**Modifified atmosphere packaging for shelf life extension of fresh-cut apples**

**(气调包装可延长鲜切苹果的保质期)**

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Processing steps, such as cutting and peeling, increase the respiration rate and ethylene production of apples, quickening senescence phenomena with effects on texture, color and flflavor.(加工步骤（例如切皮和去皮）可提高苹果的呼吸速率和乙烯产量，加快衰老现象，并影响质地，颜色和风味) Modifified atmosphere packaging (MAP) and antioxidant pre-treatments are used to control the decay of fresh-cut apples during shelf life.(改良气调包装（MAP）和抗氧化剂预处理可控制鲜切苹果在保质期内的腐烂。) MAP has become a widely used food preservation technique as it minimally affects fresh product characteristics.(MAP已经成为一种广泛使用的食品保存技术，因为它对新鲜产品的影响最小。) The purpose of this paper was to discuss the inflfluence of conventional (O2, N2 and CO2) and alternative (Ar and N2O) MAPs as well as the interaction between anti-browning treatment and MAPs on ethylene production, fifirmness, browning, off-flflavor and sensory characteristics, contextualizing the results obtained in a case study on ‘Golden Delicious’ apple slices developed within the Stayfresh project.(本文的目的是讨论常规（O2，N2和CO2）和替代（Ar和N2O）MAP的影响，以及抗褐变处理和MAP在乙烯生产，牢固度，褐变，异味方面的相互作用。 以及感官特性，总结了在Stayfresh项目中开发的“金冠”苹果片案例研究中获得的结果。) The packaging under conventional modifified atmospheres, characterized by low O2 level (1 and 5%), and the alternative mix Ar + CO2 successfully preserved the fifirmness of apple slices during all refrigerated storage limiting the ethylene production, even if the preserving effificacy of MAP resulted almost completely nullifified by the dipping treatment, which caused a structural breakdown.(在传统的改良气氛下包装，其特征在于O2含量低（分别为1和5％），以及Ar + CO2的替代混合物在所有冷藏存储过程中成功地保持了苹果片的坚硬，从而限制了乙烯的生产，即使MAP的保存效果有所提高 通过浸入处理几乎完全无效化，从而导致结构破坏。) MAPs were not able to control the enzymatic browning if not combined with an anti-browning dipping treatment. It was highlighted the key role of sensory analysis in fifinding the best combination between MAP, anti-browning treatment and shelf life time. (如果不与抗褐变浸渍处理结合使用，MAPs将无法控制酶促褐变。 强调了感官分析在确定MAP，抗褐变处理和保质期之间的最佳组合中的关键作用)The contrasting results among the various research groups could be reasonably also due to the different periods and temperatures of shelf life.( 由于货架期的不同时期和温度的不同，各个研究小组之间的对比结果也可能是合理的。)

#### Introduction

Modifified atmosphere packaging (MAP) is a technique used for prolonging the shelf life of fresh or minimally processed food (Sandhya, 2010). MAP has become a widely used food preservation technique as it minimally affects fresh product characteristics and it is perceived as a natural and additive-free technique by consumers (Day, 1996). This preservation technique consists of substituting the air surrounding the food in the package with an atmosphere with a different composition. So the shelf life of perishable products like meat, fifish, fruit and vegetables could be prolonged with MAP delaying the physic-chemical changes related to quality loss of the product. The atmosphere composition in the package depends mainly on the type of product, but also on packaging materials and storage temperature.**(改良大气包装（MAP）是一种用于延长新鲜或最低加工食品保质期的技术（Sandhya，2010）。MAP已成为一种广泛使用的食品保鲜技术，因为它对新鲜产品的特性影响最小，而且被消费者视为一种天然的、无添加剂的技术（Day，1996）。这种保存技术包括用不同成分的空气代替包装内食品周围的空气。因此，map可以延长肉、鱼、水果、蔬菜等易腐产品的货架期，延缓与产品质量损失相关的理化变化。包装中的大气成分主要取决于产品的类型，也取决于包装材料和储存温度。**) As fruit and vegetables are respiring products, the interaction between the product and the packaging material is particularly important. The permeability of the packaging film for O2 and CO2 has to be suitable for the specific product respiration rate in order to establish a balanced modified atmosphere in the package. This packaging technology is the most commonly used for fresh-cut products. For packaging vegetables and fruit, the modified atmosphere usually consists of a lower O2 level and a higher CO2 level than those of air, which slow down the normal respiration rate, prolonging the shelf life of the product. Current low oxygen MAP techniques may suffer from some inherent disadvantages. Novel high O2 MAP is an innovative development that has been shown to be particularly effective in inhibiting enzymic discoloration, preventing anaerobic fermentation reactions and inhibiting both aerobic and anaerobic microbial growth (Day, 2001). It is hypothesized that active oxygen radical species damage vital cellular macromolecules and thereby inhibit microbial growth when oxidative stresses overwhelm cellular protection systems (Day, 2001). The microbiological aspect will not be in-depth analyzed in this review. (**由于水果和蔬菜是呼吸产品，产品与包装材料之间的相互作用显得尤为重要。包装膜对氧气和二氧化碳的渗透性必须与特定产品的呼吸速率相适应，以便在包装中建立一个平衡的改性气氛。这种包装技术是最常用的鲜切产品。对于蔬菜和水果的包装而言，与空气相比，改性后的空气通常含有较低的氧气和较高的二氧化碳，这会减慢正常的呼吸速率，延长产品的保质期。目前的低氧MAP技术可能存在一些固有的缺点。新型高氧map是一项创新性发展，已被证明在抑制酶变色、防止厌氧发酵反应以及抑制需氧和厌氧微生物生长方面特别有效（Day，2001）。据推测，活性氧自由基损伤重要的细胞大分子，从而抑制微生物生长时，氧化应激淹没细胞保护系统（天，2001）。微生物方面将不会在这篇综述中进行深入分析。**)

The three main conventional gases used in modifified atmosphere packaging are CO2, O2 and N2. They could be used singularly or in combination with the aim of safely extending product shelf life as well as preserving optimal sensory properties of the food(**改性气相包装中常用的三种气体是co2、o2和n2。它们可以单独使用，也可以与安全延长产品保质期以及保持食品最佳感官特性的目的结合使用。**).Recently, there has been a great interest in the potential benefifits of using argon and other noble gases for MAP applications (Mostardini & Piergiovanni, 2002; Spencer, 1995). Argon is a tasteless and odorless gas, denser than nitrogen, which is included in the positive list of food additives (E-398) and can be used as balance gas in MAP (Spencer, 2005). Another “new” packaging gas, nitrous oxide (N2O), has been allowed for food use in the EU (Day, 1996). Noble gases such as argon are in commercial use for products such as coffee and potato-based snack products. Day (2001) reported that a broad range of patents claim that argon, compared to N2, can more effectively inhibit enzymic activities, microbial growth and degradative chemical reactions in selected perishable foods. More specififically, an Air Liquide patent for fresh produce applications claims that Ar and N2O are capable of extending shelf life by inhibiting fungal growth, reducing ethylene emission and slowing down sensory quality deterioration (Fath & Soudain, 1992).(**最近，人们对在MAP应用中使用氩和其他惰性气体的潜在好处非常感兴趣（Mostardini&Piergiovanni，2002；Spencer，1995）。氩是一种无味无味的气体，比氮密度大，被列入食品添加剂的阳性清单（E-398），可作为MAP中的平衡气体（Spencer，2005）。另一种“新”包装气体，氧化亚氮（N2O），已获准在欧盟使用食品（日，1996）。氩气等惰性气体在商业上用于咖啡和土豆类零食等产品。Day（2001）报告称，大量专利声称，与N2相比，氩能更有效地抑制选定易腐食品中的酶活性、微生物生长和降解化学反应。更具体地说，液化空气新鲜产品申请专利声称ar和n2o能够通过抑制真菌生长、减少乙烯排放和减缓感官质量恶化来延长保质期（fath&soudain，1992）。**) However, literature data on their application and benefifits for the shelf life of fresh-cut fruit is limited (Char et al., 2012; Cocci, Rocculi, Romani, & Dalla Rosa, 2006; Rocculi, Romani, & Dalla Rosa, 2004; Rocculi, Romani, & Dalla Rosa, 2005). Recently, Wu, Zhang, and Wang (2012) have been coupling the use of argon with high pressure, finding that the inhibiting effect of argon was enhanced in such conditions because of the formation of a glass hydrate of the inert gas which, inhibiting the enzymatic reactions, reduced the metabolism of the product. This combination could be an effective method for improving quality of fresh-cut apples at cold storage conditions. **(然而，关于它们的应用和对鲜切水果保质期的益处的文献数据是有限的（Char等人，2012；Cocci、Rocculi、Romani和Dalla Rosa，2006；Rocculi、Romani和Dalla Rosa，2004；Rocculi、Romani和Dalla Rosa，2005）。最近，Wu、Zhang和Wang（2012）将氩气的使用与高压相结合，发现在这种情况下，氩气的抑制作用增强，因为惰性气体的玻璃水合物的形成抑制了酶反应，降低了产品的新陈代谢。该组合可作为提高鲜切苹果冷藏品质的有效方法。)**

This review is dedicated to MAP technology, applied to extend the shelf life of fresh cut apples with special attention to fruit physiology, quality characteristics such as texture (fifirmness), color (browning) and aroma (off-flflavor formation) and their relationship with sensory characteristics. The interaction between MAP and dipping treatment, applied to preserve color and texture, was also debated in depth. **(本文综述了MAP技术在延长鲜切苹果货架期方面的应用，着重介绍了苹果的生理特性、质地（硬度）、色泽（褐变）、香气（异味形成）等品质特性及其与感官特性的关系。地图和浸渍处理之间的相互作用，应用于保存颜色和纹理，也进行了深入的讨论。)**

**Ethylene 乙烯**

Ethylene is a natural plant hormone and plays a central role in the initiation of ripening and it is physiologically active in trace amounts (0.1 mL L1 ). On the strength of the role of ethylene in the ripening process, fruit can be divided into two groups (Lelievre, Latche, Jones, Bouzayen, & Pech, 1997):**(乙烯是一种天然的植物激素，在催熟过程中起着重要作用，在生理上有微量的活性（0.1毫升？1）。根据乙烯在果实成熟过程中的作用强弱，可将果实分为两组（乐力？埃弗雷，拉奇？E、Jones、Bouzayen和Pech，1997年）：)**

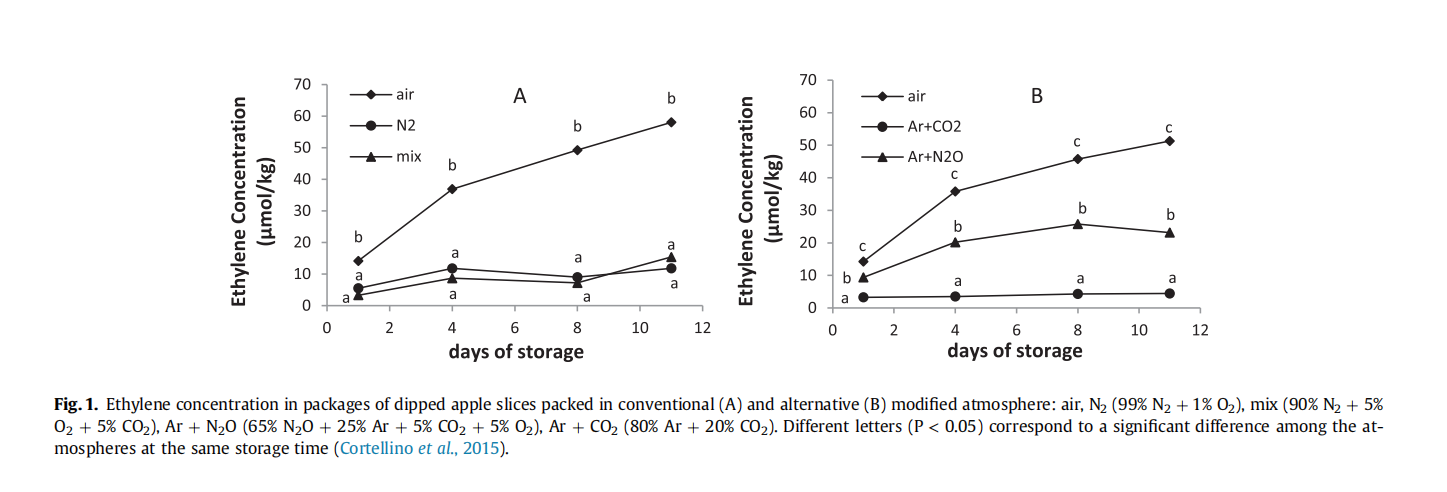
1 fruit that could produce large amount of ethylene, which promotes their ripening, defifined “climacteric”, such as tomato, peach, apple, banana and kiwifruit;

