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Effects of Rapid Refrigeration and Modified Atmosphere Packaging on Litchi (*Litchi chinensis* Sonn.) Fruit Quality Traits

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Litchi (*Litchi chinensis* Sonn.) is a tropical fruit characterized by a rapid pericarp browning and dehydration during postharvest, resulting in an accelerated shelf life and in a loss of consumer appreciation and consequently of its market value. The aim of our study was to assess litchi fruit chemical-physical and sensory quality changes during postharvest and shelf life using rapid refrigeration (RR) and active modified atmosphere packaging (MAP). Litchi fruits were picked at commercial harvest and were divided in 4 groups: not treated fruit (CTR); rapid refrigerated fruit (RRF); modified atmosphere packed fruit (MAP); hydrogen peroxide treated and modified atmosphere packed fruit (MAP+). CTR and RRF fruit were packed in microperforated plastic bag whereas MAP and MAP+ fruit were packed in unperforated high-density polyethylene package in which a gas mixture (60 kPa N_2, 30% CO_2 and 10 kPa O_2) was flushed and then the bag was hermetically sealed. RRF, fruit were submitted to cooling in order to rapidly reduce their temperature using a blast cabinet which allows to reach 4° C in 15 minutes in three different steps. Finally, all the treated fruit were submitted to cold storage (5°C) for 12 days. Chemical-physical and sensory characteristics were analyzed after 4, 8 and 12 days of cold storage and their shelf life was monitored after 2 and 4 days at 20° C. Generally, the fruit submitted to RRF treatment presents a more intense red color in particular referring to L parameter and the best chemical-physical characteristics. Moreover, RRF fruit revealed having more consistency, juicy flesh, fruity flavour and exotic flavour after 4 days and of fruity odor and exotic odor after 8 days of cold storage. After 12 days, MAP and MAP+ showed a sensory decay. Finally, RRF technique, by rapid refrigeration, permits to prolong fruit color and taste during cold storage and consequent shelf life.

1. Introduction

Litchi (*Litchi chinensis* Sonn.) is a tropical fruit tree native to the Guangdong and Fujian provinces of China (Wu, 2007). The fruit is of high commercial value (Baoyao et al., 2011) having demand world over and in the European market (Pandey, 2013), due to its intense and attractive red peel colour as well as to its sweet and juicy flesh (Nakasone & Paull, 1998). China is the main producing country, and now this fruit is cultivated in many parts of the world, with an annual production between 2.6 and 2.8 Mt (Chen et al., 2014). In Italy litchi is diffused only in Sicily where, in the last decade, its cultivation is quickly expanding (Liguori at al., 2017). Appropriate physiological maturity at harvest is crucial for proper marketable quality and shelf life (Reichel et al., 2010). Fruit maturity is judged according to the fruit peel color: fruit for immediate consumption are normally harvested at full color (Underhill et al., 1990), but for long distance transport, it is harvested at 70% of the full color (Yen et al., 1984) or often picked when the pericarp partly turns red (Semeerbabu et al., 2007; Kumar et al., 2012). Fruits for immediate consumption are normally harvested at full colour (Underhill, 1990). On the other hand, an attractive red skin color is considered a very important parameter for the commercial quality of this fruit. The international trade standard of the Codex Alimentarius requires minimum ripeness without defining details, and the colouring of litchis may vary from pink to red (FAO/WHO, 2011). Indeed, litchi diffusion is limited by color loss, rapid pericarp browning, and dehydration of fruits at postharvest, resulting in an accelerated shelf life and in a less of its market value and consumer appreciation (Zheng et al., 2006). The effects of different treatments, including controlled atmosphere, high relative humidity, anti-browning agents, low temperature and surface coating on the quality of litchi fruit during

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storage, were evaluated in several studies (Zheng et al., 2006; Jiang et al., 2003; Jiang et al., 2000; Kumari et al., 2015; Kumar et al., 2012). Low storage temperature and modified atmosphere packaging (MAP) are common postharvest technology used to extend the shelf life of many whole and fresh-cut fruit, as they reduce the respiration rate, surface damage and browning (Thompson, 1998; Liguori et al. 2015). In litchi fruit this technology reduced pericarp browning (Sivakumar and Korsten, 2006), controlled postharvest diseases and maintained a high humid environment for the retention of fruit at low temperatures (Kader 1994; De Reuck et al., 2009). The aim of our study was to assess litchi fruit chemical-physical and quality changes during postharvest and shelf life using rapid refrigeration (4°C) and active modified atmosphere packaging (MAP) with different gas partial pressures.

