INFLUENCE OF BAGGING MATERIALS ON MATURITY INDICES AND POST-HARVEST QUALITY OF 'ROMA VF' AND 'TINKER' CHERRY TOMATOES

By

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MINI-DISSERTATION

Submitted in fulfilment of the requirements for the degree of

Master of Science

in

Horticulture

in the

FACULTY OF SCIENCE AND AGRICULTURE

(School of Agricultural and Environmental Sciences)

at the

UNIVERSITY OF LIMPOPO

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2022

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DECLARATION

I, Mokgadi Pollet Mafotja, declare that the mini-dissertation hereby submitted to the University of Limpopo, for the degree of Master of Science in Horticulture, has not previously been submitted by me for a degree at this or any other University; that it is my work in design and execution, and that all material contained herein has been duly acknowledged.

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DEDICATION

I would like to dedicate this study to my two exquisite little sisters.

(Thabile and Tshegofatso Mafotja)

ACKNOWLEDGEMENTS

Firstly, I would like to give thanks to God the Almighty in the power of Jesus Christ, my Lord, for He has provided me with strength, endurance and wisdom during the period of my studies. I am grateful to my supervisor, Dr. NMD Buthelezi, and co-supervisors Prof TP Mafeo and Dr. N Mathaba, for their leadership, expertise, excellent encouragement, and constructive criticisms throughout the study and for introducing me to the world of scientific writing. I am also grateful to Mr. A Ramolotja, for his assistance and advice during the execution of the experiments at the field. My gratitude to the University of Limpopo, Department of Plant Production, Soil Science, and Agricultural Engineering, along with the staff at Aquaculture Research Unit, for allowing me to use the equipment and facilities to undertake this study. Most importantly, I would like to acknowledge and be thankful for the financial assistance from the National Research Foundation in conducting this study. I am thankful to ZZ2 for providing cherry tomato seedlings to undertake the study. Thanks to my parent (Samuel and Thabitha), sisters, and brothers for their support and motivation throughout this study. I wish to thank all my friends for assisting with all the field and laboratory work needed during the experiment.

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ABSTRACT

The purpose of this study was to assess the impact of pre-harvest bagging materials on maturity indices and post-harvest quality of cherry tomatoes. At pre-harvest, fruit were bagged with blue and transparent plastic bags of 0.075- and 0.025-mm thickness, respectively. The non-bagged fruit were considered as control treatment. The experiment was carried out in a randomized complete block design arranged in a 2 × 3 factorial arrangement with three replications. Physical quality parameters such as; colour changes (L*, a*, b*, C*, h˚, and ΔE), firmness, weight loss and size were assessed. Physico-chemical parameters such as pH, total soluble solids, and total titratable acidity were also evaluated. Bagging had a significant effect on the quality of both cherry tomato cultivars. The results showed that bagging cherry tomatoes at 1.5 cm diameter with blue and transparent plastic bags accelerated maturity. Moreover, bagging with transparent plastic bags enhanced exocarp colour, reduced weight loss, retained larger size, increased pH and TTA, with an increase in TSS when compared with blue plastic bags and control, respectively at 12 days of shelf-life. In conclusion, the findings demonstrate that pre-harvest bagging has the potential to improve maturity indices and post-harvest quality of cherry tomatoes. Therefore, pre-harvest bagging can be used as an alternative method to enhance cherry tomato fruit quality and shelf-life.

***Keywords*:** Bagging materials, fruit quality, market value, total soluble solids, weight loss

CHAPTER 1

GENERAL INTRODUCTION

1.1. Background

Tomato (*Solanum lycopersicum*) belongs to the Solanaceae family, ranking second in world production after potato and is highly rich in nutrients such as vitamin C and D, potassium, and dietary fibre (Burton-Freeman and Reimers, 2011; Petric *et al*., 2018). Globally, tomato production is estimated at 162 million tonnes, with an area of production accounting for about 4.8 million hectares (Arah *et al*., 2015). In terms of world production, China is the leading country with approximately 50 million tonnes followed by India with 17.5 million tonnes (Arah *et al*., 2015). In South Africa, tomatoes are produced on a larger scale, with Limpopo being the major producing province with about 3 590 ha accounting for about 75% of total cultivation, while Mpumalanga and Eastern Cape accounting at 770 and 450 ha, respectively (DAFF, 2019). Tomato fruit distributions occur at fresh local, processing, and export markets, having per consumption capita per person of 12 kg per annum (DAFF, 2019). In 2009, South Africa exported approximately 8 759 tonnes of tomatoes, representing 3% of the world's export (DAFF, 2010).

Practically, tomato fruit are harvested at different maturity stages, including mature green, half ripen, and red ripen (Arah *et al*., 2015). Harvest maturity has a significant influence on nutrient content, quality and fruit storage durability (Moneruzzaman *et al*., 2009). Tomato is highly susceptible to pest and disease infestations which lower crop value and quality; thus, increasing post-harvest losses (Filgueiras *et al*., 2017). The above constraints have been controlled and minimized by the application of, for example, pesticides which have been criticized due to their hazardous effect on human and environmental health; thus, a need for environmental and consumer-friendly techniques (Sharma *et al*., 2014). Therefore, the fruit bagging practice has emerged as an effective approach to enhance fruit quality (Filgueiras *et al*., 2017).