2 fruit that produce only low basal amount of ethylene during ripening and are insensitive to exogenous ethylene, defifined “non-climacteric”, such as grape, strawberry, watermelon, pineapple and citrus.**(1种果实能产生大量乙烯，促进果实成熟，定义为“跃变型”，如番茄、桃子、苹果、香蕉和猕猴桃；2种果实在成熟过程中只产生少量乙烯，对外源乙烯不敏感，定义为“非跃变型”，如葡萄、草莓、西瓜，菠萝和柑橘)**

For both fruit and vegetables the stress caused by technological steps, such as peeling and cutting, produces a physiological response with increased ethylene production and respiratory activity, with effects being observed very rapidly, often within minutes to a few hours (Toivonen & Brummel, 2008). The effect of wounding, caused by the several stages of producing fresh-cut products, can be more evident in climacteric fruit, for which wound-induced ethylene promotes ripening and softening. In climacteric fruit, wound-induced as well as exogenous ethylene may cause the same effect on tissue, causing a hastening of ripening and softening (Toivonen & Brummel, 2008). The general effects of ethylene are usually detrimental to fruit quality (Saltveit, 1999); therefore, its concentration or activity should be minimized to lengthen product shelf life. Being a climacteric-type fruit, apple results very sensitive to ethylene. It has been reported that low O2 atmospheres and elevated CO2 levels synergically act to reduce ethylene production and respiration rates, but could not completely stop senescence and tissue breakdown (Soliva-Fortuny & MartínBelloso, 2003a). On the other hand, super-atmospheric levels of O2 fail in extending the storability of fresh fruit and vegetables by enhancing the ethylene production (Kader & Ben Yehoshua, 2000).**(对于水果和蔬菜来说，由技术步骤（如剥皮和切割）引起的压力会产生一种生理反应，增加乙烯的产生和呼吸活动，这种反应会很快观察到，通常在几分钟到几小时内（Toivonen&Brummel，2008）。由鲜切产品生产的几个阶段引起的伤害效应，在跃变型果实中表现得更为明显，因为伤口诱导的乙烯促进果实成熟和软化。在更年期果实中，外源乙烯和伤口诱导的乙烯可能对组织产生同样的影响，导致催熟和软化（Toivonen&Brummel，2008）。乙烯的一般影响通常对水果质量有害（Saltveit，1999）；因此，应尽量减少其浓度或活性，以延长产品的保质期。苹果是一种跃变型水果，对乙烯非常敏感。据报道，低氧气和高二氧化碳水平协同作用，降低乙烯生产和呼吸速率，但不能完全阻止衰老和组织崩溃（soliva fortuny&martinbelloso，2003a）。另一方面，超常大气中的氧含量有助于通过提高乙烯产量来延长新鲜水果和蔬菜的贮藏能力（Kader&Ben Yehoshua，2000）。)**

The inhibition of ethylene production under anaerobic or low O2 conditions has been observed by many authors, suggesting that oxygen participates in the conversion of 1-amino-cyclopropane-1- carboxylic acid (ACC) to ethylene (Yang, 1981). The action of CO2 is complex. At low concentrations, carbon dioxide activates the biosynthesis of ethylene via the latter's role as co-factor for 1- aminocyclopropane-1-carboxylic acid (ACC) oxidase (Smith & John, 1993). At high concentrations, carbon dioxide may stimulate the activity of ACC oxidase while inhibiting its synthesis (Cheverry, Sy, Pouliquen, & Marcellin, 1988). A complete inhibition of ethylene in fresh-cut ‘Fuji’ apples stored under oxygen-free conditions was found by Gil, Gorny, and Kader (1998), Anese, Manzano, and Nicoli (1997) reported that fresh-cut ‘Golden Delicious’ apples packed in air showed a maximum headspace ethylene concentration between 8 and 16 days of storage, while those packed in presence of N2 as well as of CO2/N2 (80% CO2 þ 20% N2) did not produced ethylene in detectable amounts. Soliva-Fortuny, Oms-Oliu, and Martín-Belloso (2002) confifirmed that ethylene production of fresh-cut ‘Golden Delicious’ apple slices is almost completely inhibited in N2-packaged samples. In contrast, if air was used as initial atmosphere, ethylene dramatically increased just after processing and packaging, reaching a maximum concentration, 100-fold higher than in N2-packaged slices, at 10 days of storage. Successively ethylene concentration decreased in all bags, showing that its synthesis slowed down or even ceased after the fifirst 10 days of storage. Furthermore, Soliva-Fortuny, Ricart-Coll, and Martín-Belloso (2005), evaluating the internal atmosphere of ‘Golden Delicious’ apple cubes packaged under 0 kPa O2 and 2.5 kPa O2/7 kPa CO2, found that ethylene concentration increased dramatically from the fifirst hours after processing in both cases. Infact the ethylene developed similarly in the apple tissue for all treatments as long as the O2 was available for its biosynthesis.**(许多作者观察到在厌氧或低氧条件下乙烯的生成受到抑制，这表明氧参与了1-氨基环丙烷-1-羧酸（acc）向乙烯的转化（yang，1981）。二氧化碳的作用是复杂的。在低浓度下，二氧化碳通过乙烯作为1-氨基环丙烷-1-羧酸（ACC）氧化酶的辅因子（Smith＆John，1993）激活乙烯的生物合成。在高浓度下，二氧化碳可以刺激ACC氧化酶的活性，同时抑制其合成（ChEVRY，SY，PouLuunin，MaCelin，1988）。吉尔、Gorny和KaDER（1998）、AN、曼扎诺和Nicoli（1997）发现，在鲜切的富士苹果中，乙烯完全抑制在无氧条件下储存，新鲜包装的“金冠”苹果在空气中表现出最大的顶空乙烯浓度在8天和16天之间的储存，而那些包装。在存在n2和co2/n2（80%co2\_20%n2）的情况下，未产生可检测量的乙烯。soliva fortuny、oms oliu和mart in-belloso（2002）证实，在n2包装的样品中，鲜切的“金色美味”苹果片的乙烯生产几乎完全受到抑制。相反，如果空气被用作初始气氛，乙烯在加工和包装之后显著增加，达到最大浓度，比N2包装切片高100倍，在10天的储存。各袋乙烯浓度依次下降，表明贮藏前10天乙烯合成速度减慢甚至停止。此外，Soliva Fortuny、Ricart Coll和Martín-Belloso（2005年）评估了在0 kPaO2和2.5 kPaO2/7kPaCO2下包装的“黄金美味”苹果立方体的内部气氛，发现两种情况下，乙烯浓度从加工后的第一个小时开始显著增加。事实上，在所有处理中，只要有氧可用于其生物合成，苹果组织中的乙烯也会产生类似的变化。)** The maximum concentrations of ethylene, induced by wounding response, were reached between the fifirst and the second week of storage. However, after the fifirst week, internal ethylene concentrations resulted substantially lower in fresh-cut apples packaged under 0 kPa O2 initial atmospheres, whereas the different oxygen permeability of the plastic material (15 and 30 cm3 O2 m2 bar1 day1 ) did not have a signifificant effect on ethylene evolution. The same authors confifirmed that packaging under restrictive O2 conditions limited ethylene response. Moreover they observed that ethylene response of the apple tissue, also after re-exposure to atmospheric conditions, was slightly lower for samples stored under initial conditions of anoxia. Rojas-Graü, Grasa-Guillem, and Martín-Belloso (2007) also confirmed that ethylene production was noticeably higher in Fuji’ apple slices packaged under initial air atmosphere, achieving a maximum concentration of 60 mL L1 after one week of storage. In contrast, apple slices packaged under 2.5 kPa O2 þ 7 kPa CO2 produced less ethylene and reached a maximum peak of 35 mL L1. Contrasting results have been obtained when the influence of the dipping step in antibrowning agents, applied to preserve color, on ethylene production was investigated. Soliva-Fortuny et al. (2002) demonstrated that dipping in ascorbic acid and calcium chloride did not entail noticeable changes in ethylene concentrations compared with samples where a dip was not carried out. **(乙烯的最大浓度，由伤人反应诱导，在贮藏的第一周和第二周之间达到。然而，在第一周之后，在0 kPaO2初始空气中包装的鲜切苹果的内部乙烯浓度显著降低，而塑料材料（15和30 cm3O2m？2巴？1天？1）对乙烯释放没有显著影响。同一作者证实了限制性氧条件下的包装限制了乙烯反应。此外，他们还观察到，在大气条件下，苹果组织的乙烯反应在初始缺氧条件下储存的样品略低一些。Rojas Gra·U、Grasa Guillem和Malti-N-BeloSO（2007）也证实了在初始空气气氛下包装的富士苹果片中乙烯的产量明显较高，达到最大浓度为60 mL L。1储存一周后。与此相反，苹果片包装在2.5千帕O2，7千帕乙烯较少，达到最大峰值35毫升L？一。研究了用于保色的防褐变剂浸渍步骤对乙烯生产的影响，得到了对比结果。Soliva Fortuny等人（2002）证明，与未进行浸渍的样品相比，在抗坏血酸和氯化钙中浸渍不会引起乙烯浓度的显著变化)**RojasGraü et al. (2007) confirmed that ethylene production of fresh-cut apples was not affected by ascorbic acid but the ethylene evolution was signifificantly reduced by N-acetylcysteine. Previously, Gilet al. (1998), analyzing the interaction between ascorbic acid dips with headspace atmospheres with or without oxygen on ‘Fuji’ apple slices, found that this type of dipping reduced ethylene production only when air atmosphere packaging was used.**(Rojasgraü等（2007）证实了鲜切苹果的乙烯生产不受抗坏血酸的影响，但N-乙酰半胱氨酸显著降低了乙烯的释放。之前，Gil G.Cortellino等人/食品科学与技术趋势46（2015）320E330 321等（1998）分析了“富士”苹果切片上抗坏血酸浸提液与有氧或无氧顶空空气的相互作用，发现只有在使用空气-空气包装时，这种浸提液才能减少乙烯的生成。)**

