Taze Kesilmiş Ürünlerin Fizyolojisi ve Taze Kesilmiş Ürünlerin Kalitesini Etkileyen Etmenler

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ÖZET: Bahçe ürünlerinin tazelik kalitesini düşürmeyecek şekilde yıkama, seçme, soyma, kesme veya iri parçalara ayırma olarak tanımlanan taze kesme metodu, son 10 yıl içerisinde ABD'de popülaritesini artırmıştır ve halen de genel olarak taze ürünler ile beraber popülaritesini artırmaya devam etmektedir. Bu yeni meyve sebze işleme metodunda, ülkemiz gerek bilimsel olarak gerek ticari olarak çok geridedir. Bu nedenle, bu derleme taze kesme metodunu ülkemiz bilim adamlarına tanıtmak ve onları bu yeni araştırma alanına yöneltmek amacıyla hazırlanmıştır. Derleme taze kesilmiş ürünler tarafından sergilenen davranışları kapsamaktadır, örneğin yüksek miktarda su kaybı, ikincil ürünlerin sentezlenmesi, yüksek etilen ve solunum üretim miktarı ve kararma gibi. Bu davranışlar sıcaklık, oransal nem ve ortam gaz koşulları ile beraber hem taze kesilmiş ürünlerin fizyolojisini hem de kalitesini büyük oranda etkilemektedir.
Anahtar Kelimeler: Yaralanma, kararma, sulu görünüm kazanma, su kaybetme, paketleme

Fresh-cut Physiology and Factors Contributing to the Quality of Fresh-cut Produce

ABSTRACT: Fresh-cut processing, defined as washing, sorting, trimming, peeling, skinning or chopping of horticultural commodities in a manner that does not reduce fresh-like quality, has increased in popularity over the past 10 years in USA and continues to increase in popularity along with fresh produce in general. The process is still under study since retaining the quality of fresh-cut produce for a prolonged time has some difficulties. Our country is far behind both scientifically and commercially in this novel processing method. Therefore, this article intends to introduce the fresh-cut processing method to local scientists and guide them into this new research area. It covers aspects pertaining to behaviors shown by fresh-cut produce such as excessive water loss, synthesis of secondary compounds, higher ethylene production and respiration, softening and browning. These behaviors plus temperature, relative humidity and atmospheric composition greatly affect both the physiology and quality of fresh-cut produce.
Key Words: Wounding, browning, watersoaking, dehydration, packing

INTRODUCTION

Fresh-cut produce is a new agricultural industry that grows steadily and increases its popularity among other agricultural industries (Anonymous, 2005). In the United States, the sales of fresh-cut fruits and vegetables have increased from \$3.3 billion in 1994 to \$11 billion in 2000, with sales projected to increase to \$15 billion in 2005 (Anonymous, 2005). There is no record available for the world production since USA was the only forerunner in the past 10 years. However, during the 10-year time period, Canada, France and Italy have also shown some progress both scientifically and commercially.

Fresh-cut processing involves several steps including peeling, shredding, cutting and etc. The physical injury attendant to fruit processing initiates a series of events such as increased respiration and ethylene production, stimulated phenol metabolism, and increased enzyme activities (Rolle and Chism, 1987; King and Bolin, 1989). The secondary events resulting from wounding contribute to the challenge for improving the keeping quality of fresh-cut produce. The storage life of fresh-cut commodities can also be compromised by the proliferation of microorganisms including mesophilic microflora, lactic acid bacteria, coliforms and fecal coliforms, yeasts and other fungi, and pectinolytic microflora (Nguyen-the and Carline, 1994). Low temperature (generally 4 ºC) has been used to cut and preserve quality and extend storage life of fresh-cut produce. Although cold storage retards many biological processes in fresh-cut produce, events leading to tissue softening and deterioration continue at low temperature especially for fresh-cut fruits. The increase in consumer demand for fresh-cut produce has prompted increased research interest in devising and implementing methods for improving and prolonging the quality of these highly perishable products.