In general, fruit bagging is applied by covering individual fruit or clusters with plastic or paper bag materials (Leite *et al*., 2014). According to Sharma and Sanikommu, (2018), such materials serve as a physical barrier, protecting fruits against pests and diseases while improving fruit quality by changing the micro-environment around the fruit. The technique has been reported to increase fresh fruit mass, size and improve fruit colour in mango (*Mangifera indica*) (Sharma *et al*., 2020), apples (*Malus domestica*), pears (*Pyrus communis)*, pomegranate (*Punica granatum*), and banana (*Musa acuminata*) fruit (Sharma *et al*., 2013). Furthermore, Islam *et al*. (2020) found that pre-harvest bagging of 'BARI mango-4' mango fruit at 45 to 50 days after fruit set with brown and white paper bags enhanced the quality and shelf-life of the fruit by reducing weight loss and improving total soluble sugars and β-carotene. However, the success of bagging depends on bag type, bagging stage, duration, and weather conditions during application (Sharma *et al*., 2014, Buthelezi *et al*., 2020). Studies have reported on the effect of bagging on the quality of different fruits; however, little is known about the effect of different bagging materials on fruit quality at pre-and post-harvest stages, particularly of cherry tomatoes. Therefore, the study assessed the potential influence of pre-harvest bagging on maturity indices and post-harvest quality of cherry tomatoes.

1.2. Problem statement

The quality of fresh cherry tomatoes is determined by virtual attributes such as colour, firmness, and absence of defects which are the major qualities used by consumers (Farneti, 2014). Tomato fruit quality is highly affected by insect pests and disease infestations; thus, leading to a reduction in marketable yields (Patel *et al*., 2020). Moreover, uneven ripening is one of the major challenges faced by the cherry tomato industry resulting in reduced prices and market exclusion (Schouten *et al*., 2006). Therefore, pre-harvest bagging has emerged as a potential alternative method for improving fruit quality by protecting fruits against mechanical damage, sunburn and harsh environmental conditions (Sharma *et al*., 2014). Furthermore, fruit bagging modifies the surrounding micro-climate of fruit; thereby, enhancing physiological and biochemical quality. Previous studies have reported that pre-harvest bagging improves fruit quality such as colour, size, total soluble solutes and phenolic compounds in apples, pears and mango (Amarante *et al*., 2002; Sharma *et al*., 2013). However, although fruit bagging technique is useful, its use has been limited to pests and diseases control; and very few studies address its impact on the maturity and post-harvest quality of cherry tomatoes. Hence the proposed study addresses the potential of pre-harvest bagging in order to improve maturity indices, ripening and post-harvest quality of cherry tomatoes.

1.3. Rationale of the study

In South Africa and other production regions, tomato has high economic value (DAFF, 2019). According to Batu (2004), skin colour, firmness and absence of defects are the most important attributes which determine the market and consumer's acceptance. However, the use of many pesticides to control pests and diseases has been limited and banned by the European Union (EU) due to their hazardous effect on human and environmental health such as causing cancer and pollution, respectively; thus, increasing the demand for chemical-free products (Chávez-Sánchez *et al*., 2013). Pre-harvest fruit bagging is a phytosanitary practice intended for fruit protection against infestation of pests and diseases, fruit abrasions and harsh environmental factors such as hail and sunburn (Asrey *et al*., 2020). Fruit bagging has shown the potential to improve fruit quality, particularly, colour development, for better pricing and inclusion in both domestic and export markets (Griñán *et al*., 2019). Previous studies reported that pre-harvest fruit bagging enhances pigments such as anthocyanin and carotenoids; consequently, improving skin colour (Islam *et al*., 2020; Asrey *et al*., 2020). Moreover, it has been demonstrated that pre-harvest bagging improves the phenolic compounds and antioxidant activity in fruits (Sharma *et al*., 2013). Therefore, the impact of this technique needs to be evaluated on cherry tomato fruit quality.

1.4. Purpose of the study

1.4.1 Aim

The aim of this study is to assess the impact of pre-harvest bagging materials on maturity indices and post-harvest quality of cherry tomatoes.

1.4.2. Objective

To investigate the effect of pre-harvest bagging on maturity indices and post-harvest quality of 'Roma VF' and 'Tinker' cherry tomatoes.

1.4.3. Hypothesis

Pre-harvest bagging materials have an effect on maturity indices and post-harvest quality of 'Roma VF' and 'Tinker' cherry tomatoes.

1.5 Structure of the mini-dissertation

Chapter 1: Addresses the background of the study and the importance of cherry tomatoes. It also states the problem statement, rationale and significance of the study as well as the aims and objectives.

Chapter 2: The literature review which reviews previous and relevant work pertaining to the study; identify both research knowledge (what is already known based on previous studies) as well as the research gap (what is not known or addressed by previous studies). Moreover, it contains the analysis table highlighting the bagging materials, bagging date, fruits, findings, and references.

Chapter 3: Gives a detailed account of the experimental sites, treatment, design, procedures, data collection and analysis.

Chapter 4: Interpret results clearly to outline the difference amongst treatments (blue and transparent plastics) based on mean separation to determine the best treatment, highlighting results to provide the significance of the findings, and provides the general discussion of the findings and evaluates whether the two methods have any trends and consistency.

