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ROLE OF POLYAMINES IN FRUIT DEVELOPMENT, RIPENING, CHILLING INJURY, STORAGE AND QUALITY OF MANGO AND OTHER FRUITS: A REVIEW

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ABSTRACT

Mango is an important fruit crop of tropical and subtropical world. Being climacteric fruit it has short shelf life and susceptibility to low storage temperature limits its long term storage and distant marketing. Along with other endogenous plant growth substances polyamines have been involved in the development and ripening of mango fruit which ultimately affect its storage life and quality. The present article reviews the role of polyamines in fruit development, ripening, storage and quality of mango and other fruits.

Key words: Polyamines, mango, fruit development, ripening, chilling injury, storage, quality,

INTRODUCTION

The mango (*Mangifera indica* L.) is being grown in the tropical and subtropical climate in the world and more than 70 percent of its production is from Asia. India and China are the world's leading mango producing countries followed by Thailand, Mexico and Pakistan, while Brazil and Mexico share more then 40 percent of international mango export (FAO, 2004). Being climacteric fruit, short shelf life of mango is an obstacle in increasing its supply period in the international trade. Mango fruit growth, development and ripening have been associated with changes in endogenous levels of plant growth substances like auxins, gibberellins (GA), cytokinins, abscissic acid (ABA), ethylene and polyamines (PAs) (Ram, 1992; Murti and Upreti, 1995; Malik and Singh, 2004). However, there is a need for updated and concise information on the role of polyamines particularly in mango fruit.

PAs are positively charged aliphatic amines present in almost all living cells and have been involved in numerous biological processes including, plant growth and development, flowering, fruit growth and development, fruit ripening, stress response and senescence (Kakkar and Rai, 1993; Malik and Singh, 2003a, 2004). The term PAs mainly implies collectively to putrescine (PUT), spermidine (SPD) and spermine (SPM) along with few other related secondary conjugated product (Malmber et al., 1998). PAs are synthesized form basic amino acids, arginine, ornithine and lysine which forms basic carbon skeleton, while methionine contribute propylamino group to PUT to form SPD and SPD to form SPM (Bangi, 1986). Universal occurrence of PAs substantiated by their know behaviour in relation to senescence and stress suggest that they play important functions (Smith, 1985), which necessitate to understand their physiological roles involved in mango fruit growth, development, ripening and senescence. The current review will provide an overview of the research work reported on PAs with particular reference to its role in the Mango fruit growth, development, ripening, chilling Injury (CI) and storage quality, along with other fruits, which will help to improve our understanding and ability to manage these issues.

Role of Polyamines in Fruit Growth and Development

Mango fruit growth and development have been associated with changes in endogenous plant growth regulators including GAs, ABA, cytokinins, ethylene and PAs (Ram, 1992; Mutri and Upreti, 1995; Malik and Singh, 2004). Increase in fruit size and level of endogenous PAs in apples have been associated with exogenous application of PAs which indicating that lower level of these compounds could be growth limiting (Biasi et al., 1988). Various fruits including apple (Biasi et al., 1988), pear (Toumadje and Richardson, 1988), apricot (Paksasorn et al., 1995) and strawberry (Ponappa and Miller, 1996) shown increased amount of PAs during initial period of fruit growth followed by progressively decline near maturity, while in muskmelon (Lester, 2000) SPM and PUT concentrations increased with fruit development until 35 days after anthesis suggests that changes in PAs biosynthesis and their endogenous level differ with change in species, stage of development and as well as tissue type (Kondo et al 2001; Zuzunaga et al., 2001). Seeds are also known source of phytohormones (Nitsch, 1970), which are involved in fruit growth and development. Kushad (1998) reported a burst increase in the PAs during pit hardening stage with out increase in levels of PAs in mesocarp tissues in Peach fruit. Recently Malik and Singh (2004) monitored changes in endogenous free PAs (PUT, SPM and SPD) during mango fruit growth and development and reported that PAs content of pericarp declined form fruit set to maturity. SPD and SPM were higher than PUT during initial fruit growth (0-14 days after fruit set) compared to later during fruit development, which suggested the critical role of PA during cell division. Ovule of mango fruit exhibited higher content of PAs than pericarp tissue in Kensington Pride and Glen cultivars of Mango respectively (Malik and Singh, 2004). Potential role of embryo in relation to endogenous changes in PAs during mango fruit growth and development is still unclear and needs further studies to investigate PAs translocation form ovule to pericarp tissue during mango fruit growth and development.