CONSEQUENCES OF PROCESSING

The physiology of fresh-cut produce is similar to that of wounded tissues (Brecht, 1995). The process necessary for fresh-cut produce (fresh-cut processing) requires abrasion, peeling, slicing, chopping and shredding (O'Connor-Shaw et al., 1994), which results in a shelf life of most of fresh-cut fruits between 4 to 7 days and of fresh-cut vegetables 10 to 14 days. Each of the previous steps can generate stress conditions in living tissues. Since fruits and vegetables remain viable after the fresh-cut processing, their behavior is generally comparable to plants exposed to stress conditions in nature such as wind damage. This behavior includes enhanced ethylene and respiration rates, wound-healing processes (synthesis of secondary compounds, suberization and lignification), biochemical changes (membrane and cell changes, browning and degreening) and physical changes (softening, watersoaking and water loss; Rolle and Chism, 1987; Miller, 1992; Brecht, 1995).

Ethylene Production and Respiration

Wounding caused by fresh-cut processing may accelerate ethylene production and respiration (Rolle and Chism, 1987). In climacteric fruits, wounding causes more ethylene production in the preclimacteric and climacteric periods than in the postclimacteric period (Brecht, 1995). Respiration of fresh-cut produce generally rises with temperature depending on the severity of damage during processing. Higher ethylene production due to wounding may result in an increase in respiration rates, as well (Rolle and Chism, 1987). Additionally, starch break down and oxidation of fatty acids may contribute to this respiratory inclination (Miller, 1992).

Secondary Metabolism

Wounding causes tissues to synthesize secondary compounds, which are mostly related to wound-healing and defense mechanism processes. These secondary compounds may affect aroma, appearance, nutritive value, and safety of fresh-cut produce (Brecht, 1995). Some of these secondary compounds are phenolics, flavonoids, terpenoids (Sakai and Nakagawa, 1988), alkaloids, glucosinolates, and long-chain fatty acids and alcohols (Miller, 1992). Wounding increases the activities and transcripts of the following enzymes associated with the secondary compounds: phenyl-alanine–ammonia-lyase (PAL) (EC 4.1.3.5) (Fritzemeier et al., 1987; Liang et al., 1989), 4-coumarate:CoA ligase (EC 6.2.1.13) (Fritzemeier et al., 1987), chalcone synthase, 3-deoxy-D-arabino-heptulosonate-7-phosphate synthase (EC 4.2.3.4) (Miller, 1992), peroxidases (EC 1.11.1.6) (Bostock et al., 1987; Miller and Kelly, 1989), and stilbene synthase (EC 2.3.1.95) (Vornam et al., 1988).

Structural changes of the tissue surface may occur as a consequence of the wound-healing process. Desiccation of the wounded surface is the first observable change of fresh-cut produce (Varoquaux and Wiley, 1994). Desiccation is followed by suberin and lignin production and deposition in cell walls, and is possibly proceeded by periderm occurrence beneath the suberin layer in many tissues as potato tuber, bean pod, and cucumber pericarp (Burton, 1982).

Browning and Degreening

Browning is resulted from enzymatic oxidation of phenols and polyphenols (Ahvenainen, 1996). Polyphenol oxidase (EC 1.14.18.1), PAL, tyrosine ammonia lyase (EC 4.1.99.2), cinnamic acid -4-hydroxylase (EC 1.14.13.11), lipoxygenase (EC 1.13.11.13) and catechol oxidase (EC 1.1.3.14) are the enzymes that likely cause enzymatic browning (Ahvenainen, 1996).

Increased ethylene production and loss of membrane integrity may start rapid chlorophyll degradation due to induction of chlorophyll-degrading enzymes (Varoquaux and Wiley, 1994). The enzymes responsible for the chlorophyll degradation are chlorophyll oxidase, chlorophyllase (EC 3.1.1.15), lipolytic acid hydrolase, and other peroxidases (Varoquaux and Wiley, 1994).