Chapter 5: Provide conclusions and recommendations of the study. It also elucidates what the problem of the study was. Also, specify key points regarding the key findings and recommendations on how to improve quality using pre-harvest bagging materials. Additionally, it indicates the research gaps for future research.

CHAPTER 2

LITERATURE REVIEW

THE POTENTIAL OF FRUIT PRE-HARVEST BAGGING TO IMPROVE MATURITY AND POST-HARVEST QUALITY OF HORTICULTURAL PRODUCE

2.1. Introduction

Cherry tomato originates from the tropical and subtropical zones of America, and is widely propagated and produced in Asia and Africa (Pasorn *et al*., 2018). Globally, cherry tomatoes are largely used for fresh consumption and their commercial importance is continuously increasing (Raffo *et al*., 2006). In recent years, their consumption has been shown to have health benefits due to their high phytonutrient content. Cherry tomatoes contain high contents of lycopene (71.6%), vitamin C (12.0%), pro-vitamin A carotenoids (14.6%), β-carotene (17.2%) and vitamin E (6.0%) (Raffo *et al*., 2006). Globally, cherry tomatoes are largely produced in China, India and Japan. South Africa is one of these major producers with a strong demand for the commodity (Tilahun *et al*., 2017). As a result, cherry tomato production, marketing and distribution have increased for both domestic and international markets (DAFF, 2019).

During growth, development and maturity, cherry tomatoes fruit undergo several physical and chemical changes, including colour, acidity, soluble solids, enzyme activity, shape, texture, weight and juiciness (De Oliveira *et al*., 2016). Consequently, the fruit becomes more vulnerable to pest infestation and mechanical damage, which result in poor appearance, limited storage potential and inability to withstand postharvest handling (Sharma *et al*., 2014). Furthermore, pests and diseases infestation reduce post-harvest and internal quality which include the chemical composition of tomato fruit. The use of agrochemicals significantly controls pests and diseases; thus, improving produce quality. However, this method is highly criticized due to its negative impact not only on human health but also on the environment. According to Guilherme *et al*. (2014), negative impacts caused by chemicals include soil chemical imbalance, soil erosion, a decline of soil organic matter content and chemical residues on harvest produce. Therefore, there is a need for chemical-free technologies that are environmentally friendly to mitigate against pests and diseases (Sharma *et al*., 2014).

Pre-harvest bagging is a chemical-free technique used to protect fruits against pest and disease infestations; thus, contributing to limited pesticides use (Buthelezi *et al*., 2021). Furthermore, fruit bagging offers protection against mechanical damage and harsh environmental conditions such as sunburn, strong wind, hail and high temperatures (Sharma *et al*., 2014) (Figure 2.1). Moreover, abiotic factors such as temperature are one of the most critical environmental factors that affect quality, temperature fluctuations (low and high) may injure sensitive crops. In tomatoes, high temperatures such as those above 30° C may inhibit lycopene accumulation due to stimulation of lycopene conversion into β-carotene (Patel *et al*., 2020). Moreover, pre-harvest bagging has been reported to modify the micro-environmental conditions responsible for both internal and external fruit quality (Sharma and Sannikomu, 2018). Many fruits, such as apples cv. Golden Delicious and Red Delicious, pears cv. Conference, and mango cvs. Mishribog and Amrapali, have been bagged extensively, and various effects on quality observed depending on the cultivar and bag type used. Some fruits, for example, loquat (*Eriobotrya japonica*) and apples have been found to benefit from bagging with an improvement of quality attributes such as fruit size, colour, weight, firmness, total soluble solutes and phenolic compounds (Xu *et al*., 2010; Sharma *et al*., 2013). Therefore, this review investigated whether pre-harvest bagging influences fruit maturity and the quality of horticultural crops.

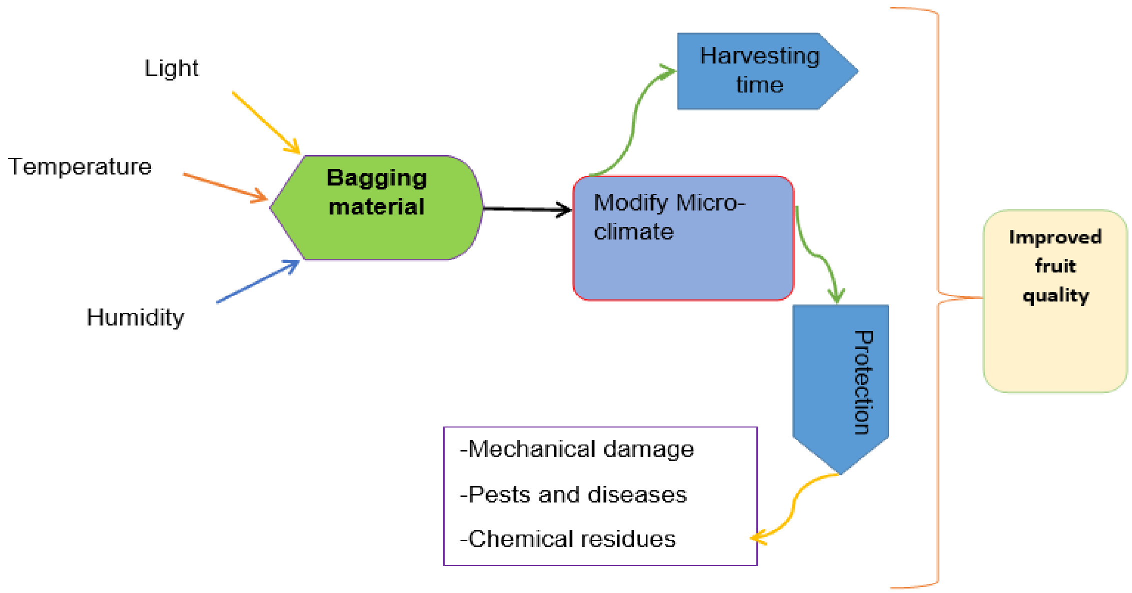

Figure 2.1: A diagram illustrating the effect of bagging material on fruit quality.