The results obtained by Cortellino, Rizzolo, and Gobbi (2015) for‘Golden Delicious’ apple slices were in agreement with literature data as it is shown in Fig. 1. Ethylene headspace concentration (Fig. 1A) was noticeably higher in apples packaged under air atmosphere, achieving a maximum concentration after 11 days of cold storage at 4 C with slightly different quantity in the two different experiments (51 and 58 mmol/kg). In contrast, apple slices packaged under either nitrogen (99% N2 + 1% O2) or in a mixture of conventional gases (90% N2 +5% O2 + 5% CO2) produced a very small quantity of ethylene (max 15 mmol/kg) with a similar trend during cold storage. To our knowledge there are no studies on the effect of alternative modified atmosphere on the evolution of ethylene during cold storage; so, the Cortellino et al. (2015) trial is the first research which tried to fifill this gap. ‘Golden Delicious’ apple slices packaged in an argon and nitrous oxide mixture (65% N2O +25% Ar + 5% O2 + 5% CO2) produced ethylene with a maximum peak (25 mmol/kg) at 8 days (Fig. 1B), which was lower than the ethylene production found for slices packed in air, but higher than those found for conventional MAPs (Fig. 1A). In contrast, the Ar and CO2 mixture (80% Ar + 20% CO2) was able to completely inhibit ethylene accumulation for the whole cold storage period. Moreover, Cortellino et al. (2015) results highlighted that the argon and nitrous oxide mixture (65% N2O + 25% Ar + 5% O2 + 5% CO2) was less effective in inhibiting ethylene production than the conventional mixture (90% N2 +5% O2 + 5% CO2), even though both atmospheres were characterized by the same percentage of O2 (5%).**(Cortellino、Rizzolo和Gobbi（2015）对“黄金美味”苹果切片的研究结果与文献数据一致，如图1所示。在空气中包装的苹果中，乙烯顶空浓度（图1A）明显较高，在4℃冷藏1天后达到最大浓度。c在两个不同的实验（51和58 mmol/kg）中的量略有不同。相比之下，在氮气（99%N2 1%O2）或传统气体（90%N2 5%O2 5%CO2）的混合物中包装的苹果切片在冷藏过程中产生的乙烯量非常小（最大15 mmol/kg），趋势相似。据我们所知，目前还没有关于替代改性气氛对冷藏过程中乙烯释放的影响的研究；因此，Cortellino等人（2015）试验是第一个试图填补这一空白的研究。用氩气和氧化亚氮混合物（65% N2O 25% Ar 5% O2 O2 5% CO2）包装的“金冠”苹果片在8天（图1B）中产生最大峰值（25毫摩尔/千克）的乙烯，其低于在空气中填充的切片所发现的乙烯产量，但高于常规地图所发现的乙烯（图1A）。相比之下，ar和co2（80%ar掔20%co2）能够在整个冷藏期内完全抑制乙烯的积累。此外，Cortellino等人（2015）结果表明，氩气和氧化亚氮混合物（65% N2O＝25%氩5% O2 O2 5% CO2）在抑制乙烯生成方面比常规混合物（90% N2×5% O2 5% CO2）效果差，即使两个气氛的O2（5%）的百分比相同。)** This finding disagrees with Leshem and Wills (1998) results suggesting that N2O is a potent antagonist of ethylene production as well of its action. Furthermore the antiethylene effects of a continuous 80% N2O + 20% O2 gas treatment in the ripening and senescence sequences in two typical climacteric fruit, tomato and avocado, was demonstrated for the first time by Gouble, Fath, and Soudain (1995). In preclimateric treated fruit, nitrous oxide largely extended the lag period, and additively lowered ethylene production rate in tomatoes. In fruits treated at the climacteric stage, nitrous oxide markedly inhibited autocatalytic ethylene evolution. Little is known about the mechanism of action of N2O on plants. Nitrous oxide is known to bind to lipids and also to proteins, such as cytochrome c oxidase (Gouble et al., 1995). Sowa and Towill (1991) reported the action of N2O on partial and reversible inhibition of respiration and cytochrome c activity in mitochondrial particles isolated from seed, leaf or cellular suspensions.**(这一发现与Leshem和Wills（1998）的研究结果不一致，他们认为N2O是乙烯生成及其作用的有效拮抗剂。此外，gouble、fath和soudain（1995）首次证明了连续80%n2o\_20%o2gas处理对两种典型的更年期水果番茄和鳄梨的成熟和衰老序列的抗乙烯作用。在预气候处理的水果中，氧化亚氮大大延长了滞后期，并进一步降低了番茄的乙烯产量。在更年期处理的果实中，氧化亚氮显著抑制了自催化乙烯的生成。对n2o对植物的作用机理知之甚少。氧化亚氮是已知的结合脂质和蛋白质，如细胞色素C氧化酶（等，1995）。sowa和towill（1991）报道了n2o对种子、叶片或细胞悬浮液中线粒体颗粒呼吸和细胞色素c活性的部分和可逆抑制作用。)**



**Firmness 硬度**

Many quality degradations occurs during processing and storage of fruit, but softening is one of the most undesirable effects. Consumer has an expectation that processing and storing a product will not interfere with the anticipated sensory properties. So limiting the textural changes in minimally processed apples is highly important in order to get the consumer acceptance of the product. Firmness is determined largely by the physical anatomy of the tissue (cell size, shape and packing, cell wall thickness and strength), and the extent of cell-to-cell adhesion, together with turgor status (Toivonen & Brummel, 2008). The severity of wounding (peeling, coring and slicing) can be greater for climacteric fruit for which wound-induced ethylene promotes ripening and softening. Another factor involved in the decline of desirable texture is water loss, which leads to a decrease in turgor and crispness. It is rapid in fresh-cut product due to the absence of a cuticle and sub-epidermal layers and, hence, to the exposure of internal tissue.**(果实在加工和贮藏过程中会出现许多品质退化现象，但软化是其中最不理想的影响之一。消费者期望产品的加工和储存不会干扰预期的感官特性。因此，限制最小加工苹果的纹理变化对于获得消费者对产品的认可是非常重要的。硬度在很大程度上取决于组织的物理解剖（细胞大小、形状和堆积、细胞壁厚度和强度）、细胞与细胞的粘附程度以及肿胀状态（Toivonen&Brummel，2008）。越年期果实的损伤（剥皮、去皮和切片）严重程度可能更大，因为伤口诱导乙烯促进果实成熟和软化。另一个导致理想质地下降的因素是水分流失，这会导致膨胀度和脆度下降。由于没有角质层和亚表皮层，因此在新鲜的切割产品中，由于暴露在内部组织中，它的速度很快。)** This degenerative phenomenon can be greatly delayed by appropriate packaging (Toivonen & Brummel, 2008). Physical and chemical changes may affect textural integrity, but also the enzymatic hydrolysis of cell wall pectic substances, due to mechanical stress of plant tissues, resulting in a loss of firmness (Varoquaux, Lecendre, & Varoquaux, 1990). Specififically, softening may also be caused by the hydrolysis of protopectins to water soluble pectins, the decrease in cellulose crystallinity, thinning of cell walls, diffusion of sugar to the intercellular spaces, ion movement from the cell wall (Toivonen & Brummel, 2008). Therefore it is difficult to preserve the texture of fresh-cut apples. **(适当的包装可以大大延缓这种退化现象（Toivonen&Brummel，2008）。由于植物组织的机械应力，物理和化学变化可能影响组织的完整性，也可能影响细胞壁果胶物质的酶水解，从而导致硬度的丧失（Varoquaux，Lecentre和Varoquaux，1990）。具体而言，软化也可能是由原果胶水解为水溶性果胶、纤维素结晶度降低、细胞壁变薄、糖向细胞间隙扩散、离子从细胞壁移动引起的（Toivonen&Brummel，2008）。因此，鲜切苹果的质地很难保存。)**Varoquaux and Wiley (1997) reported that modified atmospheres may limit the loss of compartmentalization within cells and the interaction of enzymes, such as polygalacturonases and pectin esterases, with their substrates. Many studies have demonstrated that the decrease of apple firmness during storage time is strongly dependent on the availability of oxygen, given mainly by packaging atmosphere but also by permeability of the package plastic material. The research group of Soliva-Fortuny tested the packaging in 100% N2 combined with bags of low oxygen permeability (15 cm3 O2 m2 bar1 day1 ), with effective results in preserving apple softening till 21 (SolivaFortuny et al., 2005) and 60 (Soliva-Fortuny, Lluch, Quiles, Grigelmo-Miguel, & Martín-Belloso, 2003b; Soliva-Fortuny et al., 2002) days of storage. **(Varoquaux和Wiley（1997）报告说，改良的大气可以限制细胞内的细胞分裂损失以及酶（如多聚半乳糖醛酸酶和果胶酯酶）与其底物的相互作用。许多研究表明，苹果在贮藏过程中硬度的下降很大程度上取决于氧气的有效性，氧气的有效性主要取决于包装气氛，也取决于包装塑料材料的渗透性。soliva fortuny的研究小组在100%n2o和低透氧袋（15cm3o2m？2巴？1天？1），有效地将苹果软化保存至21天（Solivafortuny等人，20 0 5）和60天（Soliva Fortuny，Lluch，Quiles，Grigelmo Miguel，和Martín-Belloso，2003b；Soliva Fortuny等人，2002）。)**An interesting evaluation of microstructural modification by CryoeScanning Electron Microscopy (SolivaFortuny et al., 2003b) identified the formation of a great quantity of exudates, as droplet-shape on the external surface of the cell walls, in fresh-cut apples stored under 2.5% O2 + 7% CO2 atmosphere, while sample stored under 100% N2 showed an intermediate state of deterioration between fresh apple and those packed in 2.5% O2 + 7% CO2 gas mixture, with droplets formation on cell surface, but also smooth and more integer cell walls.**(通过冷冻扫描电子显微镜（Solivafortuny等人，2003b）对微观结构改性进行了有趣的评估，确定了在2.5%O2\_7%Co2atmosphere下储存的新鲜切苹果中，大量渗出物的形成是细胞壁外表面上的液滴形状，而在100%N2下储存的样品显示新鲜苹果与2.5%o2\_7%co2gas混合包装苹果的中间变质状态，细胞表面有液滴形成，细胞壁光滑且更完整)** The reason of this behavior may be the maintenance of an aerobic metabolism, as long as O2 is available in the tissue, that causes cell damages. Contrasting results were obtained by Rojas-Graü et al. (2007), who found that firmness of apple slices was not significantly affected either by the composition of the packaging atmosphere (air and 2.5% O2 + 7% CO2) or by the dipping treatment, but it was greatly influenced by the type of antibrowning agent used. In fact apple slices processed from ripe fruit and dipped in ascorbic acid solution presented lower values of firmness than slices treated with Nacetylcysteine, independently of packaging atmosphere, even though this phenomenon was not observed for samples prepared from mature-green and partially ripe fruit. This effect was reported also by Ponting, Jackson, and Watters (1972), who demonstrated that acid solutions containing ascorbic acid significantly reduced apple slice firmness.**(这种行为的原因可能是有氧代谢的维持，只要组织中有氧，就会造成细胞损伤。由Rojas Graüet al.（2007年），世界卫生组织发现，苹果切片的硬度不受包装空气成分（空气和2.5%O2\_7%CO2）或浸渍处理的显著影响，但受使用的抗褐变剂类型的影响很大。事实上，从成熟水果加工的苹果切片，浸在抗坏血酸溶液中，其硬度值低于用Nactylcysteine处理的切片，与包装气氛无关，尽管从成熟的绿色水果和部分成熟的水果制备的样品没有观察到这种现象。Ponting，Jackson和Watters（1972）也报道了这种效应，他们证明了含有抗坏血酸的酸性溶液显著降低了苹果切片的硬度)**