Membrane Changes

Wounding causes cellular disruption, leading to decompartmentation of enzymes and substrates (Rolle and Chism, 1987). Wounding enhances the activities of lipid acyl hydrolase (EC 3.1.1.26) (act like phospholipase D), polyphenol oxidase (Ikediobi et al., 1989) and lipoxygenase (Lulai, 1988; Ikediobi et al., 1989). These enhanced enzyme activities may result in increases in free fatty acids and free radicals that are toxic to many cellular processes and capable of causing organelle inactivating proteins and lysis (Brecht, 1995). Additionally, excessive ethylene production enhances permeability of membranes and reduces phospholipid biosynthesis (Watada et al., 1996). For example, in fresh-cut carrot, total phospholipids and phosphatidic acid increased but phosphatidylcholine decreased (Picchioni et al., 1994). Picchioni et al. (1994) also found that rough endoplasmic reticulum numbers increase in fresh-cut carrot, which may be correlated to lipid synthesis and the enzyme induction process.

Textural and Cell Wall Changes

Firmness loss is immediate and faster in wounded tissues due to cell rupture and loss of tissue integrity (Miller, 1992). Cell wall enzyme activity may be accelerated by wounding (Miller, 1992; Karakurt and Huber, 2002), which may contribute extensive softening in fresh-cut tissues. For example, Karakurt and Huber (2002) found that PG and α- (EC 3.21.22) and β-galactosidase activity (EC 3.2.1.23) was higher in fresh-cut papaya fruit compared to intact fruit at 5 ºC. The enhanced cell wall enzyme activity, thus, causes depolymerization of pectic and hemicellulosic polyuronides, which may result in further textural changes in fresh-cut tissues.

Watersoaking

Watersoaking is another consequence of fresh-cut processing and exact reason of watersoaking is not known. However, Jeong et al (2004) proposed that watersoaking development in fresh-cut tomato slices could be an ethylene-mediated symptom of senescence, that is, ethylene may promote watersoaking.

Dehydration

Fresh-cut processing causes interior tissues to be exposed to air and to increase in evaporation rate which results in water loss. Dehydration at the cut surface is sometimes obligatory to control microbial growth; however, it may provoke undesirable visual appearances such as color fading in carrot skin (Watada et al., 1996).

EXTERNAL AND INTERNAL FACTORS CONTRIBUTING TO QUALITY OF FRESH-CUT PRODUCE

Wounded tissues rapidly deteriorate and senesce. Hence, minimizing the negative consequences of wounding is a crucial step that affects storage life and maintenance of interior and exterior qualities of fresh-cut produce. These qualities are greatly affected by morphological, physiological, environmental, pathological and practical factors.

Raw Product and Processing Methods

Since fresh-cut fruits and vegetables are already at the table-ripe edible stage, they should have excellent interior and exterior qualities. Fresh-cut produce should also have superior characteristics such as slower ripening rate, good texture and flavor qualities, and less sensitivity to chilling injury and microorganisms than their counterparts because they are more perishable compared to intact produce (Watada et al., 1996). Moreover, postharvest applications and treatments prior to fresh-cut processing can greatly affect quality of fresh-cut processing, such as washing with tap water, using 1-methylclycyclopropene (Ergun, 2003), heat (Lamikanra et al., 2005; Kim et al., 2005) and ethanol treatments, and gamma irradiation (Bai et al., 2004).

Physical applications, such as peeling, coring and cutting, needed for fresh-cut processing, can significantly affect the shelf life of the produce and eventually the quality (Soliva-Fortuny and Matin-Belloso, 2003). For example, melon fruit cut with sharper knives showed in their produce less ethanol production rates, off-odors and electrolyte leakages compared to fruit cut blunt knives. A study conducted by Abe at al., (1998) showed that cutting direction can affect the quality of fresh-cut produce as well.

Temperature

Fresh-cut fruits and vegetables should be held at lower temperatures to slow down metabolic activity. Lower temperatures are also necessary to control microbial growth. However, most of tropical and some subtropical commodities are chill sensitive; therefore, storage at a lower temperature may lead to chilling injuries. On the other hand, keeping fresh-cut produce at lower temperatures suppresses the development of chilling injury symptoms for a limited period (Watada and Qi, 1999).