Role of Polyamines in Fruit Ripening

Mango fruit is harvested at hard green, pre-climacteric stage, and it undergoes numerous biochemical changes during ripening within 9-12 days at ambient temperature, depending upon cultivar and stage of maturity (Gomez-Lim, 1997). The short ripening period along with its low temperature sensitivity (<13 °C) limits its potential for distant marketing. Ethylene, an endogenous plant hormone is involved in ripening of fruits (Sisler, 1991) sharing common precursor s-adenosyl methionine (SAM) with polyamines, for their biosynthesis (Bouchereau et al., 1999), but having antagonistic functions in fruit ripening and senescence (Pandey et al., 2000). Exogenous PAs application inhibits ethylene production (Apelbaum et al., 1982) while, exogenous ethylene application has been reported to inhibit PAs biosynthesis (Apelbaum et al., 1985) in some fruits, although is not common in all fruits. Studies conducted on mango showed that postharvest ethephone dip application resulted in 23 and 4.9 fold increase in ethylene production compared with control on days 2 and 5 respectively, while the endogenous free PAs also increased simultaneously by 32% and 20% respectively, which suggest that PA and ethylene may not necessarily have the only one common precursor (SAM). PAs have been determined to delay senescence in a number of plant tissues by inhibiting ACC synthase biosynthesis (Davies et al., 1991) and modulate fruit ripening and senescence (Saftner and Baldi, 1990). Yet the relationship between ethylene and polyamines is not clear and warrants further investigations particularly in tropical fruits.

Endogenous levels of PAs have been observed to change during fruit ripening, though these changes depend on maturity (Bouchereau et al., 1999) and cultivar (Zuzunaga et al., 2001).

Generally endogenous levels of PAs decrease during normal fruit ripening followed by ethylene production as in Avocado (Winer and Apelbaum, 1986), pear (Toumadje and Richardson, 1988). However Nathan et al. (1984) and Kondo et al. (2001) reported an increased level of PAs during fruit ripening in mandarins and rambutans respectively, which supported the hypothesis that variation in PAs biosynthesis and endogenous levels not only exit between species but also with different stages of ripening. Malik and Singh (2004) reported that total free PAs increased in skin and pulp tissues during ripening of "Kensington Pride" mango along with climacteric rise of ethylene and skin exhibit 55.8% higher mean PAs content then pulp. During fruit ripening PAs maintained membrane stability by acting as free radical scavengers (Bors et al., 1989) produced by lipoxygenase (LOX) and phospholipase-D (PL-D) (Lester, 2000). Pre harvest application of putrescine (1 mM) effectively delayed fruit ripening at ambient temperature in mango cv "Kensington Pride" (Malik, 2003).

Role of polyamines in fruit chilling injury

Mango fruit is susceptible to chilling injury (CI) when stored below 13^{o}C (Mitra and Baldwin, 1997). CI symptoms include darkening of skin, prominence of lenticels, poor flavour and ultimately uneven fruit ripening (Chaplin et al., 1991; Ledermam et al., 1997) with increased membrane permeability and alternation of activities of membrane proteins (Wang, 1982). Polyamine biosynthesis has been reported to alter various kinds of stress including chilling injury (McDonald and Kushad, 1986; Wang, 1987) with accumulation of PAs through increased activity of arginine decarboxylase (Mathooko et al., 1995). Chilling injury symptoms in mango have been observed to be associated with biosynthesis of PAs (Nair and Singh, 2004). Postharvest dip application of PAs has been reported to inhibit CI in Zucchini squash (Kramer and Wang, 1989) and mango (Nair and Singh, 2004). Nair and Singh (2004) determined higher amount of total free PAs in skin and pulp of chill injured "Kensington Pride" mango as compared to non-chill injured fruits during storage and ripening with accumulation of PUT and depletion of SPD and SPM in skin and pulp of chill injured fruit. Commercial use of PAs to inhibit CI in mango would be a future tool to extend its marketing potential but it needs to be studied and standardized with other important mango cultivars and storage conditions.