Few research data are available about the preserving action onfirmness of non-conventional gases (Ar and N2O). Rocculi et al.(2004) found that firmness increased in all samples of ‘GoldenDelicious’ apple slices packed both in air and in MAP, and suggested that this result may be explained by the effect of CaCl2 used in the dipping solution, as confirmed in other experiments (Abbott,Conway, & Sams, 1989; Glenn & Poovaiah, 1990). However, apple slices packed in modified atmospheres composed of 5% O2, 5% CO2 together with N2O and/or Ar (the remaining 90%) showed the greatest firmness increase throughout 12 days of cold storage. On the other hand, Cocci et al. (2006), testing the mixture 90% N2O þ 5% O2 þ 5% CO2, obtained conflicting results. In fact, apple slices without dipping treatment packaged in MAP (sample MA)

showed the highest firmness values for all the storage period, while those packaged in air (control) had slightly but not significantly decreasing firmness at the end of storage. In contrast, dipped apple slices showed about a 50% firmness decrease (from 8.50 to 4.50 N)just after 1 day of cold storage, maintaining these levels until the end of the experiments, independently of the MA used. This finding confirmed that the dipping treatment in ascorbic and citric acids solution caused a structural breakdown of the fruit, with consequent softening of apple tissue, as also confirmed by other researchers (Gil et al.,1998; Ponting et al., 1972; Rojas-Graü et al.,2007). Furthermore, Pardilla, Mor-Mur, Vega, and Guri (2015)verified that the firmness loss of ‘Golden Delicious’ apple slices,treated with 35% CO2 + 5% O2 þ 60% N2 atmosphere was statistically lower than in slices packaged in 90% Ar + 5% CO2 + 5% O2 and90% N2 + 5% CO2 + 5% O2 atmospheres between days 0 and 4;however, the presence of argon did not improve firmness propertyrespect to the regular gas mixture.**(关于非常规气体（ar和n2o）对硬度的保护作用的研究资料很少。Rocculi等人（2004）发现在空气和MAP中包装的“金色美味”苹果切片的所有样品的硬度都增加了，并建议这一结果可以用浸泡溶液中使用的CaCl2的效果来解释，其他实验也证实了这一点（Abbott、Conway和Sams，1989；Glenn和Pooviah，1990）。然而，在由5%o2、5%co2、n2o和/或ar（剩下的90%）组成的改性气氛中包装的苹果切片在整个冷藏12天内表现出最大的硬度增加。另一方面，Cocci等人（2006）对90%n2o\_5%o2\_5%co2的混合物进行测试，得到了相互矛盾的结果。事实上，未经浸渍处理的苹果片在map（样品ma）中的硬度值在整个贮藏期间最高，而空气（对照）中的硬度值在贮藏结束时略有下降，但没有显著下降。相比之下，浸过的苹果切片在冷藏1天后硬度下降了50%（从8.50 N降到4.50 N），在实验结束前保持在这个水平，与使用的MA无关。这一发现证实了在抗坏血酸和柠檬酸溶液中浸泡处理会导致果实的结构破坏，从而导致苹果组织软化，其他研究人员也证实了这一点（Gil等人，1998年；Ponting等人，1972年；Rojas Graü等人，2007年）。此外，Pardilla、Mor Mur、Vega和Guri（2015）证实，在第0天到第4天期间，用35%CO2+5%O2+60%N2atmosphere处理的“金色美味”苹果切片的硬度损失在统计学上低于用90%Ar+5%CO2+5%O2和90%N2+5%CO2+5%O2atmosphere包装的切片；然而，氩的存在并没有提高天然气混合物的硬度。)**

On the other hand Cortellino et al. (2015) results concerning firmness of undipped ‘Golden Delicious’ apple slices showed that the conventional mixtures 99% N2+ 1% O2 and 90% N2 + 5% O2 +5%CO2 (Fig. 2) preserved better this important quality parameter than air atmosphere, even though the difference was not always statistically significant. If the other atmospheres studied by Cortellino et al. (2015) are considered, the Ar+ CO2 combination (80%Ar + 20% CO2) (Fig. 2) positively and significantly influenced firmness of apple slices during the whole shelf life. In contrast, the Ar + N2O mix (65% N2O + 25% Ar + 5% O2+ 5% CO2) had not any influence on slice firmness, as Ar + N2O packaged slices were as firm as those packed in air. Furthermore, Cortellino et al. (2015) found that the beneficial effect of modified atmosphere on slice firmness was completely nullified by the dipping treatment for the conventional mixes and only partially for the Ar + CO2 combination, whose samples were char acterized by somewhat higher, even if not significant, firmness values. This neutralizing effect of dipping treatment with anti-browning agents (ascorbic and citric acids) on MAP preservation tissue apple from softening was in agreement with Cocci et al. (2006) and Rojas-Graü et al. (2007) findings. Even though the ethylene production of undipped slices might have been slightly different compared with that of dipped apples, as found by Gil et al. (1998) and Rojas-Graü et al. (2007), the results of undippedapple firmness confirmed the relationship between ethylene production and firmness retention during the shelf life.**(另一方面，Cortellino等人（2015）关于未开发的“金色美味”苹果切片硬度的结果表明，传统混合物99%N2\_1%O2和90%N2\_5%O2\_5%CO2（图2）比空气中保存的这一重要质量参数更好，尽管差异并不总是具有统计学意义。如果其他大气由Cortellino等人研究。考虑到（2015年），Ar\_Co2混合物（80%Ar\_20%CO2）（图2）在整个货架期内对苹果切片的硬度产生积极而显著的影响。相比之下，ar\_n2o混合物（65%n2o\_25%ar\_5%o2\_5%co2）对切片硬度没有任何影响，因为ar\_n2o包装切片与空气包装切片一样坚硬。此外，Cortellino等人（2015）发现，传统混合物的浸渍处理完全抵消了改性气氛对切片硬度的有益影响，而ar\_co2混合物的浸渍处理仅部分抵消了这一影响，其样品的硬度值稍高，即使不显著。抗褐变剂（抗坏血酸和柠檬酸）浸泡处理对MAP保存组织苹果软化的中和作用与Cocci等人一致。（2006）和Rojas Graüet al.（2007）调查结果。尽管gil等人发现，未浸切切片的乙烯生成量可能与浸切苹果的乙烯生成量略有不同。（1998）和Rojas Graü等人。2007年，未剥皮的苹果硬度结果证实了货架期乙烯产生与硬度保持之间的关系。)**

**Browning 褐变**

The appearance of a fresh-cut fruit is the attribute with the most immediate impact on the consumer and strongly affects the decision to buy (Toivonen & Brummel, 2008). This represents a problem especially for fruit with a white flesh such as apple and pear. The oxidative browning process is triggered by the breakdown of membranes inside cells of plant tissues (Toivonen, 2004) and by the resulting mixing of polyphenol substrates with polyphenol oxidase (PPO). In the presence of oxygen, the enzyme PPO catalyzes two reactions: (1) hydroxylation of monophenols to diphenols and (2) oxidation of diphenols to quinones. The hydroxylation reaction is relatively slow and results in colorless products, while the oxidation reaction is relatively rapid and the resultant quinones are colored. Subsequent reactions of the quinones lead to melaninaccumulation, which is the brown or black pigment associated to“browning” in plant tissues. **(新鲜水果的外观是对消费者最直接影响的属性，并强烈影响购买决定（Toivonen&Brummel，2008）。这代表了一个问题，特别是对于果肉白色的水果，如苹果和梨。氧化褐变过程是由植物组织细胞内的膜破裂引起的（Toivonen，2004年），以及多酚底物与多酚氧化酶（PPO）的混合引发的。在氧的存在下，PPO催化两种反应：（1）羟甲基化为羟甲基化，（2）醌氧化为醌。羟基化反应相对缓慢，导致无色产物，而氧化反应相对较快，合成醌着色。醌的后续反应导致黑色素的积累，黑色素是与植物组织中的“褐变”有关的棕色或黑色色素。)**The specific reaction sequence which results in brown or black-colored products depends on the specific structure of the polyphenolic substrate (Toivonen & Brummel,2008). Tissue browning is mostly due to changes in lightness (L\*)and in the greenness-redness (a\*) of the pulp and may be caused bythe enzymatic action of catechol oxidases, which are the most common polyphenol oxidases in apple fruit (Harel, Mayer, & Shain,1964). The most important factors that determine the rate ofenzymatic browning in fruit and vegetables are the concentrations of both active PPO and phenolic compounds, the pH, the temperature and the oxygen availability of the tissue (Martinez &Whitaker, 1995).**(产生棕色或黑色产物的具体反应顺序取决于多酚底物的具体结构（Toivonen＆Brummel，2008）。 组织褐变主要是由于果肉的亮度（L \*）和绿色-红色（a \*）的变化所致，可能是由于儿茶酚氧化酶的酶促作用引起的，这是苹果果实中最常见的多酚氧化酶（Harel， Mayer＆Shain，1964）。 决定水果和蔬菜中酶促褐变速率的最重要因素是活性PPO和酚类化合物的浓度，组织的pH值，温度和氧气可用性（Martinez＆Whitaker，1995）)** As oxygen is required by PPO at the site of wounding to initiate the browning reaction, the exclusion of O2 is used in juices and wines, by bottling them under nitrogen, in order to prevent the onset of this degrading phenomenon (Martinez &Whitaker, 1995). To this aim the use of O2-impermeable packaging or edible films may also be useful. Because the O2 is needed for browning reactions, MAP with low O2 and high CO2 levels can positively contribute to avoid browning in fresh-cut products.However, low O2 and elevated CO2 atmospheres can not effectivelyinhibit browning of fresh-cut fruit and vegetables such as apple,banana, pear, potato or artichoke, because of their high phenolic content (Rojas-Graü, Oms-Oliu, Soliva-Fortuny, & Martín-Belloso,2009). Consequently MAP system has to be combined with antioxidant treatments to delay browning of fresh-cut tissues. **(由于PPO在伤口处需要氧气才能引发褐变反应，因此将果汁和葡萄酒中的氧气排除在氮气中装瓶以防止这种降解现象的发生（Martinez＆Whitaker，1995）。为此目的，使用不透氧包装或食用薄膜也可能是有用的。由于褐变反应需要氧气，所以低氧气浓度和高二氧化碳浓度的MAP有助于避免鲜切产品的褐变。然而，由于新鲜水果和蔬菜（如苹果、香蕉、梨、土豆或洋蓟）的高酚含量，低氧和高二氧化碳气体不能有效抑制其褐变（Rojas Graü、Oms Oliu、Soliva Fortuny和Martín-Belloso，2009）。因此，MAP系统必须与抗氧化剂处理相结合，以延缓鲜切组织的褐变。)**Soliva-Fortuny et al. (2002) for ‘Golden Delicious’ apple slices reported a limited action of the depletion of L\* values throughout storage (60 days) by the packaging under 100% N2 in comparison with air, independently of dipping treatment. The same author (Soliva-Fortuny, Grigelmo-Miguel, Odriozola-Serrano, Gorinstein,& Martín-Belloso, 2001) proved that N2 combined with the use of packaging with low oxygen permeability was more efficient than 2.5% O2 +7% CO2 atmosphere in limiting color difference (DE) and the change of L\* value. **(Soliva Fortuny等人（2002）对于“黄金美味”苹果片，报告了在整个贮藏期间（60天）在100%N2下包装（与空气相比）损失L\*值的有限作用，与浸渍处理无关。1.同一作者（Soliva Fortuny、Grigelmo Miguel、Odriozola Serrano、Gornstein和Martín-Belloso，2001）证明N2与低透氧包装相结合在限制色差（De）和L\*值变化方面比2.5%O2+7%Co2atmosphere更有效。)**However, Soliva-Fortuny et al. (2001) described also an intense reduction of enzymatic activity (PPO) by the presence of CO2 (2.5% O2 + 7% CO2 +90.5% N2) compared with nitrogen (100% N2) in the packaging atmosphere. Similar results were previously observed for not treated sliced apples packed in presence of CO2/N2 (20:80 v/v) (Nicoli, Anese, & Severino, 1994) and N2 (Anese et al., 1997) atmospheres: in both the experiments a limited decrease of hue angle coupled to a limited increase of lightness difference between the final and the initial L\* values (DL\*) were found. Rojas-Graü et al. (2007) proved that browning intensity of apples dipped in N-acetylcysteine solution, evaluated by a decrease in L\* value, was much higher in samples packaged under air than those packed under 2.5% O2+ 7% CO2 atmosphere, whereas apple slices dipped in ascorbic acid, showing lower initial L\* values (about 72) than samples treated with N-acetylcysteine (about 76), behaved independently of packaging atmosphere.**(然而，Soliva Fortuny等人（2001）还描述了包装大气中二氧化碳（2.5%O2+7%CO2+90.5%N2）与氮气（100%N2）相比，酶活性（PPO）的强烈降低。先前观察到的类似结果是，未经处理的切片苹果在存在CO2/N2（20:80 V/V）（Nicoli，Anese和Severino，1994）和N2（Anese等人，1997）的大气中包装:在两个实验中，都发现色相角的有限减小与最终L \*值和初始L \*值（DL \*）之间的亮度差的有限增大有关。 Rojas-Graü等。 （2007年）证明，浸泡在N-乙酰半胱氨酸溶液中的苹果褐变强度（通过L \*值的降低来评估）在空气中包装的样品中要比在2.5％O2 + 7％CO2大气中包装的样品高得多，而将苹果片浸在空气中包装 抗坏血酸的初始L \*值（约72）比用N-乙酰半胱氨酸处理的样品（约76）低，其表现与包装气氛无关。)**

