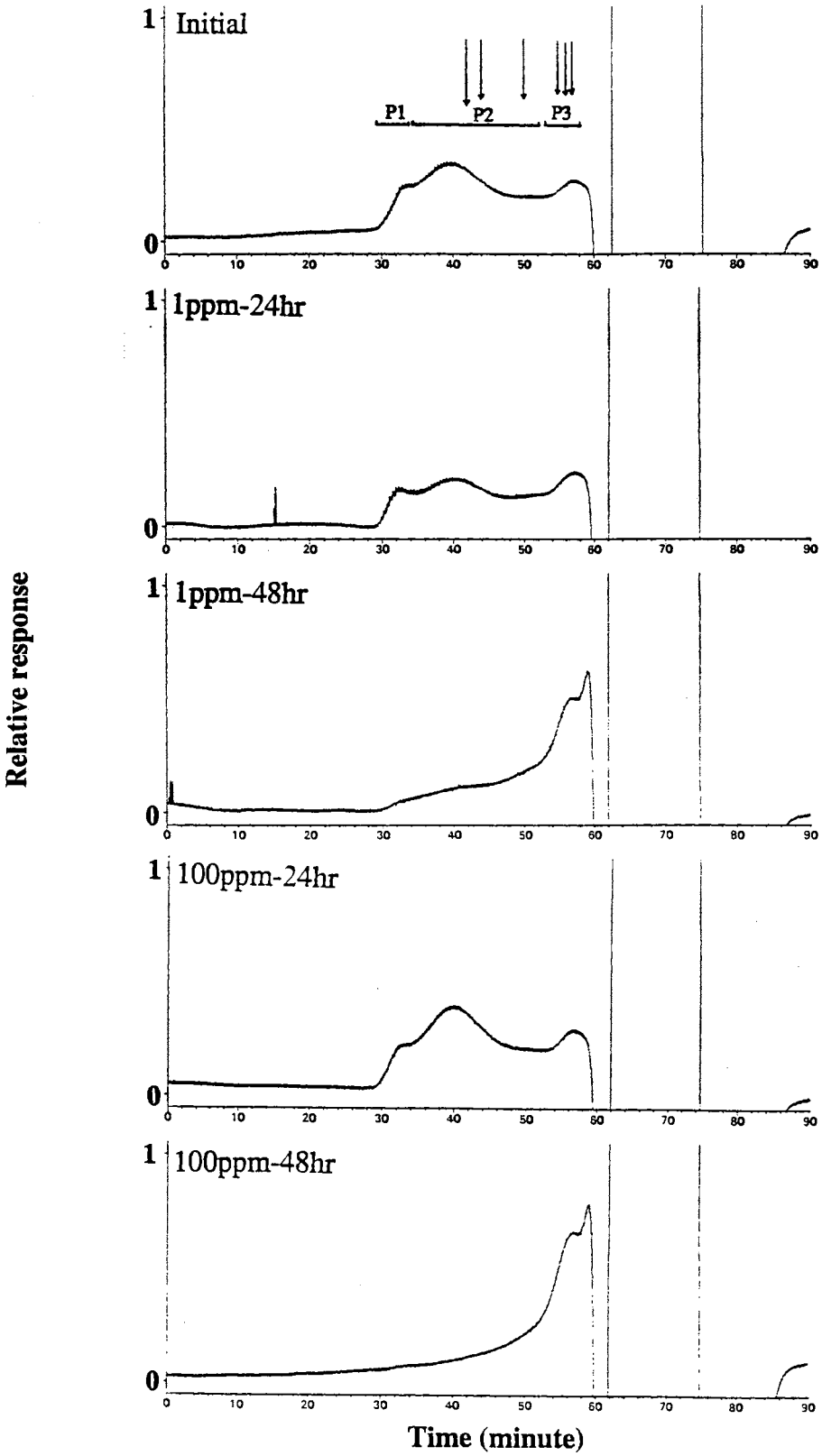
Relative response
Time (minute)