2.2. Importance of bag type

Fruit bagging is a labour-intensive production practice, while some bagging materials such as paper and plastics are cheaper, easily recyclable and re-usable with excellent results such as controlling sunlight, temperature, humidity, evaporation, reducing mechanical damage and regulating harvest time and control pest attacks (Ali *et al*., 2021). Bagging materials used include plastic bags such as transparent polyethylene bags, blue polyethylene plastic bags, cellophane bags; and paper bags such as newspaper and brown paper bags (Figure 2.2). These different bagging materials have varying effects on fruit quality attributes such as temperature regulation (Sharma and Sanikommu, 2018). Moreover, bag colour plays a significant role in micro-environment characteristics by modifying the temperature and humidity surrounding the fruits (Rajan *et al*., 2020). In addition, bagging materials also vary in thickness. For example, bagging banana fruit with perforated blue and shiny plastic of 5 µm thickness improved fruit quality such as colour, weight and total soluble solids (Muchui *et al*., 2017).

Figure 2.2: Bagging materials used to improve fruit quality: **A**-transparent polyethylene plastic bag, **B**-blue polyethylene plastic bag, **C**-brown paper bag, **D**-

organza bag, **E**-newspaper bag, and **F**-yellow polyethylene plastic bag (Ali *et al*, 2021).

2.3. Impact of pre-harvest bagging on fruit maturity indices

2.3.1. Colour

In horticultural fruit crops, colour development is due to pigmentation compounds such as carotenoids, anthocyanin and chlorophyll (Farneti, 2014). Fruit colour is influenced by the concentration and skin pigments distribution such as anthocyanins, chlorophyll and carotenoids and, environmental conditions such as light influences pigment synthesis; and therefore, skin colour (Lima *et al*., 2013). In apples and peaches, pre-harvest bagging has been reported to enhance the synthesis and accumulation of anthocyanins and total carotenoids (Wang *et al*., 2015; Liu *et al*., 2015). In a study conducted by Hudina and Stamper (2011), bagging pear fruit cv. Conference 65 days after full bloom with paper bags resulted in high lightness value (L*). While in pomegranate fruit (*Punica granatum*) cv. Kandari, bagging with red coloured cellulosic bag 60 days after flowering improved fruit colour through enhancement of anthocyanins synthesis (Asrey *et al*., 2020). Furthermore, bagging Chinese sand pears 'Meirensu' and 'Yunhongli No.1' with yellow-black paper bags 20 days after full bloom enhanced red colour due to upregulated anthocyanin synthesis and accumulation and chlorophyll degradation (Table 2.1) (Huang *et al*. 2009).

2.3.2. Weight loss

Generally, cherry tomato is a climacteric fruit consisting of high-water content, and water loss which results in post-harvest shriveling (Chutichudet and Chutichudet, 2014). According to Proulx *et al.* (2005), fresh fruits lose weight as a result of water loss through metabolic processes and the natural porosity of the skin. However, cherry tomato fruit do not have stoma or lenticels, and most water vapour and other gases move through the stem scar (Coutts *et al*., 2004). Water loss is the factor that contributes most to weight loss, and for products sold by weight, this will have negative economic consequences (Hailu and Derbew, 2015). Therefore, more severe water loss results in a reduction in appearance quality including wilting, shriveling, less gloss, and limpness, which will reduce both the domestic and export market value (Coutts *et al*., 2004). Conversely, pre-harvest fruit bagging has been found to have a significant effect by reducing weight loss in pomegranate and mango fruits (Islam *et al*., 2019b).

In mango fruit cv. Langra, bagging with brown paper bags 55 days after fruit set reduced weight loss (Islam *et al*., 2019a). Similarly, Raphak (2016) found that bagging mango fruit cv. Amrapalin 35 days after fruit set with brown paper bags significantly reduced fruit weight loss percentage (Islam *et al*., 2019). A study by Ghete *et al*. (2021) showed that bagging pomegranate fruit cvs. Phule, Bhagwa, and Super with parchment bags 9 days after fruit set reduced weight loss percentage (Table 2.1).

2.3.3. Size

Tomato size, which can influence nutritional value, is an important factor for consumer choice (Islam *et al*., 2019b). There is a transient size increase during cherry tomatoes' fruit growth, development, and maturation (Sharma and Sanikommu, 2018). According to Islam *et al*., (2019b), many factors influence tomato fruit size, such as low ambient-light conditions, which can result in smaller tomatoes and reduced vitamin C content. In litchi (*Litchi chinensis*) fruit cv. Rose scented, bagging with pink polypropylene bags for 30 days before harvest significantly increased fruit size by modifying the micro-climate surrounding the fruit (Shah *et al*., 2020). In guava fruit cv. Latif, bagging with yellow polythene bags 15 days after fruit set improved fruit size through adequate light transmission (Meena *et al*., 2016). Moreover, tomato bagged with butter and newspaper bags at the marble stage (30 days after fruit set) enhanced both equatorial and polar diameter, respectively (Patel *et al*., 2020) (Table 2.1).