Rocculi et al. (2004) tested the efficiency of alternative (Ar and N2O) modified atmospheres for the inhibition of browning phenomenon obtaining positive results. In fact apple slices packed in 90% N2O + 5% CO2 + 5% O2 and in 65% N2O + 25% Ar + 5% CO2 + 5%O2 atmospheres showed higher values of whiteness index and hue angle as well as lower Chroma (less saturated color) than apple slices packed in air and in the conventional mix (90% N2 +5%CO2 + 5% O2). **(Rocculi等人（2004）测试了替代（ar和n2o）改性气氛对褐变现象的抑制效果，获得了肯定的结果。事实上，在90%n2o+5%co2+5%o2和65%n2o+25%ar+5%co2+5%o2atmospheres中包装的苹果切片，其白度指数和色调角的值都高于在空气和常规混合物（90%n2+5%co2+5%o2）中包装的苹果切片，且色度（饱和颜色较低）。)**These results were also confirmed by image analysis,as samples packed in N2O-Ar mixture showed the lowest browning level (15% of browning area) and those packed in N2O-CO2-O2mixture an intermediate level (about 25%) in comparison with air(about 70%) and conventional mix (about 80%). The authors hypothesized that these results could be due to the higher solubility of Ar respect to N2 and that Ar is in competition with O2 at chemicalenzymatic level; in fact argon, having the same solubility andmolecular weight as O2, replaces it causing PPO inhibition (Day,1996). Moreover Spencer's (1995) experiments indicated that noble gases are biochemically active, probably due to their highersolubility in water compared with nitrogen and to the possibleinterference with enzymatic oxygen receptor sites. In Rocculi et al.(2004) experiment these effects could be enhanced due to the lowpackaging permeability, that allowed the retention of MA inside theboxes, as well as to the interaction of MA with the product. **(这些结果也通过图像分析得到了证实，因为与空气相比，装在N2O-Ar混合物中的样品显示出最低的褐变水平（占褐变面积的15％），而装在N2O-CO2-O2中的混合物显示出中等水平（约25％） （约70％）和常规混合（约80％）。作者假设，这些结果可能是由于Ar对N2的溶解度更高，并且Ar在化学酶水平上与O2竞争；实际上，具有与O2相同的溶解度和分子量的氩气会取代它而引起PPO抑制（Day，1996）。此外，Spencer（1995）的实验表明，惰性气体具有生物化学活性，这可能是因为它们在水中的溶解度高于氮，并且可能干扰酶氧受体的位置。在Rocculi等人。（2004）实验由于低的包装渗透性，使MA保留在盒子内，以及MA与产品的相互作用，这些效果可以得到增强。)**In another experiment carried out by Cocci et al. (2006), it was provedthat the N2O mixture (90% N2O + 5% CO2 + 5% O2) was efficient in limiting color change provided that its use was combined with antibrowning dipping (ascorbic and citric acids). In fact there was not any significant difference in the level of percent browning area between not dipped samples packed in air and in the N2O mixture,showing the highest values (around 90%) just after the first day of storage, and maintaining high levels of percent browning area until the end of the experiment (from about 70 to 85%)**.(在Cocci等人进行的另一项实验中。（2006）证明了n2o混合物（90%n2o+5%co2+5%o2）与抗褐变浸渍（抗坏血酸和柠檬酸）结合使用可以有效地限制颜色变化。事实上，未浸过的样品在空气中的褐变率与在n2o混合物中的褐变率没有显著差异，在贮藏的第一天之后出现了最高值（约90%），并且在实验结束之前一直保持较高的褐变率（从约70%到85%）。)** On the other hand, if dipping was applied, sample packed in modified atmosphere showed a significant lower browning level (ranging from 10 to 20%) over all the storage period than those packed in air, whose browning area ranged from about 25% just after 1 day to about 50% after 6 days of cold storage. Concerning the influence of argon on polyphenol oxidase (PPO), a specific study on mushroom and apple conducted by O'Beirne, Murphy, and Ni Eidhin (2011) demonstrated that apple and mushroom PPO were more inhibited by atmospheres enriched with argon than by those enriched with nitrogen: at each concentration of argon, the Km value (constant of MichaeliseMenten) of mushroom and apple PPO was greater than that for the corresponding level of nitrogen. Atmospheres containing low level of O2 (air enriched with nitrogen) are known to inhibit PPO reducing the availability of oxygen through dilution (Ballantyne, Stark, & Selman, 1988; O'Beirne, 1990). **(另一方面，如果采用浸渍法，在改性气氛中包装的样品在整个贮藏期间的褐变程度（从10%到20%）明显低于在空气中包装的样品，其褐变面积在冷藏1天后约为25%到冷藏6天后约为50%。关于氩对多酚氧化酶（PPO）的影响，O'Berne、Murffy和Ni Eidhin（201－1）对蘑菇和苹果的具体研究表明，富含氩气的空气比富含氮的气氛更能抑制苹果和蘑菇PPO：在氩气的每一个浓度下，蘑菇和苹果多酚氧化酶的Km值（迈克尔斯门汀常数）大于相应氮水平下的Km值。已知含有低水平氧气（富含氮气的空气）的大气通过稀释抑制ppo降低氧气的可用性（ballantyne，stark，&selman，1988；o'beirne，1990）**。)As an inhibitory effect on PPO activity was still recorded when the oxygen was present at a maximum concentration (21%) and the balance was argon instead of nitrogen, such effect is characteristic of competitive inhibition (O'Beirne et al., 2011). Since the inhibitory effects of argon were greater than those of nitrogen, inhibition of argon must be greater than the dilution effect of nitrogen. Previously Spencer, Schvester, and Boisrobert (1998), in their patent, attributed the special “inhibitory” effect of argon and other noble gases on PPO activity in low-O2 atmospheres in a nonspecific way to molecular effects such as polarizability, iconicity, Van der Waals force and atomic radii. However Spencer et al. (1998) demonstrated that the greater inhibitory action of argon and other noble gases, compared with nitrogen, was linked to the atomic mass: the higher the atomic mass the greater the inhibition. The findings of O'Beirne et al. (2011) are comparable with the theory that the “additional benefits” of argon are directly related to the higher Van der Waals radius value of argon compared with nitrogen, being 1.91 Å for argon and 1.54 Å for nitrogen. O'Beirne et al. (2011) found that the inhibitory effects of argon on apple PPO were 1.2/1.5-times than that of nitrogen with atmospheres characterized by different oxygen contents (3-21%). **(当氧存在于最大浓度（21%）和平衡是氩而不是氮时，仍然抑制PPO活性的影响，这种效应是竞争抑制的特征（O'Berne et al.，2，0，1，1）。由于氩气的抑制作用大于氮气，所以氩气的抑制作用必须大于氮气的稀释作用。以前，Spencer、Schvester和Boisrobert（1998）在他们的专利中，将氩和其他惰性气体对低氧大气中PPO活性的特殊“抑制”效应归因于分子效应，如极化率、象似性、范德华力和原子半径。然而，Spencer等人（1998）证明，与氮相比，氩和其他惰性气体的抑制作用更大，与原子质量有关：原子质量越高，抑制作用越大。奥贝恩等人的发现。（201 1）与氩的“附加效益”与图2中较高的范德华半径值直接相关的理论相当。鲜切苹果在空气中包装前，在常规氮气（99%N2\_1%O2）、混合气体（90%N2\_5%O2）和Ar\_N2O（65%N2O\_25%Ar\_5%CO2\_5%O2）或Ar\_CO2（80%Ar\_20%CO2）的替代改性气氛中浸泡（A）和不浸泡（B）的硬度（N）。不同字母（p<0.05）对应显著差异（Cortellino等人，2015）。G.Cortellino等人/《食品科学与技术趋势》46（2015）320e330 324氩与氮的比较，氩为1.91\_，氮为1.54\_。O'beirne等人（201 1）在不同含氧量（3e21%）的气氛中，氩对苹果多酚氧化酶的抑制作用是氮的1.2/1.5倍。)**Furthermore, the results by Zhang, Quantick, Grigor, Wiktorowicz, and Irven (2001) indicated that both nitrogen and argon reduced markedly the tyrosinase (PPO) activity and the reaction of the enzyme with its substrate, compared to those without gas treatment. In details tyrosinase activity with argon treatment was reduced by up to 14.2% more than nitrogen treatment when treated directly, and by up to 22.6% in the mixture of the enzyme and substrate. This may be because argon has a better ability than nitrogen to reduce the level of dissolved oxygen whose presence is necessary for tyrosinase to catalyze the reaction. Argon is reported to be biochemically active, probably due to its enhanced solubility in water compared with nitrogen (Spencer, 1995).**(此外，Zhang、Quantick、Grigor、Wiktorowicz和Irven（2001）的结果表明，与未经气体处理的酶相比，氮气和氩气都显著降低了酪氨酸酶（PPO）活性和酶与底物的反应。结果表明，氩处理的酪氨酸酶活性比氮处理的酪氨酸酶活性降低了14.2%，酶与底物的混合物中酪氨酸酶活性降低了22.6%。这可能是因为氩比氮具有更好的能力来降低溶解氧的水平，而溶解氧的存在是酪氨酸酶催化反应所必需的。据报道，氩具有生物化学活性，可能是因为它在水中的溶解度比氮高（Spencer，1995）。)**

In this context the study conducted by Cortellino et al. (2015) (Fig. 3) on ‘Golden Delicious’ apple slices concerned the evaluation of conventional and modified atmosphere, combined or not with dipping treatment (citric and ascorbic acid), iBoth conventional modified atmospheres (99% N2 + 1% O2 and 90% N2 + 5% O2 +5% CO2) and the Ar + CO2 combination (80% Ar + 20% CO2) successfully maintained the initial value of BI for all the 11 days of cold storage. In contrast, the slices packed in Ar + N2O mix (65% N2O + 25% Ar + 5% CO2 + 5% O2) showed the same behavior as those stored in air. In slices without dipping treatment, browning developed quite quickly in the first 24 h; then, slices packaged in air showed a high value of BI (~40),which remained stable or decreased slightly with cold storage time**.**n preventing browning. The technological step of dipping caused a decrease of the browning index (BI) from 28 to 26, indicating that a slight phenomenon of pulp whitening occurred with the dipping treatment. The BI value of dipped samples packed in air increased during the shelf life even though they reached only the initial value of fresh slices (Fig. 3A).(**在这方面，Cortellino等人进行的研究。（2015年）（图3）“金美味”苹果片涉及评估传统和改良气氛，结合或不浸泡处理（柠檬酸和抗坏血酸），防止褐变。浸渍工艺步骤使褐变指数（bi）从28下降到26，表明浸渍处理后纸浆有轻微的增白现象。在保质期内，即使浸泡在空气中的样品仅达到新鲜切片的初始值，其Bi值也会增加（图3A)** **(常规改性气氛（99%n2+1%o2和90%n2+5%o2+5%co2）和ar+co2组合（80%ar+20%co2）在冷藏的11天内都成功地保持了bi的初始值。相比之下，在ar+n2o混合物（65%n2o+25%ar+5%co2+5%o2）中包装的切片显示出与在空气中存储的切片相同的行为。在未经浸渍处理的切片中，褐变在最初的24小时内发展很快；然后，在空气中包装的切片显示出较高的bi（~40），随着冷藏时间的延长，bi值保持稳定或略有下降。)**The two conventional MAP atmospheres induced more degrading phenomenon (higher BI) till the fourth day of storage than air atmosphere. Afterward, the BI of slices packed under conventional MAPs decreased and reached the value of sample packed in air, and this fact may be due to further biochemical processes leading to the formation of less dark color compounds. The same initial phenomenon was also observed for slices packed in alternative MAP,then the Ar + N2O sample behaved as air sample and the Ar + CO2 sample showed the worst performance with higher BI value.**(两种传统的map气氛在贮藏第4天之前都比空气气氛诱发了更多的降解现象（bi）。之后，传统图谱下的切片比降低，达到了空气中样品的值，这可能是由于进一步的生化过程导致形成的深色化合物较少。交替map包装的切片也出现了同样的初始现象，ar\_n2o样品表现为空气样品，ar\_co2样品表现出最差的性能和较高的bi值。)** On the whole, data proved that MAP without or with low level of oxygen could not effectively prevent browning in absence of a dipping treatment. Specifically argon played a contradictory role as the atmosphere with 80% Ar controlled the browning in dipped sample but enhanced it in undipped ones, in agreement with the con- flicting results by Day (1996) but in disagreement with Spencer's(1995) findings.**(总的来说，数据证明，在没有浸渍处理的情况下，不含或含氧量低的map不能有效地防止褐变。特别是氩在大气中扮演着矛盾的角色，80%的氩控制了浸提样品的褐变，但在未浸提的样品中却增强了褐变，这与Day（1996年）的矛盾结果一致，但与Spencer（1995年）的发现不一致)**