2. Materials and methods

Litchi fruit (cv 'Kwai Mai') were harvested from a commercial orchard, located in Acquedolci, in the coastal area of the province of Messina (Sicily, Italy; 38°3' N, 14°33' E; 5 m a.s.l.). Three uniform 12–year–old trees, grafted on their own rootstock and trained to a globe shape were selected. Trees were planted in single rows (north–south oriented), 5 x 3 m spacing. Plants were submitted to routine cultural cares.

The fruits were collected at commercial harvest using skin color as maturity index (Semeerbabu et al., 2007; Kumar et al., 2012). Litchi fruits of regular shape and uniform size without any defect were selected. 558 fruits (186 per tree) were divided in 4 groups: not treated fruit (CTR); rapid refrigerated fruit (RRF); modified atmosphere packed fruit (MAP); hydrogen peroxide (H_2O_2) treated and modified atmosphere packed fruit (MAP+). For each group 27 replicates of 5 fruits were used. CTR and RRF fruit were packed in microperforated plastic bag whereas MAP and MAP+ fruit were packed in unperforated high-density polyethylene package in which a gas mixture (60 kPa N_2, 30% CO_2 and 10 kPa O_2) was flushed and then the bag was hermetically sealed. RRF fruit were submitted to cooling in order to rapidly reduce their temperature using a blast cabinet which allows to reach 4° C in 15 minutes in three different steps. Finally, all the treated fruit were submitted to cold storage (5°C) for 12 days.

A ~~S~~ sample~~s~~ of 18 fruits were analysed immediately after the harvest and 15 fruits (3 replicates of five fruits per treatment) twice a week during the cold storage period: chemical-physical and sensory characteristics were analysed after 4, 8 and 12 days and during the shelf life after 2 and 4 days at 20° C: the first shelf life (I SL) after 4 days, the second shelf life (II SL) after 8 days and the third shelf life (III SL) after 12 days of cold storage respectively. Fruit were submitted to the determination of total soluble solid content (TSSC), titratable acidity (TA), peel color and sensory analysis. Total soluble solid content (TTSC) was determined by digital refractometer (Palette PR-32, Atago Co., Ltd) and titratable acidity (TA) was measured by titration of 10 ml juice with 0,1 N NaOH to pH 8,1 and expressed as % citric acid (mod. S compact titrator, Crison Instruments, Barcelona, Spain), peel color using CIELab coordinates (Zheng et al., 2012). In-package O_2 and CO_2 partial pressure were analyzed using an O_2 and CO_2 portable analyzer (Checkpoint, Dansensor Italia, Milano, Italy).

The sensory profile analysis was performed by by a semi-trained panel consisting of ten judges (5 females and 5 males, 22-45 years old). All panelists were trained and developed a wide expertise in sensory evaluation of fruits (Farina et al., 2016; Liguori et al., 2014). The judges, in preliminary sessions, using both commercial and experimental litchi samples, generated 15 sensory descriptors: flesh color (FC); consistency (C), fruity odour (FO), exotic fruits odour (EXO), off-odour (OFO), sweet (S), acid (A), juicy (J), astringent (AS), pungent (PU), fruits flavour (FRF), exotic fruits flavour (EXF), flavour alcohol (ALF), off-flavour (OFF) and overall evaluation (OVE). The judges evaluated samples, using a hedonic scale, assigning to each descriptor a score from 1 to 9. Data were submitted to one-way analysis of variance (ANOVA) and means were separated with Tukey's test at P≤0.05 while data concerning the color evolution were subjected to analysis of the regression.