Figure 23a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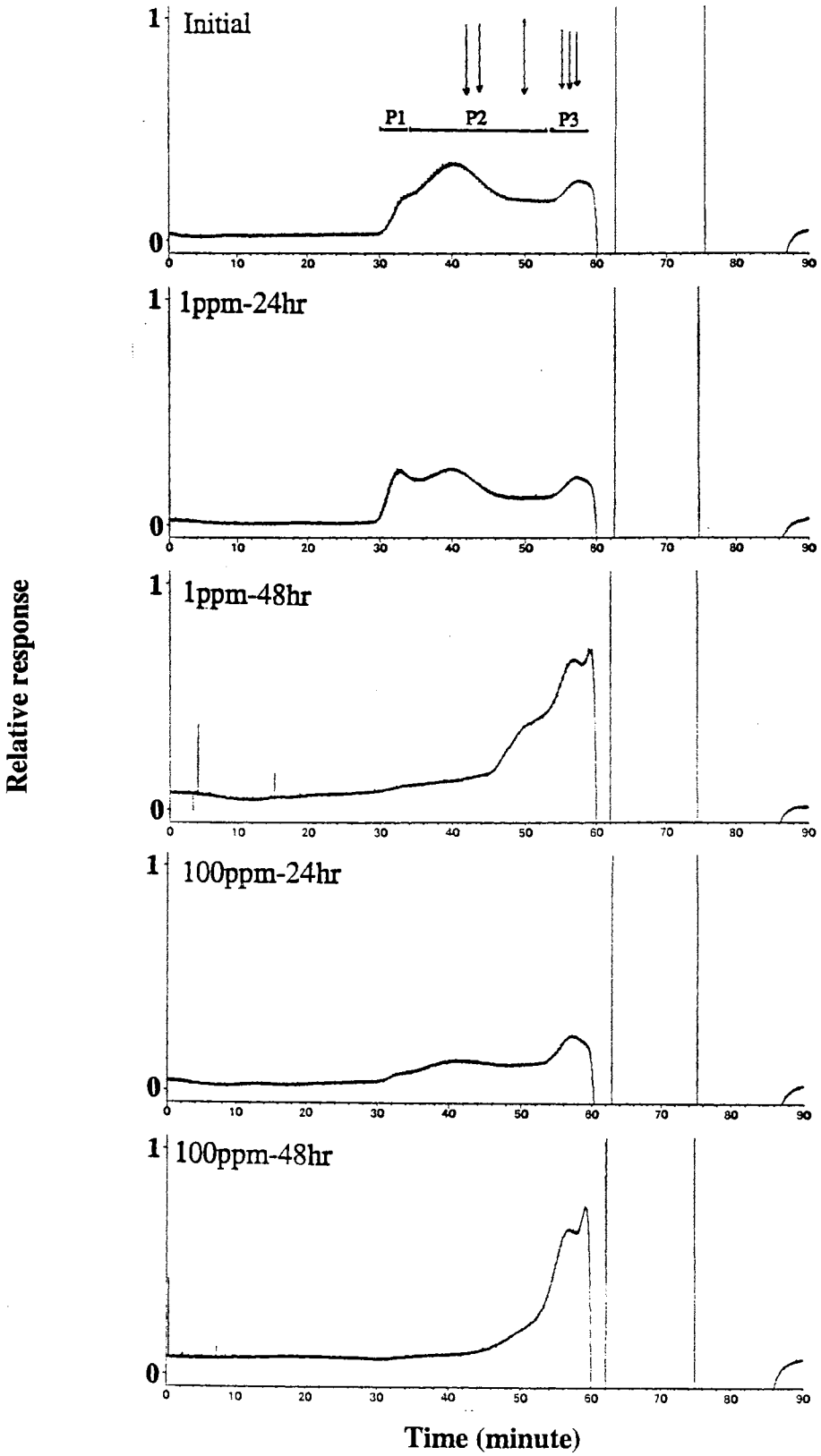
Relative response
Time (minute)

Figure 23b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100ppm-48hr
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0
0 10 20 30 40 50 60 70 80 90
Relative response
Time (minute)

VITA

Xinhua Wang

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Doctor of Philosophy

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Professional Membership: American Society for Horticultural Sciences.