The effectiveness of superoxygen atmospheres in preserving color characteristics was little known. A recent study by Ghidelli et al. (2012) indicated that the use of soy protein-based coatings in combination with an elevated O2 (80 kPa O2) atmosphere allowed to retain slightly lower a\* value of apple pieces than when packed in air and in 15 kPa CO2 + 5 kPa O2 atmosphere, but the subjective visual quality ratings did not differ among the atmosphere treatments. In addition, Day (2001) reported that high O2 and high Ar MAP did not prevent the enzymic browning of nonsulphite dipped apple slices, even if no further browning took place after pack opening.**(超氧环境在保存颜色特征方面的效果鲜为人知。Ghidelli等人最近的一项研究。（2012）表明，与空气和15 kpa co2+5 kpa o2大气相比，使用大豆蛋白基涂层和升高的o2（80 kpa o2）大气可以保留略低的苹果片a\*值，但不同大气处理的主观视觉质量等级没有差异。此外， 此外，Day（2001）报道，即使打开包装后没有发生进一步的褐变，高O2和高Ar MAP也不能阻止非亚硫酸盐浸苹果片的酶褐变。**

**Fermentative metabolites 发酵代谢产物**

Modified atmosphere packaging systems can severely modify the fruit volatile profile (Rojas-Graü et al., 2009). Ke, Goldstein,Omahony, and Kader (1991) reported that ethanol and acetaldehyde are the main products of fermentative metabolism in fruits and their accumulation is correlated with off-flavor development. Lakakul, Beaudry, and Hernandez (1999) pointed out the importance of maintaining in the package headspace both O2 levels just above the fermentation threshold and CO2 concentrations below the range that causes injury. Thus, under specific circumstances,low O2 and high CO2 may lead to the production of fermentative metabolites, which are responsible for unpleasant off-flavors and odors. Too low O2 atmospheres may trigger anaerobic metabolism in fresh-cut fruit resulting in an increase of fermentation. It has been shown that the maximum rate of O2 uptake increases with increasing temperature, and that the lowest O2 partial pressure to which fruit could be exposed without having the onset of fermentation processes also increases with increasing temperature (Lakakul et al., 1999). Besides, it has been suggested that CO2 dissolution enhances acidity in the cell medium and may be responsible for physiological disorders. High CO2 concentrations also inhibit several enzymes of Krebs' cycle, including succinate dehydrogenase, which either triggers anaerobic respiration or results in the accumulation of succinic acid, which is potentially toxic to the fruit tissue (Varoquaux, 1991). The use of high O2 atmospheres have been also proposed to prevent anaerobic conditions and to reduce the production of fermentative metabolites (Day, 1996). However the stress response, caused by the highly oxidative environment combined with the accumulation of carbon dioxide into the packages, induces ethanol accumulation throughout storage in fresh-cut melons and pears packaged under 70 kPa O2 (Oms-Oliu, Raybaudi-Massilia Martinez, Soliva-Fortuny, & MartínBelloso, 2008; Oms-Oliu, Soliva-Fortuny, & Martín-Belloso, 2008).No literature data are available about the content of fermentative metabolites in apple slices packed under superoxygen atmosphere. The most accepted explanation for O2 toxicity is the formation of superoxide radicals (O2), which are destructive to cell metabolism (Fridovitch, 1975).**(改良的气调包装系统可以严重改变水果的挥发性成分（Rojas Graüet al.，2 0 0 9）。ke，goldstein，omahony和kader（1991）报道了乙醇和乙醛是水果发酵代谢的主要产物，它们的积累与异味的形成有关。Lakakul、Beaudry和Hernandez（1999）指出了在包装顶空中保持刚好高于发酵阈值的O2水平和低于造成伤害范围的CO2浓度的重要性。因此，在特定情况下，低氧和高二氧化碳可能导致发酵图3的产生。鲜切苹果在空气中包装前，在常规氮气（99%N2-1%O2）、混合气体（90%N2-5%O2-5%CO2）和Ar-N2O（65%N2O-25%Ar-5%CO2-5%O2）或Ar-Ar-CO2（80%Ar-20%CO2）的替代改性气氛中浸（A）和不浸（B）的颜色（褐变指数）。不同字母（p<0.05）对应显著差异（Cortellino等人，2015）。G.Cortellino等人/食品科学与技术趋势46（2015）320E330 325代谢物，这些代谢物导致不愉快的异味和异味。过低的氧气浓度可能会引起鲜切水果的厌氧代谢，从而增加发酵。已经表明，最大吸收速率随温度的升高而增加，并且在没有发酵过程的情况下，可以暴露水果的最低O2-分压也随着温度的升高而增加（LakaCal等，1999）。此外，有人认为，二氧化碳的溶解提高了细胞培养基中的酸度，可能导致生理紊乱。高CO2-浓度也抑制克雷布斯循环的几种酶，包括琥珀酸脱氢酶，其触发厌氧呼吸或导致琥珀酸的积累，琥珀酸对果实组织具有潜在毒性（ValoQuux，1991）。还建议使用高氧气浓度的空气以防止厌氧条件并减少发酵代谢产物的产生（Day，1996）。然而，由高度氧化环境所引起的应激反应与二氧化碳的积累一起进入包装，在贮藏在鲜切甜瓜和梨中包装的乙醇积累在70 kPa O2以下（OMS OLIU，Raybaudi Massilia Martinez，Suliava Funy，Mand NbBoSoO，2008；OMS OLIU，SOLIVA Fulty，马丁贝洛佐，2008年）。在超氧环境下包装的苹果切片中，发酵代谢物的含量没有文献资料。对O2毒性最为公认的解释是超氧化物自由基（O2？）的形成。，对细胞代谢具有破坏性（Fridovitch，1975）。)**

Soliva-Fortuny et al. (2002) and Rojas-Graü et al. (2007) studied the evolution of the headspace ethanol developed by apple slices packaged under air and modified atmospheres (100% N2 and 2.5%O2 + 7% CO2+ 90.5% N2). Soliva-Fortuny et al. (2002) observed a mild but progressive accumulation of ethanol during the first 40 days of storage with similar levels under all packaging conditions (air and 100% N2). Then, an important increase was triggered in bags under air, while only a slight rise in ethanol levels was observed in 100% N2 and 2.5% O2 + 7% CO2 + 90.5% N2 packages. Under air, ethanol production was avoided during the first 10 days of storage, when there was a high availability of O2 in the package headspace which prevented apple tissue from anaerobic metabolism. However, ethanol concentrations rose markedly beyond 6 weeks of storage, showing a sudden increase of anoxic pathways that may be due to the more severe conditions underwent by apple slices.**(Soliva Fortuny等人（2002）和Rojas Graü等人。（2007）研究了在空气和改性气氛（100%n2和2.5%o2掔7%co2掔90.5%n2）下包装的苹果切片形成的顶空乙醇的演变。Soliva Fortuny等人（2002）观察到在所有包装条件下（空气和100%氮气）以类似水平储存的前40天内乙醇有轻微但渐进的积累。然后，在空气中的袋子中触发了一个重要的增加，而在100%n2和2.5%o2\_7%co2\_90.5%n2包装中只观察到乙醇水平的轻微上升。在空气中，在贮藏的前10天避免了乙醇的产生，因为在包装的顶空中有很高的氧气供应，这就阻止了苹果组织的厌氧代谢。然而，乙醇浓度显著增加超过6周的存储，显示缺氧途径的突然增加，这可能是由于苹果切片所经历的更严重的条件。)**

Rojas-Graü et al. (2007) compared the influence of air and 2.5%O2 þ 7% CO2 þ 90.5% N2 atmosphere on the headspace of ‘Fuji’ apple slices packages. It was highlighted a slight but progressive accumulation of ethanol until 2 weeks of storage. The successive increase in the headspace ethanol levels was regardless of the type of packaging atmosphere and of dipping treatment, but it depended on maturity degree of fruit; in fact a sudden ethanol increase was triggered only in ripe apple slice samples after 3 weeks of storage, but not in samples prepared from partially-ripe or mature-green fruit. This rise could have been triggered by the low O2 concentrations inside of packages observed in samples prepared from ripe fruit after the third week of storage.**(Rojas Graü等人。（2007）比较了空气和2.5%o2\_7%co2\_90.5%n2atmosphere对富士苹果片包装顶空的影响。在贮藏2周前，乙醇有轻微但渐进的积累。顶空乙醇浓度的连续升高与包装气氛和浸渍处理方式无关，但取决于果实的成熟度；事实上，只有在贮藏3周后的成熟苹果切片样品中，乙醇浓度才突然升高，而在部分成熟或成熟的果岭样品中则没有。水果。这种上升可能是由于在贮藏第三周后从成熟水果中制备的样品中观察到包装内的低O2浓度引起的)**