3. Results and discussion

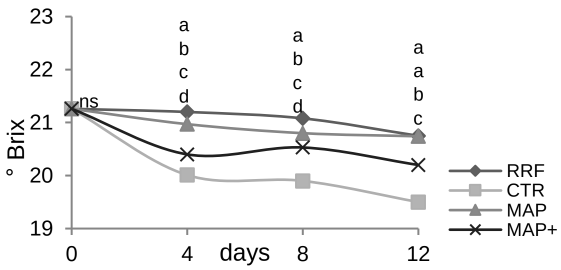

Figure 1: Time course of TSSC after 4, 8 and 12 days of cold storage at 5° C.

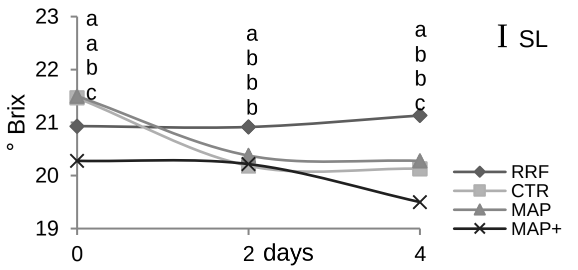

Figure 2: Time course of TSSC after 4 days of cold storage at 5°C and 2 and 4 days of shelf life at 20°C.

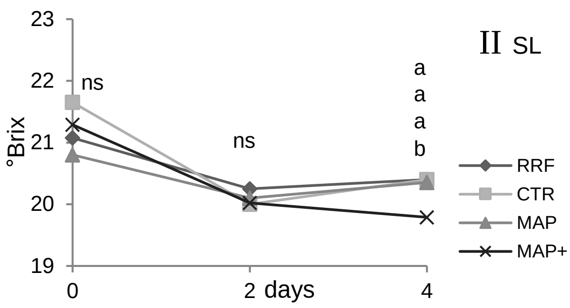

Figure 3: Time course of TSSC after 8 days of cold storage at 5°C and 2 and 4 days of shelf life at 20°C.

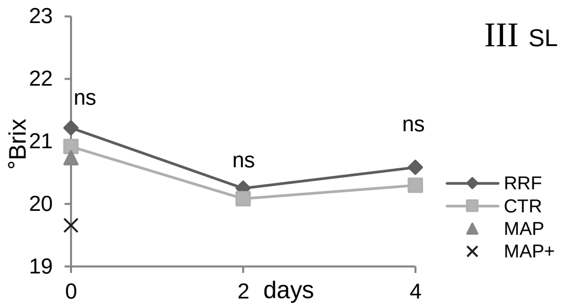

Figure 4: Time course of TSSC after 12 days of cold storage at 5°C and 2 and 4 days of shelf life at 20°C.

3.1 Total Soluble Solid

Taking into consideration the period of cold storage (Figure 1) and the three shelf-life (Figure 2,3,4) we observed that in all treatments there has been a decrease in the TSSC.

The lowest values were observed in MAP+ and CTR fruits. This is probably due to the maturation processes resulting in a starch hydrolysis in mono and disaccharides (Mahajan et al., 2004) and in the activation of the processes of respiration (Dong et al., 2004). This behavior confirm the positive effect of RR and MAP in slowing the post maturation process. During the I SL, TSSC decreased after 2 and 4 days at 20° C in all treatments except in RRF highlighting its role to slowed fruit maturation (Figure 2). Instead, during the II SL, RRF and MAP does not differ from CTR even MAP+ showed the littlest value after 4 days (Figure 3).

Regarding the last shelf life, MAP and MAP+ fruits showed a quality decay and were not analyses. The remaining treatments did not differ significantly. So, after 12 days of cold storage, RRF treatment not influenced fruit shelf life whereas MAP and MAP+ seem to affect fruit quality (Figure 4). TSSC is an analytical parameter useful for the qualitative characterization of the fruits.

3.2 Titratable acidity

During the cold storage, TA decreased in all treatments following a linear model (Figure 5). In MAP and MAP+ treatments during the I SL, TA increased after 4 days of refrigerator and 2 days at room temperature and then decreases after 4 days in MAP only (Figure 6). RRF fruit maintained higher values of TA in respect to CTR fruits. TA acidity probably decreases due to the degradation of organic acids during the ripening process.