Role of Polyamines in Fruit Storage

Exogenous application of PAs have been demonstrated to influence shelf life and quality of various fruit crops such as apple (Kramer et al., 1991), strawberry (Ponappa, 1993), Plum (Ren et al., 1995), peaches (Martinez Romero et al., 2000) and mango (Purwoko et al., 1998 ; Malik and Singh, 2003a, 2005). Application of 1mM PUT, SPM and SPD to litchi fruit before storage at 5^{o}C showed an increased level of PAs and delayed the changes associated with senescence such as ethylene production, browning, peroxide level and cell leakage (Jiang and Chen, 1995). Exogenous (2 mM.L^{-1}) application extended the shelf life and improved the fruit quality of "Kensington Pride" mango by maintaining high fruit firmness (Malik and Singh, 2003a). Pre vs postharvest PUT application on mango showed that after 20 days of storage, pre-harvest treated fruit exhibited higher firmness, TSS, whilst acidity, total sugars and non-reducing sugars were reduced in fruit treated with both methods as compared to control. In yet another study by Malik and Singh (2005), pre-storage dip application of polyamines resulted in reduced fruit softness (10.3%), fruit colour (26.3%) and physiological weight loss (6.8%) of mango cv 'Kensington Pride' during three week storage without significantly inhibiting ethylene production. Extended storage life of mango fruit would be possible by further standardizing PAs concentration, time of application and cultivar response.

Role of Polyamines in Fruit Quality

Fruit quality is the one of the most important factor from a consumer's perspective, which includes nutritive as well as visual and organoleptic criteria (Salveit et al., 1999). CA storage (Bender et al., 2000), MA storage (Yahia, 1998) and low temperature storage (Ketsa et al., 1999) have been investigated to extend the shelf life of mango fruit but results are variable. Exogenous application of PAs has revealed their potential to retard fruit ripening process and extend the shelf life of fruit with better quality. In apple exogenous application of PUT ($5x10^{-5}$ M) exhibited higher TSS (Costa and Bagni, 1983), while in litchi application of PUT at full bloom stage improved fruit quality by increasing TSS, TSS/acidity ratio and Vitamin C contents (Mitra and Senyal, 1990). Recently Malik and Singh (2003 and 2006) made extensive studies on the effects of exogenous application of polyamines on mango fruit. PAs application at final fruit set stage retarded fruit skin colour development compared to the control. Sugars and total soluble solids (TSS) were generally reduced in PA-treated fruit. Fruit acidity was increased (16.7%) with SPM, whereas it was 11% with PUT treatment as compared to the control. Total carotenoids in pulp were generally improved (49%) with PA treatments, compared to the control. Ascorbic acid concentrations were significantly reduced with spermidine (SPD) (24%) and PUT (20%) treatments. Studies on pre vs postharvest application showed that PUT spray onto trees 7 days prior to first commercial harvest or postharvest fruit dip treatments for 6 min showed that PUT application increased fruit firmness and decreased sugar contents as compared with control. Both applications also retarded fruit colour development. In conclusion, preharvest spray was comparatively more effective method of putrescine application as compared to postharvest dip treatment. Preharvest spray of putrescine (1 mM) was effective in delaying fruit ripening at ambient temperature, whilst 2 mM extended the shelf life of 'Kensington Pride' mango. The influence of PAs to the organoleptic characteristic of mango fruit at molecular level, changes in softening enzymes and quality issues like influence of PAs on antioxidant activity need further investigations.

CONCLUSION

In conclusion presence of higher levels of endogenous free PAs especially SPD and SPM at initial fruit development suggest their possible role in cell division and the concurrent increase in PAs and ethylene during mango fruit ripening suggest that endogenous PAs level may have increased in response to higher ethylene production. Prolonged shelf life and improved quality of exogenously treated mango demonstrate involvement of PAs biosynthesis during ripening process and its possible use to extend shelf life for distant marketing. However, the effects of pre and postharvest polyamine applications on biosynthesis of aroma volatile compound during ripening and storage and changes in organoleptic characteristic of mango fruit at molecular level warrant further investigations.

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