A different approach was carried out by Cortellino, Gobbi, and Rizzolo (2014a), who didn't evaluate the fermentative metabolite composition in the packages' headspace, but that of apple slice tissue, considering not only ethanol but also acetaldehyde and ethyl acetate (Fig. 4). The content of ethanol increased progressively starting from the first day of storage for all MAP treatments, but only after 8 days of cold storage for slices packaged under air. Samples packaged under 80% Ar + 20% CO2 atmosphere showed the highest production of ethanol throughout the whole storage time. At the end of shelf-life (11 days) apples under 80% Ar + 20% CO2 and 65% N2O+ 25% Ar + 5% CO2 + 5% O2 alternative MAPs were characterized by higher values of ethanol content (350e450 mg kg1) than samples under 99% N2 + 1% O2 and 90% N2 +5% O2 +5% CO2 conventional MAPs (~300 mg kg1), while apple slices packed under air developed limited quantity of ethanol (<100 mg kg1).The overall results underlined that the production of ethanol is greatly influenced by the packaging atmosphere, in disagreement with both Soliva-Fortuny et al. (2002) and Rojas-Graü et al. (2007) findings. Moreover, the results confirmed that the absence or the presence of low O2 concentration leads to production of fermentative metabolites, like ethanol, which are responsible for unpleasant off-flavors and odors. Apple slices produced also acetaldehyde in the 3e10 mg kg1 range, but without a clear trend. Air sample developed a somewhat lowest amount of this fermentative product. However, its production seems to be independent from the packaging atmosphere. Apple samples, except those packed under air, produced also increasing amounts of ethyl acetate from 0.1 mg kg1 at the first day of cold storage for all the samples to 0.6e1.1 mg kg1 at the end of storage time for all the MAP samples: slices packed either under only 1% O2 (99% N2 + 1% O2) or completely anoxic (80% Ar+ 20% CO2) atmospheres produced higher quantities of ethyl acetate than the other two packaging conditions characterized by 5% O2 (90% N2+ 5% O2+ 5% CO2 and 65% N2O + 25% Ar + 5% CO2 + 5% O2). On the other hand, apple slices packaged under air developed very low amounts (~0.15 mg kg1) of ethyl acetate during the whole cold storage time. On the whole the considerations regarding the correlation between packaging condition and ethyl acetate development are very similar to those previously reported for ethanol.(**Cortellino、Gobbi和Rizzolo（2014a）采用了不同的方法，他们不评估包装顶空中的发酵代谢物成分，而是评估苹果切片组织的发酵代谢物成分，不仅考虑乙醇，还考虑乙醛和乙酸乙酯（图4）。在所有map处理中，乙醇含量从贮藏的第一天开始逐渐增加，但在空气中包装的切片冷藏8天后，乙醇含量才逐渐增加。在80%ar\_20%co2气氛下包装的样品显示在整个储存时间内乙醇的产量最高。在保质期（11天）结束时，80%ar\_20%co2和65%n2o\_25%ar\_5%co2\_5%o2下的苹果替代图谱的特征是乙醇含量较高（350e450 mg kg？1）比99%N2\_1%O2和90%N2\_5%O2\_5%CO2常规图谱下的样品（约300 mg kg？1），而在空气中包装的苹果片中乙醇含量有限（<100毫克千克？1）。总体结果表明，乙醇的生产受包装气氛的影响很大，这与Soliva Fortuny等人的观点不一致。（2002）和Rojas Graü等人。（2007）调查结果。此外，研究结果证实，不含或存在低浓度的O2会导致发酵代谢产物的产生，如乙醇，这些代谢产物会导致令人不快的异味和异味。苹果切片中产生的乙醛也在3e10毫克公斤？1范围，但没有明确的趋势。空气样本中这种发酵产物的含量略低。然而，它的生产似乎独立于包装环境。苹果样品，除了那些在空气中包装的，其乙酸乙酯含量也从0.1毫克千克增加了？所有样品在冷藏的第一天达到0.6e1.1 mg kg？1在所有的MAP样品的储存时间结束时：仅在1%的O2（99% N2×1% O2）下填充的Ar完全缺氧（80% Ar×20% CO2）气氛产生了比其它两个包装图4更高的乙酸乙酯量。新鲜切苹果在空气中的乙醛、乙醇和乙酸乙酯的含量，在常规N2（99%N2\_1%O2）、混合（90%N2\_5%O2\_5%CO2）和Ar\_N2O（65%N2O\_25%Ar\_5%CO2）或Ar\_CO2（80%Ar\_20%CO2）的替代改性气氛中。介质±ST.误差（Cortellino等人，2 0 1 4 A）。G.Cortellino等人/食品科学与技术趋势46（2015）320E330 326以5%O2为特征的条件（90%N2\_5%O2\_5%CO2和65%N2O\_25%Ar\_5%CO2\_5%O2）。另一方面，在空气中包装的苹果片含量很低（~0.15毫克千克？1）整个冷藏期间的乙酸乙酯。总的来说，关于包装条件和乙酸乙酯发展之间的关系的考虑与以前报道的乙醇非常相似。)**

The physiological respiratory activity data involves CO2 production and O2 consumption (Fonseca, Oliveira, & Brecht, 2002).Aerobic respiration consists of oxidative breakdown of organic reserves to simpler molecules, including CO2 and water, with release of energy. The process consumes O2 in a series of enzymatic reactions. Glycolysis, the tricarboxilic acid cycle, and the electron transport system are the metabolic pathways of aerobic respiration. The respiratory quotient (RQ), which is the ratio between CO2 production and O2 uptake, is normally assumed to be equal to 1.0 if the metabolic substrates are carbohydrates. When this value falls in the range of 0.7e1.3, it denotes that a product aerobically respires (Makino, 2013). The RQ is much greater than 1.0 when anaerobic respiration takes place. In fermentative metabolism, ethanol production involves decarboxylation of pyruvate to CO2 without O2 uptake (Fonseca et al., 2002). Concerning this point of view Cortellino, Gobbi, and Rizzolo (2014) confirmed that for samples packed under either nitrogen (99% N2 þ 1% O2) or low oxygen (90% N2 þ 5% O2 þ 5% CO2) atmosphere a fermentative anaerobic respiratory process occurs, since high respiratory quotient values (RQ>>1) were found from the beginning of cold storage This phenomenon didn't occur for apples packed under air (RQ < 1), which showed an RQ ¼ 1.22 only at the end of shelf life indicating that fermentative metabolism was just triggered only when fruit slices were near to the senescence. Furthermore Soliva-Fortuny et al. (2005) observed a noticeable rise in RQ during the third week of storage, especially in fresh-cut apples packaged under initial 0 kPa O2 atmosphere, suggesting that fermentative anaerobic respiratory processes had begun to be triggered. The increase in RQ coupled with declining O2 partial pressure determines the fermentation threshold, which in apple slices was found to be about half of the O2 partial pressure for whole apples (Lakakul et al., 1999). O2 partial pressures can be lower for cut fruits than for whole apples because skin removal reduces the diffusion path length, thus increasing gas permeation to the surrounding environment (Soliva-Fortuny et al.,2005).**(生理呼吸活动数据包括二氧化碳的产生和二氧化碳的消耗（Fonseca，Oliveira和Brecht，2002）。好氧呼吸包括有机物的氧化分解到更简单的分子，包括CO2和水，释放能量。这个过程在一系列酶促反应中消耗氧气。糖酵解、葡萄糖酸循环和电子传递系统是有氧呼吸的代谢途径。呼吸商（rq）是二氧化碳产生量和氧气吸收量之间的比率，如果代谢底物是碳水化合物，则通常假定呼吸商等于1.0。当该值在0.7e1.3的范围内时，表示产品有氧运动有呼吸（Makino，2013）。当发生无氧呼吸时，rq远大于1.0。在发酵代谢中，乙醇的生产涉及丙酮酸脱羧基为二氧化碳而不吸收氧气（Fonseca等人，2 0 0 2）。关于这一观点，Cortellino、Gobbi和Rizzolo（2014）证实，对于在氮气（99%N2\_1%O2）或低氧（90%N2\_5%O2\_5%CO2）气氛下包装的样品，会发生发酵性厌氧呼吸过程，由于在冷藏开始时就发现了高呼吸商值（rq>>1），所以这种现象在空气包装的苹果中并没有发生（rq<1），这表明只有在货架期结束时rq为1.22，表明只有当水果切片接近衰老时才触发发酵代谢。此外，Soliva Fortuny等人（2005）观察到在贮藏的第三周，RQ显著上升，特别是在最初0 kPaO2气氛下包装的鲜切苹果，这表明已经开始触发发酵性厌氧呼吸过程。rq的增加加上o2分压的下降决定了发酵阈值，在苹果切片中发现，发酵阈值约为整个苹果的o2分压的一半（lakakul等人，1999）。对于切割的水果来说，O2部分压力可能低于整个苹果，因为剥皮减少了扩散路径长度，从而增加了气体对周围环境的渗透（Soliva Fortuny等人，2005）。)**

The changes in aroma fingerprint of fresh-cut apples during the shelf life period can be detected with a fast and simple approach by electronic nose system, a sensor-based technology, which responds to the whole set of headspace volatiles, creating a unique digital pattern. Usually, a little portion of fruit tissue (3e10 g) is sealed in a vial and, after an equilibration time, the headspace gas is sampled by an automatic sampler and injected into the sensor chamber. This methodology was used by Tanprasert, Beaudry, and Harte (2007) to study the influence of postharvest treatments on ‘Jonagold’ apple slices packed under air, by Guarrasi, Giacomazza, Germana, Amenta, and San Biagio (2014) to study the influence of a traditional MAP on ‘Fuji’ apple slices, and by Siroli et al. (2014) to study the use of various natural antimicrobials to extend the shelf life of‘Golden Delicious’ apple slices packed under a traditional MAP. Tanprasert et al. (2007) reported that there is an influence of postharvest treatments of fruit before processing (storage atmosphere, time of storage, 1-methylcyclopropene treatment) on electronic nose pattern of ‘Jonagold’ apple slices packed under air only at the beginning of the shelf life period at 3℃; after 2 weeks of shelf life the effect of processing overrides the effect of postharvest treatments. Guarrasi et al. (2014) found a different e-nose pattern between ‘Fuji’ apple slices packed in air and under 100% N2, and, for both the treatments, changes in e-nose pattern during the 14 days of shelf-life at 4℃. Siroli et al. (2014) showed that the addition to the dipping solution of natural antimicrobials, such as hexanal,citral, 2-(E)-hexenal, citron EO and carvacrol, alone or in combination, combined with MAP (7% O2, 0% CO2) quite unaffected the enose pattern, which indeed changed during the 35 days of shelf life at 6 C. A different approach was carried out by Cortellino, Rizzolo,et al. (2014), who performed the electronic nose analyses with the commercial portable PEN3 (Win Muster Airsense Analytic Inc.) on the packages, before opening them for the analysis of apple slices.They compared the electronic nose patterns of ‘Golden Delicious’apple slices packaged under air and 99% N2+ 1% O2 and 90%N2 + 5% CO2 + 5% O2 modified atmospheres, processed at harvest and after 7 months' storage at 2 C in a controlled atmosphere (1%O2+2% CO2). Results highlighted that the responses of W5C, W1C and W2S sensors were higher for samples from stored fruit than those from fruit processed at harvest independently from the type of the packaging atmosphere, and increased during the 10 days of shelf life at 4 C; in contrast, the responses of W1C and W5C sensors gradually decreased throughtout the shelf life and in a similar way in all the treatments. By coupling the electronic nose data with discriminant analysis, Cortellino, Rizzolo, et al. (2014) were able to distinguish for every packaging atmosphere the samples processed at harvest from those processed after storage during the whole shelf life time, obtaining 93.55% (air), 100% (99% N2 + 1% O2) and 96.77% (90% N2 + 5% CO2 + 5% O2) of correct classification percentages for the combination of processing time and days of shelf life.**(利用基于传感器技术的电子鼻系统，对全套顶空挥发物进行响应，形成独特的数字模式，可以快速、简便地检测出鲜切苹果在保质期内香气指纹图谱的变化。通常，将一小部分水果组织（3e10g）密封在小瓶中，在平衡时间后，通过自动取样器对顶空气体进行取样并注入传感器室。Tanprasert、Beaudry和Harte（2007）采用该方法，研究了瓜拉西、Giacomazza、德国人Guarrasi在空气中包装的“Jonagold”苹果片采后处理的影响。A、Amenta和San Biagio（2014）研究传统地图对“富士”苹果切片的影响，Siroli等人（2014）研究使用各种天然抗菌剂延长传统地图下包装的“黄金美味”苹果片的保质期。Tanprasert等人（2007）报告说，水果在加工前的采后处理（贮藏气氛、贮藏时间、1-甲基环丙烯处理）对“Jonagold”苹果片的电子鼻型有影响，这些苹果片仅在保质期开始时在3？贮藏2周后，加工的效果超过采后处理的效果。Guarrasi等人（2014）发现在空气中包装的“富士”苹果片和100%氮气下的“富士”苹果片之间的电子鼻模式不同，并且，对于这两种处理，电子鼻模式在4？C.Siroli等人（2014）表明，添加天然抗菌剂（如己醛、柠檬醛、2-（e）-己烯醛、柠檬酸环氧乙烷和香芹醇）浸泡液，单独或联合添加MAP（7%O2，0%C O2）对eNOSE模式没有影响，eNOSE模式确实在保质期的35天内发生了变化，为6？C.Cortellino、Rizzolo等人采用了不同的方法。（2014年），他用商用便携式Pen3（Win Muster Airsense分析公司）对包装进行了电子鼻分析，然后打开包装进行苹果切片分析。他们比较了在空气和99%n2\_1%o2和90%n2\_5%co2\_5%o2改性气氛下包装的“黄金美味”苹果片的电子鼻型，这些苹果片在收获时加工，在2？下储存7个月后。c在受控大气中（1%氧气和2%二氧化碳）。结果表明，w5s、w1s和w2s传感器对贮藏水果样品的响应高于不受包装气氛影响的采收水果样品的响应，在贮藏期的10天内，w5s、w1s和w2s传感器的响应在4？与此相反，w1c和w5c传感器的响应在整个保质期内逐渐降低，并且在所有处理中都以类似的方式降低。通过电子鼻数据与判别分析的耦合，Cortellino，Rizzolo等。（2014）能够区分在整个保质期内收获时处理的样品和储存后处理的样品的每个包装大气，获得93.55%（空气）、100%（99%N2\_1%O2）和96.77%（90%N2\_5%CO2\_5%O2）的正确分类百分比，用于处理时间和保质期天数的组合。)**

**Sensory characteristics 感官特性**

Very little sensory studies have been carried out to evaluate the influence of packaging conditions on the quality perception of fresh-cut apples by trained judges. In fact most of the research evaluated instrumentally the visual and texture quality, as well as the off-flavors presence. An interesting approach was realized by Soliva-Fortuny et al. (2005), where ‘Golden Delicious’ apple cubes treated with calcium chloride and packaged under modified atmospheres were compared with those prepared just before consumption. Panelists gave low visual quality scores only to sample preserved under an initial packaging atmosphere of 2.5 kPaO2 + 7 kPa CO2 in plastic packages of lower permeability, at 3 weeks of storage, coinciding with the greatest color variation. No other differences were detected between treatments. For panelists all treated samples had slightly higher or not significantly different scores for firmness than untreated freshly prepared apple cubes. The reason may be due to the great protective effect of calcium chloride treatments that hindered the packaging atmosphere influence. These observations are supported by Soliva-Fortuny et al.(2002) results showing that calcium treatments have much more influence than MAP on the texture preservation of fresh-cut apples.