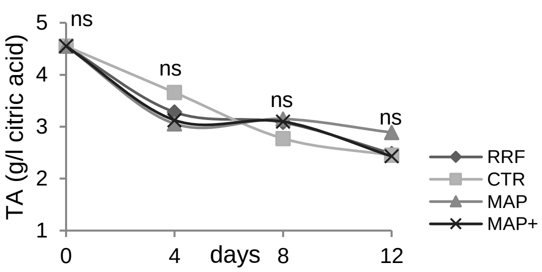

Figure 5: Time course of TA after 4, 8 and 12 days of cold storage.

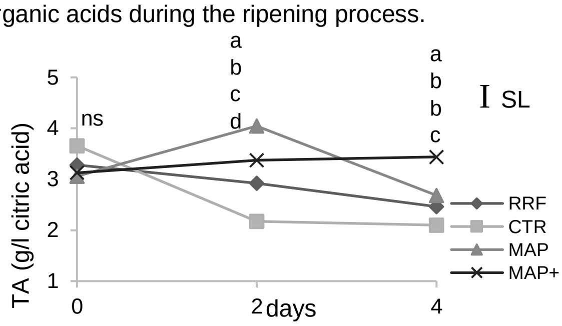

Figure 6: Time course of TA after 4 days of cold storage at 5°C and 2 and 4 days of shelf life at 20°C.

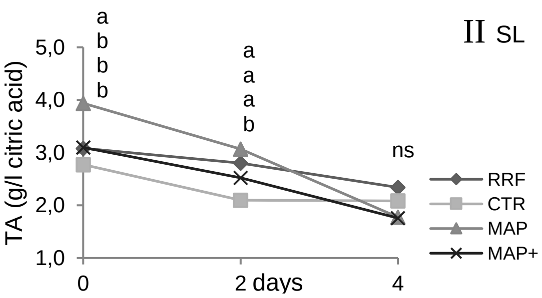

Figure 7: Time course of TA after 8 days of cold storage at 5°C and 2 and 4 days of shelf life at 20°C.

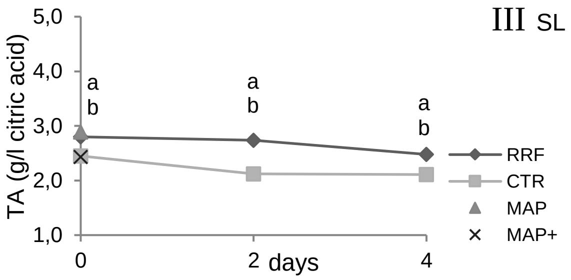

Figure 8: Time course of TA after 12 days of cold storage at 5°C and 2 and 4 days of shelf life at 20°C.

After 8 days of cold storage (II SL) AT decreased in all treatment during 2 and 4 days of SL (Figure 7). A similar behaviour was observed during III SL (Figure 8). MAP and MAP+ fruits showed a decay and were not analysed.

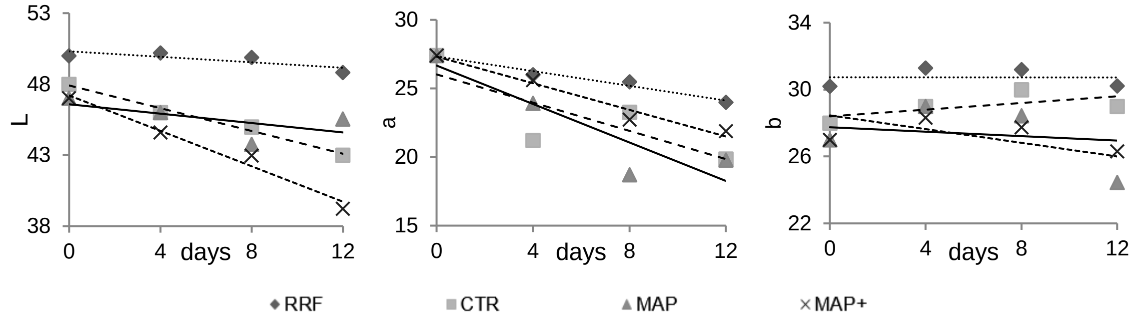

Figure 9: Time course of color after 4, 8 and 12 days of cold storage at 5°C. L indicate brightness, a and b* indicate the color-opponents green-red and blue-yellow.*