2.3.4. Firmness

Fruit firmness is one of the important attributes for harvest maturity; and ultimately, influences postharvest-life and consumer acceptance (Hong *et al*., 2012). In cherry tomato quality, firmness is the most important factor which is closely associated with the ripening stage (Gharezi *et al*., 2012). Additionally, tomatoes continue to ripen or soften after harvest; and, therefore, inherently soften, which results in a relatively short shelf-life for both the retailer and consumer. Therefore, necessitates the need to find alternative for methods for reducing firmness loss (Raffo *et al*., 2002). However, fruit bagging has been reported to have a significant effect by enhancing fruit firmness at harvest in pears, litchi and mango (Amarante *et al*., 2002; Sharma *et al*., 2014).

In mango fruit cv. Amrapali, pre-harvest bagging 20 days before harvest using a single layer brown paper bag, improved firmness at harvest but decreased during storage due to cell softening during ripening and senescence (Jhakhar and Pathak, 2016). However, bagging guava fruit cv. Allahabad Sefeda with polypropylene woven, butter paper, and brown bag 30 days after pollination enhanced firmness at harvest, gradually decreasing during postharvest storage (Sharma *et al*., 2020). A study by Sharma *et al*. (2013), showed that bagging apple fruit cv. Delicious with spun-bounded light yellow fabric bags 30 days before harvest improved firmness than non-bagged fruits which was maintained yet declined during storage (Table 2.1).

Table 2.1: Pre-harvest bagging effect on maturity indices

Commodity	**Cultivar**	**Bagging period**	**Bagging material**	**Findings**	**Reference**
Pineapple	Mauritius	After flowering	Paper bag and black polythene bag	Increased fruit length and circumference	Prabha *et al*., (2018)
Litchi	Rose scented, Shahi	30 days before harvest 40 days after bloom	Pink polypropylene bag Brown paper bag	Increased fruit size, colour, and firmness	Shah *et al*., (2020); Purbrey and Kumar (2015)
Guava	Latif,	15 days	Yellow	Increased	Meena *et*

	Allahabad Safeda	after fruit set 30 days after pollination	polythene bag, Polypropylene packaging woven, butter paper and brown paper bags	fruit diameter, peel colour; Enhanced firmness at harvest, size, and fruit maturation	*al*., (2016); Sharma *et al*., (2020)
Tomato		Marble stage	Butter and newspaper bagging, respectively	Increased polar and equatorial size	Patel *et al*., (2020)
Pear	Conference	65 days after full bloom 30 days after full bloom	Paper bags Micro-perforated polypropylene bags	Enhanced fruit colour Firmness gradually decreased during post-harvest storage	Hudina and Stampar, (2011); Amarante *et al*., (2002)
Pomegranate	Kandari, Phule, Bhagwa ,Super	60 days after flowering 9 days after harvest	Red coloured cellulosic bags Parchment bag	Improved fruit colour Reduced weight loss	Asrey *et al*., (2020), Gethe *et al*., (2021)
Mango	Mishribog, Amrapali, Langra	40 to 50 days after fruiting 20 days before harvest	Brown paper bags; single-layer paper bag	Enhanced fruit colour and diameter Enhanced fruit firmness at harvest, gradually	Sharma *et al*., (2014), Jhakhar and Raphak (2016);

		55 days after fruit set		decreased at the storage, Reduced weight loss	Islam *et al*., (2019a)
Apple	Delicious	30 days before harvest	Spun-bounded light yellow fabric bags	Higher firmness at harvest sharply declined during storage	Sharma *et al*., (2013)

2.4. Impact of pre-harvest bagging on physico-chemical parameters

2.4.1. Titratable Acidity (TA) and pH

In general, pH level measures fruit acidity degree. The pH value indicates the hydrogen ion concentration depicting the acidity level (Astuti *et al*., 2018). Moreover, titratable acidity explains the measure of the amount of the dominant acid (Lawal *et al*., 2019). Titratable acid is determined by pH level having a desirable level below 4.5 pH units (Aoun *et al.*, 2013). Although the pH of ripe tomatoes may exceed 4.6, tomato products are generally classified as acidic foods (pH < 4.6), pH below 4.5 is a desirable trait because it halts the proliferation of microorganisms (Tigist *et al*., 2013). Generally, TA is considered an indicator of fruit maturity or ripeness and acids make an important contribution to fruit post-harvest quality, as taste is mainly a balance between the sugar and acid contents (Hanif *et al*., 2020). According to Prabha *et al*. (2018), bagging pineapple fruit cv. Mauritius with paper and jute bags after flowering significantly decreased TA levels. In litchi fruit cv. Shahi, bagging 40 and 50 days after bloom with polyethylene, white butter, brown paper bag, and muslin cloth significantly increased pH (Purbey and Kumar, 2015). The decrease of titratable acidity might be attributed to the utilization of organic acids in respiration process and other bio-degradable reactions, moreover, being accounted by the modified micro-climate around the bagged fruit (Meena *et al*., 2016) (Table 2.2).