Acidity scores also didn't have significant changes, whereas sweetness scores decreased during the second and third week of storage, suggesting a reduction in the amount of sugars. Acceptance scores for the overall quality of apple cubes dropped gradually throughout storage. At 3 weeks of storage these scores fell to low values as the off-odors presence started to be detectable by panelists. This trend was emphasized in samples packaged in 2.5 kPa O2 + 7 kPa CO2, which showed a faster quality degradation, suggesting that high CO2 concentrations were more detrimental to the sensory quality than storage under anoxic conditions.**(很少有感官研究被用来评估包装条件对鲜切苹果品质感知的影响。事实上，大多数研究都是通过仪器来评估视觉和纹理质量，以及异味的存在。soliva fortuny等人实现了一种有趣的方法。（2005年），将用氯化钙处理并在改性气氛下包装的“黄金美味”苹果立方体与食用前制备的苹果立方体进行了比较。小组成员给出的低视觉质量分数仅适用于在初始包装气氛为2.5 kpa o2\_7 kpa co2的低渗透性塑料包装中保存的样品，保存时间为3周，与最大的颜色变化一致。两组间未发现其他差异。对于小组成员来说，所有处理过的样品在硬度上的得分都比未处理过的新鲜制备的苹果立方体稍高或没有显著差异。原因可能是氯化钙处理的保护作用很大，阻碍了包装气氛的影响。这些观察结果得到了Soliva Fortuny等人的支持。（2002）结果表明，钙处理对鲜切苹果质地保存的影响远大于map处理。酸度评分也没有显著变化，而甜度评分在储存的第二周和第三周下降，表明糖的数量减少。在整个贮藏过程中，苹果立方体的整体质量验收分数逐渐下降。在储存3周后，这些评分下降到低值，因为小组成员开始检测到异味的存在。在2.5 kPa O2·7 kPa CO2中包装的样品中强调了这一趋势，这表明降解速度更快，这表明高CO2浓度比缺氧条件下的贮藏对感官质量的危害更大。)**

Considering this scarce background, sensory analysis carried outby Cortellino et al. (2015) on ‘Golden Delicious’apple slices packed in air, conventional MAPs (99% N2+ 1% O2 and 90% N2 þ 5% O2 + 5% CO2) and alternative MAPs (80% Ar + 20% CO2 and 65% N2O + 25% Ar + 5% CO2 + 5% O2) provides useful information (Fig.5).(**考虑到这种稀缺的背景，Cortellino等人进行了感官分析。（2015）在包装在空气中的“黄金美味”苹果切片上，传统地图（99%N2\_1%O2和90%N2\_5%O2\_5%CO2）和替代地图（80%Ar\_20%CO2和65%N2O\_25%Ar\_5%CO2\_5%O2）提供了有用的信息（图5）。**)Considering that the exposure to O2 and CO2 levels outside the limits of tolerance led to anaerobic respiration with the production of undesirable metabolites and other physiological disorders, as found by Soliva-Fortuny et al. (2002), Cortellino et al. (2014a),Cortellino, Rizzolo, et al. (2014), it was important to consider the flavor judgment. The concentration of fermentation product did not negatively influence the flavor evaluation of panelist in the case of conventional MAPs and Ar + N2O mixture after 11 days of storage, while this sensory attribute was slightly affected and only after 8 days of shelf-life, for the Ar + CO2 combination (80% Ar +20% CO2).The sensory tests partially confirmed the instrumental results of firmness. Concerning this sensorial aspect, the no-dipped slices packed in nitrogen and Ar + CO2 atmospheres, as well as the dipped (in anti-browning solution) sample packed in Ar + CO2, obtained higher scores. The appearance attribute score was extremely dependent on the application of dipping pre-treatment: in fact if the anti-browning treatment was not applied, low scores (~50) for appearance were given independently of the atmosphere composition. Furthermore, in order to study in depth the interaction between alternative MAPs and anti-browning dipping treatment on sensory profile of ‘Golden Delicious’ apple slices packed in air, 80% Ar + 20% CO2 and 65% N2O + 25% Ar+ 5% CO2 + 5% O2 during shelf life at 4 C, Cortellino, Gobbi, and Rizzolo (2014b) analysed the sensory scores related to the intensity of firmness and crispness and to the pleasantness of appearance and flavor by Cluster analysis, using Ward's method and Square Euclidean distance metric. In this way samples were grouped into five clusters, each one having a distinctive sensory profile. Dipped slices packaged in Ar + CO2 and Ar +N2O mixtures after 1 day of shelf life at 4 C were judged the firmest (75.2) and the most crispy (68.8), with the highest pleasantness for flavor (67.8) and appearance (89.6); the undipped slices from all the 3 atm after 1 day of shelf life had mediumehigh values for firmness (69), crispness (60.2) and flavor pleasantness (62); the dipped and undipped slices packed in air and the undipped ones packed in Ar+ N2O mixtures after 4, 8 and 11 days of shelf life at 4 ℃ were the least firm (49.6) and crispy (38.7), but had medium scores for pleasantness of appearance (64.6) and flavor (61.1). The dipped slices packed in Ar + CO2 and Ar + N2O mixtures in shelf life for more than 8 days had a good appearance (83.1), medium-low values for firmness (57.4) and crispness (52.6) and the least flavor pleasantness (43.3), due to the production of undesirable metabolites induced by the anaerobic respiration (Cortellino, Rizzolo, et al., 2014; Cortellino et al., 2014a, Soliva-Fortuny et al., 2002), whereas those in shelf life for less than 8 days and the undipped ones packed in Ar + CO2 obtained mediumehigh scores for firmness (60.2), crispness (62.7), and pleasantness of appearance (69.4) and flavor (52.3).(**考虑到暴露于超出耐受极限的氧和二氧化碳水平导致无氧呼吸，产生不良代谢物和其他生理疾病，如Soliva Fortuny等人发现的。（2002），Cortellino等人。（2014a），Cortellino，Rizzolo等。（2014），考虑味道判断很重要。在常规MAP和Ar\_N2O混合物贮藏11天后，发酵产物的浓度不会对专家的风味评价产生负面影响，而对于Ar\_Co2混合物（80%Ar\_20%CO2），这种感官属性仅在贮藏8天后受到轻微影响。感官测试部分证实了仪器的硬度结果。在感官方面，氮和ar\_co2atmospheres中的未浸切片，以及ar\_co2中的浸（抗褐变溶液）样品获得了更高的分数。外观属性得分非常依赖于浸渍预处理的应用：事实上，如果不应用防褐变处理，则外观的低得分（~50）与大气成分无关。此外，为了深入研究不同图谱和防褐变浸渍处理对“金美味”苹果片在4℃贮藏期间的感官品质的影响，研究了80%ar掔20%co2和65%n2o掔25%ar掗5%co2掗5%o2在贮藏期间的感官品质。C、Cortellino、Gobbi和Rizzolo（2014b）使用Ward方法和平方欧几里德距离法，通过聚类分析，分析了与硬度和脆度以及外观和风味愉悦度相关的感官评分。以这种方式，样本被分成五个簇，每个簇都有一个独特的感官轮廓。浸泡切片在Ar\_Co2和Ar\_N2O混合物中包装，保存期为4天。c为最硬（75.2）和最脆（68.8），风味（67.8）和外观（89.6）的愉悦度最高；货架期1天后所有3atm切片的硬度（69）、脆度（60.2）和风味愉悦度（62）均为中等高值；浸过的和未浸过的切片在空气中包装，未浸过的切片在Ar\_N2O混合物中包装，在4？下保质期4、8和11天后包装。c的硬度最低（49.6），脆度最低（38.7），但外观愉悦度（64.6），风味中等（61.1）。在Ar\_Co2和Ar\_N2O混合物中保存超过8天的浸片外观良好（83.1），硬度（57.4）和脆度（52.6）为中-低值，风味最差（43.3），这是由于厌氧呼吸产生了不良代谢物（Cortellino，Rizzolo等人，2014；Cortellino等人，2014a，Soliva Fortuny等人，2 0 0 2），而那些保质期少于8天的和未开发的包装在Ar\_Co2中获得了中等的硬度（60.2）、脆度（62.7）、外观愉悦度（69.4）和风味（52.3）的高分)**

**Conclusion 结论**

The packaging under conventional modified atmospheres,characterized by low O2 level (1 and 5%), successfully preserved the firmness of apple slices during all refrigerated storage limiting the ethylene production. In addition also the alternative mix Ar + CO2 was able to control the ethylene production and consequently to maintain firmness, even if an interaction between anti-browning dipping treatment and modified atmosphere was found: the preserving efficacy of MAP resulted almost completely nullified by the dipping treatment, which, based on ascorbic and citric acid, caused a structural breakdown. However, MAPs were not able to control the enzymatic browning if not combined with an anti-browning dipping treatment. The studies on the interaction between antibrowning treatments and modified atmosphere packaging highlighted the key role of sensory analysis in finding the best combination between MAP, anti-browning treatment and shelf life time. The contrasting results among the various research groups could be reasonably also due to the different periods (from 14 to 60 days) and temperatures (from 3 to 6 C) of shelf life. Furthermore it was shown that using electronic nose it is possible to classify apple slices according to the shelf life time, and so it could be useful to manage fresh-cut apple products during production and along the distribution chain in order to limit waste.**(在常规的改性气氛下进行包装，其特点是低氧含量（1%和5%），在所有限制乙烯生产的冷藏储存过程中成功地保持了苹果片的硬度。此外，即使发现防褐变浸渍处理与改性气氛之间存在相互作用，替代混合物Ar\_CO2也能够控制乙烯的生成，从而保持硬度：浸渍处理几乎完全丧失了MAP的保存效果，以抗坏血酸和柠檬酸为基础，引起结构破坏。但是，如果不结合抗褐变浸渍处理，maps不能控制酶促褐变。抗褐变处理与气调包装相互作用的研究，突出了感官分析在寻找map、抗褐变处理与货架期的最佳组合中的关键作用。不同研究组之间的对比结果也可以合理地归因于不同的时期（从14天到60天）和温度（从3天到6天？c）保质期。研究还表明，利用电子鼻可以根据保质期对苹果切片进行分类，从而有助于在生产过程中以及在销售链上对新鲜苹果切片进行管理，以减少浪费。)**

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