Relative Humidity

Relative humidity of the atmosphere of fresh-cut produce should be higher to reduce extensive water loss (Schlimme, 1995). Edible or non-edible coating and proper packing may reduce water loss from fresh-cut produce (Watada et al., 1996; Schlimme, 1995). In many cases, water loss in fresh-cut produce results from epidermal membrane deterioration. Particularly, at higher temperatures where the water vapor deficit is large, the water loss hastens in fresh-cut produce (Watada et al., 1996).

Controlled Atmosphere and Modified-Atmosphere Packing

Reduced oxygen and elevated carbon dioxide levels are basic practices of controlled atmosphere condition. The response of fresh-cut produce stored in controlled atmosphere is different from that of intact produce; therefore, fresh-cut produce should be stored differently and separately. On the other hand, because of the short handling period, controlled atmosphere may not be economically applicable for fresh-cut produce (Watada et al, 1996). Gas compositions in film-packed and edible-coated fresh-cut produce can be modified and this modification may extend storage life of fresh-cut produce (Watada et al., 1996; Schlimme, 1995).

Packing and Edible Coating

Fresh-cut produce may be packed or coated to reduce mechanical damage and water loss, to identify produce and to carry information to consumer (Schlimme, 1995). Nevertheless, packing may cause an increase in temperature that evokes higher respiration and ethylene production rates. Therefore, ethylene must be excluded or absorbed by ethylene absorbents such as charcoal or palladium chloride (Schlimme, 1995). Edible films reduce moisture loss, limit gas exchange, retard ethylene production and keep aroma inside (Ahvenainen, 1996). Lipids, resins, polysaccharides and proteins are the basic components of edible films (Baldwin et al., 1995). Some coatings may carry some additives that can prevent discoloration and microbial growth by serving as antioxidants and/or anti-microbial agents (Baldwin et al., 1995). Some of these additives are sucrose polyesters of fatty acids, sodium salts of carboxymethylcellulose, carrageenan and chitosan (Ahvenainen, 1996).

Chemical Application

Chemical applications are mostly used for reducing decay and browning, and retaining firmness in fresh-cut produce. Chlorine is the standard sanitizing agent for fresh-cut produce in proper concentrations (100 to 300 ppm; pH, 7). Higher chlorine concentrations (> 500 ppm) may cause fresh-cut produce to discolor, equipment to corrode and aromatic hazardous chloramines to form (Hurst, 1995). Hong and Gross (1998) reported that sodium hypochlorite caused some physiological and biochemical alterations in fresh-cut tomato fruit (higher electrolyte leakage and ethylene production). Sulphating agents are the most common chemicals for inhibiting browning reactions. In addition to sulphites, sodium dehydroacetic acid, potassium sorbate, citric acid, zinc, chloride and calcium chloride, resorcinol derivatives, and carbon dioxide, carbon monoxide, ascorbic acid (Ahvenainen, 1996), isoascorbic acid (Gonzales-Aguilar et al. 2005), honey (Jeon and Zhao, 2005), sodium hexametaphosphate, (Pilizota and Sapers, 2004) are used as anti-browning agents. Ascorbic acid (0.05 to 0.01 M) (Gonzales-Aguilar et al. 2005), calcium ascorbate (%7) (Fan et al., 2005) may also be used for maintaining quality of fresh-cut fruits. 1-methylcyclopropene an ethylene action inhibitor has showed some promising results in terms of maintaining quality of fresh-cut produce especially in apple (Jiang and Joyce, 2002), lettuce (Wills et al., 2002), tomato (Jeong et al., 2004), papaya and melon (Ergun, 2003).