2.4.2. Total Soluble Solids (TSS)

Total soluble content measures the carbohydrates, organic acids, proteins, fats, and minerals of the fruit, moreover, it represents approximately 10-20% of the fruit's fresh weight and increases as fruit matures to produce a less acidic and sweeter fruit (Basit *et al*., 2020). Total soluble solids (TSS) content is one of the major parameters of quality, most importantly used to measure maturity and ripeness (Xu *et al.*, 2018). In tomatoes, increased accumulation of reducing sugars, partial breakdown of pectin and celluloses during ripening enhances the TSS content (Patel *et al*., 2020).

In pomegranate cv. Wonderful, pre-harvest bagging with agril red bag for 21 days after fruit set increased the total soluble content than the non-bagged fruits (Abou El-Wafa, 2014). In tomato fruit, the use of newspaper bags 30 days after fruiting resulted in a significant increase in soluble solutes (Patel *et al*., 2020). According to Omar and El-Shemy (2014b), TSS increased following the use of a large craft paper bag 35 days after pollination in palm fruit cv. Zaghloul. Similarly, bagging palm date cv. Rothana with grill cloth for one month after pollination improved soluble solute content (Omar *et al*., 2014a). The increase of TSS content is due to the conservation of complex carbohydrates into simple sugars, resulting from the increase in temperature (Meena *et al*., 2016) (Table 2.2).

Table 2.2: Pre-harvest bagging effect on physico-chemical parameters

Commodity	**Cultivar**	**Days**	**Bagging material**	**Findings**	**Reference**
Tomato		30 days after fruit set	Newspaper bag	Increased total soluble contents	Patel *et al*., (2020)
Pomegranate	Wonderful	21 days after fruiting	Agril red bag	Improved soluble solutes,	Abou El-Wafa, (2014),
Guava		30 days after fruit	Perforated polyethylene	Increased total	Abbasi *et al*., (2014)

		set	and newspaper bags	soluble solutes and pH	
Palm	Zaghloul	35 days after pollination	Large craft paper bag	Increased total soluble solutes	Omar and El- Shemy (2014b)
Litchi	Shahi	40 DAB 50 DAB	Polyethylene, white butter, brown paper, muslin cloth	Higher pH	Purbey and Kumar (2015)

2.5. Future prospective and conclusion

Pre-harvest bagging is a simple and grower-friendly technique that is safe to use and an alternative technique for improving the marketable quality of fruits. Previous studies have demonstrated that bagging materials enhance fruit quality in apples, mango, pear, tomato and pineapple, litchi, and loquat. This technique has the potential to improve the post-harvest qualities of fruit to meet both the market and consumer’s acceptance. However, with the available literature, the influence of bagging materials on cherry tomatoes at both pre-and post-harvest quality is not adequately investigated. Therefore, future studies should investigate the effect of pre-harvest fruit bagging materials on maturity indices and post-harvest quality of cherry tomatoes.

CHAPTER 3

METHODOLOGY AND ANALYTICAL PROCEDURES

3.1. Description of the study site

The study was conducted at Aquaculture Research Unit, University of Limpopo, South Africa (23°53'10"S, 29°44'15"E). The climate in this area is semi-arid with annual precipitation of ±459 mm and a mean annual temperature of ± 25 °C (Phadu, 2019).