3.3 Color

Considering peel color using the coordinate values L*a* b, several treatments during cold storage tend to lose brightness (Figure 9). The decrease in L, a*, b* indicated a lower brightness and intensity of the fruit red color corresponding to a start of peel browning. This is due to an increase of the temperatures, with consequent intensification of metabolic processes. This behaviour was observed always in MAP and MAP+ whereas RRF and CTR maintained color characteristic. After 12 days of cold storage treatment RRF fruits reaching the best values of L*a*b demonstrating that the RR treatment has helped the fruit to keep color characteristics. As regards to the shelf life, even in this case all the treatments tend to lose color (Figure 10). During the ISL, L, a* and b* values decreased in all treatments except for RRF that maintained L values. This fact indicates a lower browning of fruits, with a maintenance of the initial color compared to the fruits of the other treatments. During the IISL RRF treatment had a positive effect on L parameter whereas not influenced a* e b* color components. Taking into account the color value a*, all treatments had the same descendent trend whereas for b* MAP had a positive effect. During the IIISL third shelf (12 days), it has not been possible analyse MAP and MAP+ treatments due to a decay of the main quality standards: we evidenced a positive role of RRF only for L values (data not shown).

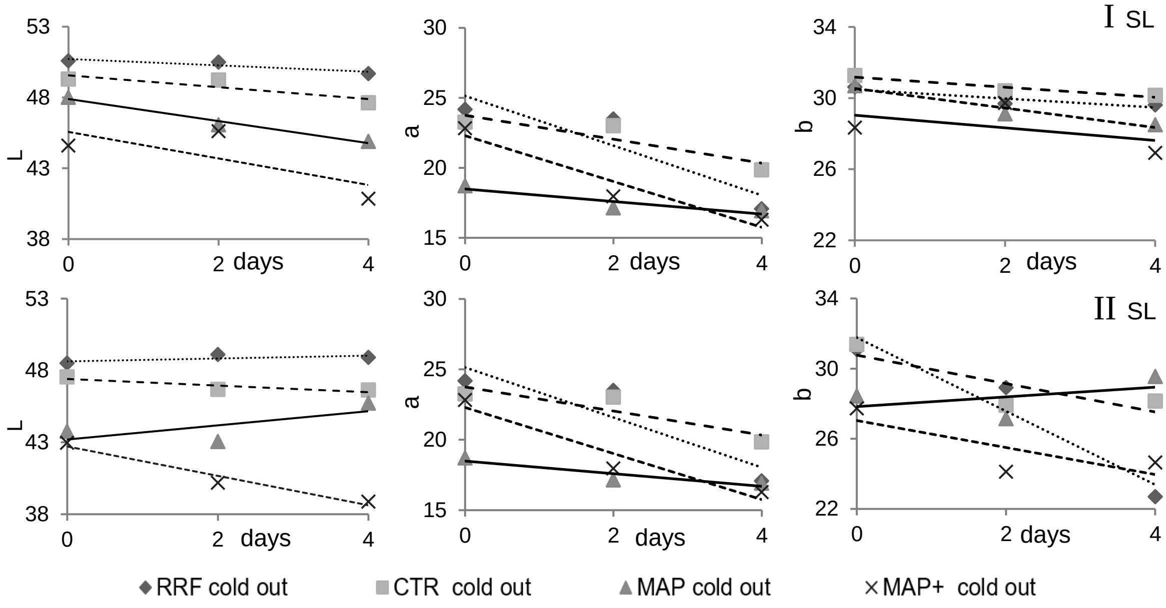

Figure 10: Time course of color after 4, 8 and 12 days of cold storage at 5°C and 2, 4 days of shelf life at 20°C.

3.4 Sensory analysis

Fruits at harvest appear very colorful, sweet, juicy and compact with pleasant organoleptic properties and an intense flavor of exotic fruit. (Figure 11). After 4 days of cold storage, RRF fruits presented the best values of C, J, FRF and EXF and after 8 days of FO and EXO. MAP and MAP+ showed similar values of several key attributes compared to CTR. After 12 days no differences were notice among the treatments.