Microorganisms

Microorganisms readily grow on and in fresh-cut produce, and some of them may be detrimental to human beings such as *Escherichia coli*. The following microorganisms have been found in fresh-cut produce: mesophilic bacteria, lactic acid bacteria, coliforms and fecal coliforms, yeast and molds, and pectinolytic microflora such as *Pseudomonas fluorescens* and *Xanthomonas maltophila* (Nguyen-the and Carlin, 1994). Mesophilic microflora is the largest population followed by lactic acid bacteria (Watada et al., 1996). Moreover, some food-borne microorganisms have been reported in fresh-cut produce that includes *Listeria monocytogenes*, *Yersinia enterocolitica*, *Aeromonas hydrophila* (Nguyen-the and Carlin, 1994; Alfred, 1994), *Staphylococcus aureus* (Nguyen-the and Carlin, 1994), *Escherichia coli* (Nguyen-the and Carlin, 1994; Alfred, 1994), *Salmonella* spp. (Nguyen-the and Carlin, 1994), *Clostridium botulinum* (Alfred, 1994), *Bacillus cereus, Giardia lamblia* (Beuchat, 1995), *Shigella* ssp., and *Plesiomonas shigelloides* (Alfred, 1994). The hepatitis A and Norwalk agent virus also have been reported in fresh-cut produce (Beuchat, 1995).

Microbial growth, particularly of human pathogens, may be inhibited by competing bacteria such as lactic acid bacteria or naturally existing antimicrobials released during fresh-cut processing (Luna-Guzman and Barrett, 2000). Low temperature is one of the most effective methods to control and prevent microbial growth (Nguyen-the and Carlin, 1994) while some of the organisms can survive in low temperatures such as *Listeria*, *Yersinia* and *Aeromonas* (Alfred, 1994). Before cutting, removing debris or remains from the product surface by brushing and washing is the first step taken against microorganisms. Washing fresh-cut produce with chlorine solution (up to 300 ppm) is another effective way to impede development of microorganisms (Nguyen-the and Carlin, 1994). This process cannot completely eliminate all microorganisms because microorganisms can survive when they are inside tissues where disinfectants cannot penetrate (Watada et al., 1996). Washing fresh-cut produce in trisodium phosphate is one of the other effective ways to control microbiological growth (Beuchat, 1995). Ozone, a strong oxidant, is also used for its lethal activity upon microorganisms at microgram per milliliter concentrations (Beuchat, 1995). Recently, the efficacy of methyl jasmonate upon microbial growth has been under investigation and showed some promising results in fresh-cut pineapples (Martinez-Ferrer and Harper, 2005).

In addition to chemical solutions, organic antagonism, gamma irradiation, dipping in hot water and edible coatings containing biochemical agents are also used for the control of microbial growth (Watada et al., 1996; Nguyen-the and Carlin, 1994). Irradiation is a safe, effective and hazard-free antimicrobial method (Farkas, 1998). *Campylobacter*, *Yersinia*, *Vibrio* and *Escherichia coli* have low resistance to ionizing radiation (Farkas, 1998). Slow ripening and senescence induced by restricted ethylene action or synthesis may extend the storage life of fresh-cut produce: in a less ripe condition, the growth of most opportunistic microorganisms would be expected to be retarded since they tend to grow most rapidly on senescent tissues (Zagory, 1999).

FUTURE RESEARCH DIRECTIONS

Some questions still remain especially concerning deterioration of fresh-cut produce and microbial involvement into this deterioration; therefore, researchers should before all else focus on these subjects. Once these issues are addressed, research direction should focus upon the biochemical processes concerning deterioration. Texture and membrane changes, and degreening and/or browning have priority in the list to be studied since they are more influential biochemical process upon the quality than others mentioned above. Maintaining quality will require more investigations upon internal and external quality factors addressed above. Especially, processing methods, modified atmosphere packing, packaging, coating and chemical application should be studied more intensively. More researches will be needed on microbial and chemical applications to obtain microbiologically and chemically safe produces. Finally, consumers demand food products with fewer synthetic additives but with increased safety, quality and shelf-life; therefore, natural antimicrobials and preserving methods should be extensively studied.

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