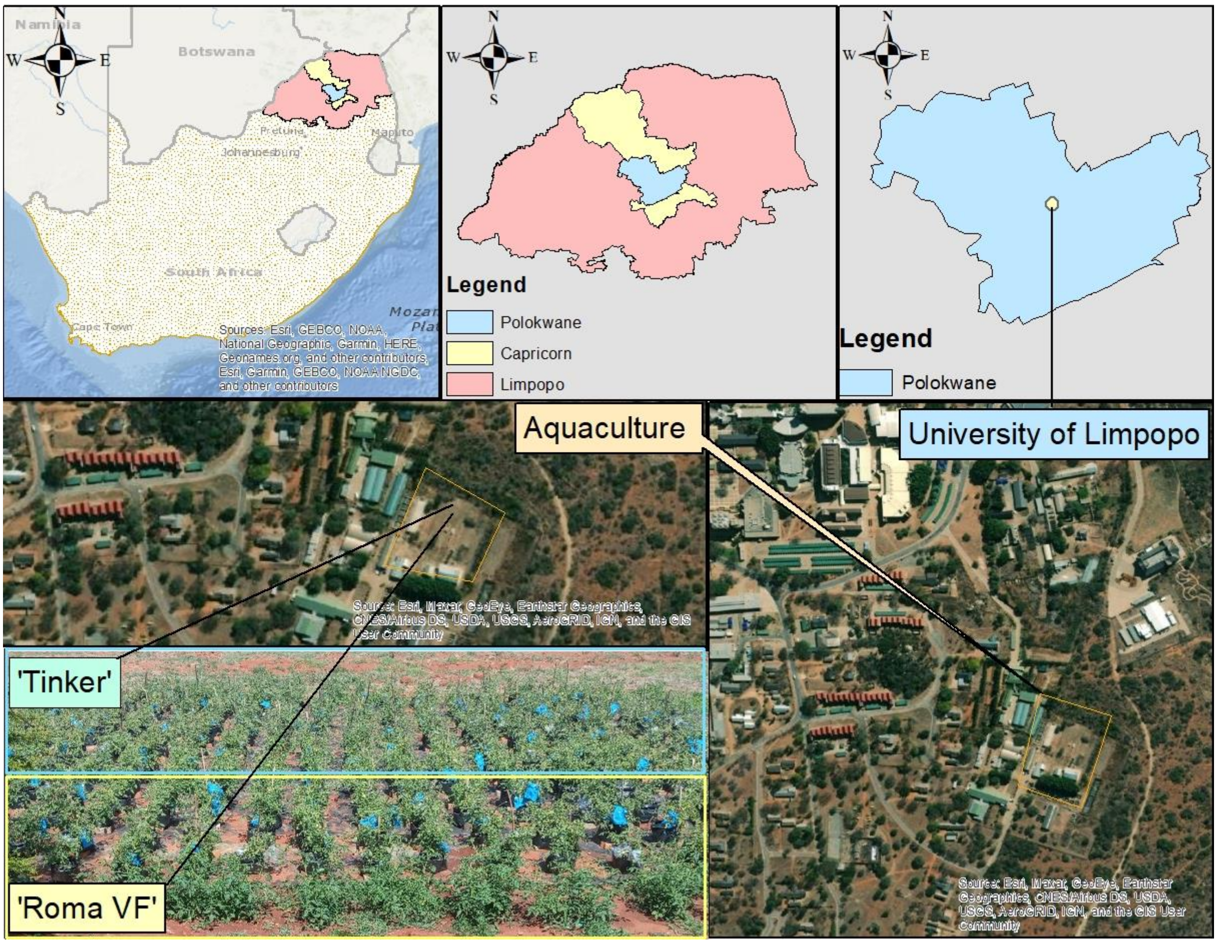

Figure 3.1: Location of the study site (ArcGIS software).

3.2. Experimental design, treatments, and procedures

Two cherry tomatoes cultivars were used ,namely, 'Roma VF' and 'Tinker', where 100 plants per cultivar were bagged with blue and transparent polyethylene plastic bags of 0.075 and 0.025 mm thickness, respectively; and 20 plants per cultivar were used as control. The experiment was carried out in a randomized complete block design arranged in a 2 × 3 factorial arrangement with three replications. The experimental factors included two tomato cultivars ('Roma VF' and 'Tinker') and three bagging materials (control, transparent plastic, and blue plastic).

Seedlings of the cultivar 'Roma VF' and 'Tinker' cherry tomato were collected from ZZ2 farm in Moeketsi, Limpopo province, South Africa (23° 35' 41" S, 30° 5' 51" E), with a monthly maximum and minimum temperatures of 21 and 12°C, respectively (Novela, 2016). They were transplanted in black plastic bags (30 cm) containing steam-pasteurized soils (300°C for 45 min) and 5 g of superphosphate fertilizer (Tseke *et al*., 2013). An area of 45 m^2 was prepared using a hand hoe to remove weeds and sprayed with roundup; then covered with black plastic to suppress weeds. Plants were placed at an inter-row spacing of 50 cm and intra-row spacing of 40 cm (Coutts *et al*., 2004), immediately irrigated with 500 ml of tap water per day and trellised with 1 m stick (Nkosi, 2019). Thereafter, the seedlings were fertigated with 500 ml mixture of tap water and fertilizer per week. The fertilizer mixture was prepared as follows: 50 g of monoammonium phosphate (MAP), potassium nitrate (KNO_3), and calcium nitrate ($CaNO_3$) in 25 ℓ of water.

Pests were controlled by the application of 15 ml of cypermethrin per 16 ℓ of water for bollworm, 5 ml of protec complete for whitefly per 5 ℓ of water and 20 g of Dithane-M.45 per 10 ℓ of water. For disease control, 50 ml of copper-flow-plus per 10 ℓ of water and 20 ml of mycoguard per 10 ℓ of water were applied every 10 to 14 days.

A total of 100 plants/cultivar/treatment were bagged at fruit diameter of 1.5 cm, whereas 20 plants/cultivar were used as control.

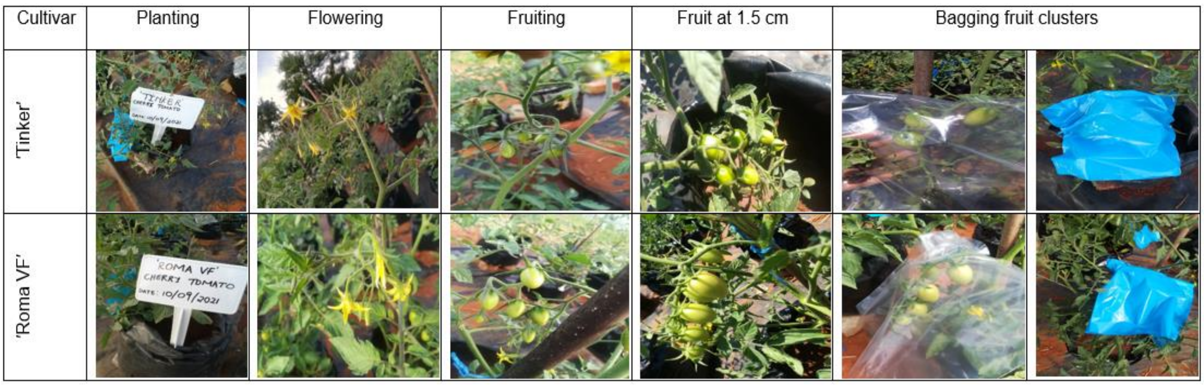

Figure 3.2: Phenological stage of cherry tomato cultivars until bagging stage.