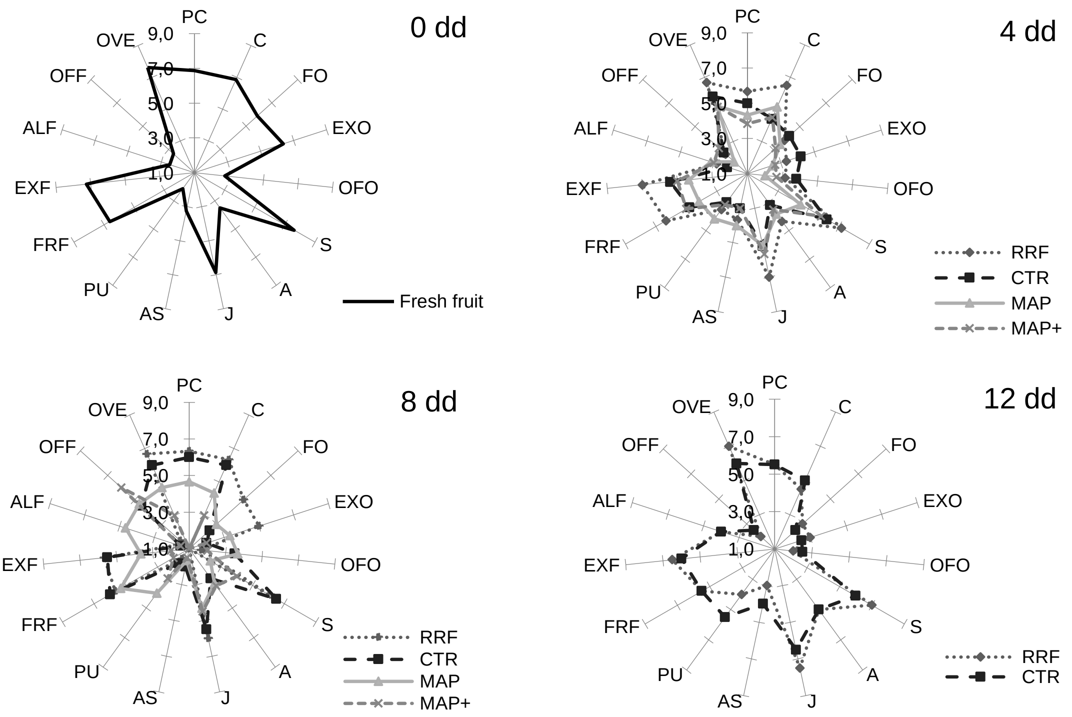

Figure 11: Scores for the sensory analysis of litchi fruit after 0, 4,8 and 12 days cold storage at 5°C. Flesh color (FC); consistency (C), fruity odour (FO), exotic fruits odour (EXO), off-odour (OFO), sweet (S), acid (A), juicy (J), astringent (AS), pungent (PU), fruits flavour (FRF), exotic fruits flavour (EXF), flavour alcohol (ALF), off-flavour (OFF) and overall evaluation (OVE).

4. Conclusions

After storage for 12 days at 5°C, MAP fruits obtained the lowest grades for visual appearance, compared to 4 and 8 days where the results were very similar to CTR. In MAP+ visual decay is increased during I and II shelf life, while MAP showed a similar trend to CTR. Hence, MAP treatment maintained the initial color for 4 and 8 days and an acceptable level of chemical physical traits, as evidenced by Sivakumar et al. (2006) and De Reuck et al. (2009), although RRF ensured the best shelf life and the best appearance of the fruits. In conclusion, it can be said that the rapid cooling treatment technology allows to limit the loss of fruit color compared to not treated fruits with the advantage of presenting to the consumer a more attractive external appearance. In fact, after 12 days of cold storage RRF reaching the best values of L*a*b demonstrating that the RR treatment has helped the fruit to keep color characteristics. As regards to the shelf life, even in this case RRF maintained L values. This fact indicates a lower browning of fruits. Moreover, RRF litchi reached the best chemical and physical characteristics in terms TSSC,TA, sweetness and juiciness during cold storage and the first and the second shelf-life.

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