At a mature green stage, fruit clusters per cultivar/treatment without any visible defects were manually harvested using a sterilized scissor. Maximum of three fruit clusters/cultivar/treatment having 6-8 fruit were harvested and packed in open boxes and taken to a post-harvest laboratory for sorting and storage at ambient temperature (± 25 °C and 90% relative humidity) and data were collected at 3 days interval for 12 days of shelf-life.

3.3. Data collection

3.3.1. Evaluation of physico-chemical parameters

Skin colour

The colour of cherry tomatoes was determined using a standard handheld Minolta chromameter (Model: CR-400, Konica Minolta, Sensing Incorporation, Japan). Colour characteristics such as L* (lightness), a* (greenness/redness), and b* (yellowness/blueness) were assessed according to McGuire (1992). Total colour difference (ΔE*) was calculated using Eq. (2) according to Sarkar *et al*. (2020):

$$\Delta E = (\Delta L^2 + \Delta a^2 + \Delta b^2)^{1/2}$$

Where:

$$\Delta L = L^*_{standard} - L^*_{sample} \quad \Delta a = a^*_{standard} - a^*_{sample}, \quad \Delta b = b^*_{standard} - b^*_{sample}.$$

The standard calibation plate (calibration plate CX0738, L*= 92.23, a*= -1.28, b*= 1.22).

Weight loss

Weight loss was determined using an electronic weighing scale (Model HCB 1002, Adam equipment, Shanghai-China). The percentage of weight loss was calculated as the difference between initial fruit weight and final fruit weight to the initial fruit weight. Weight loss percentage was calculated using Eq. (1) as previously assessed by Gharezi *et al*. (2012):

$$Weight\ loss\ (\%) = \frac{\text{initial fruit weight} - \text{final fruit weight}}{\text{initial fruit weight}} \times 100$$

Fruit firmness and size

Fruit firmness was measured using a handheld penetrometer (FT 40, Wagner Instruments, and Greenwich CT, USA), and results were expressed as newton (N) (Alenazi *et al*., 2020). Fruit size was determined using Vernier caliper (KG 15, Guilin Guanglu, China) and results were expressed as millimeters (mm) (Fu *et al*., 2016).

pH, Total soluble solids (TSS) and titratable acidity (TA)

The pH was determined using a pH meter (Thermo Scientific^{TM} OrionTM Star A211, Beverly, United States of America) (Sinha *et al*., 2019). To determine total soluble solids (TSS), a refractometer (Atago, DR-A1, Tokyo, Japan) was used, and results were expressed as % °Brix (Hanif *et al*., 2020). Titratable acid was determined following the method described by Pastori *et al*. (2017), 5 ml of fruit juice was diluted with 95 ml distilled water and; titrated with 0.1 M NaOH using 1% phenolphthalein as an indicator, and results were expressed as a citric acid percentage using Eq. (3) as follows:

$$TA(\%) = \frac{0.1\ \text{NaOH} \times 0.067 \times 100}{\text{mL of juice used}}$$

Where: NaOH = sodium hydroxide:- mL= millilitres

3.4. Data analysis

Data were subjected to analysis of variance (ANOVA) using GenStat® version 20th (VSN International, Hemel Hempstead, UK), and means were separated using Least Significant Difference (LSD) at 5% level of significance.

CHAPTER 4

RESULTS AND DISCUSSION

4.1. Results

4.1.1. Colour

Blueness (b*)

The cultivar and treatment had a significant interaction ($p = 0.005$) on cherry tomato fruit exocarp blueness. Similarly, the treatment had a significant effect ($p < 0.001$) on cultivar blueness (Figure 4.1). Regarding the treatment, blueness values significantly decreased with 'Roma VF' cherry tomatoes fruit having the lowest blueness (27.98 to 20.41) when bagged with transparent plastic when compared with blue plastic (35.22 to 24.67) and non-bagged fruit at day 12 shelf-life. However, fruit bagged with blue plastic showed the lowest blueness (27.31 to 20.64) compared with fruit bagged with transparent plastic (31.96 to 17.45) and control (27.8 to 20.41) at day 9 of shelf-life in 'Tinker' cherry tomato fruit.

Redness (a*)

The cultivar and treatment had a significant interaction ($p < 0.001$) on cherry tomato fruit exocarp redness. Also, individual treatment and cultivar had a significant effect ($p < 0.001$) on fruit exocarp redness (a*) (Figure 4.2). Fruit redness progressively increased during shelf-life days. In 'Roma VF' cherry tomato fruit, high exocarp redness was observed with treatment of transparent plastic bag (-2.23 to 3.45) when compared with blue plastic (-1.03 to 2.24) and non-bagged fruit (-2.54 to 1.56) at day 9 of shelf-life. Similarly, 'Tinker' cherry tomato fruit showed an increase in redness (-1.24 to 5.12) when treated with transparent plastic compared with blue plastic (-5.90 to 0.66) and non-bagged treatment (-4.52 to -0.18) at 12-days shelf-life.

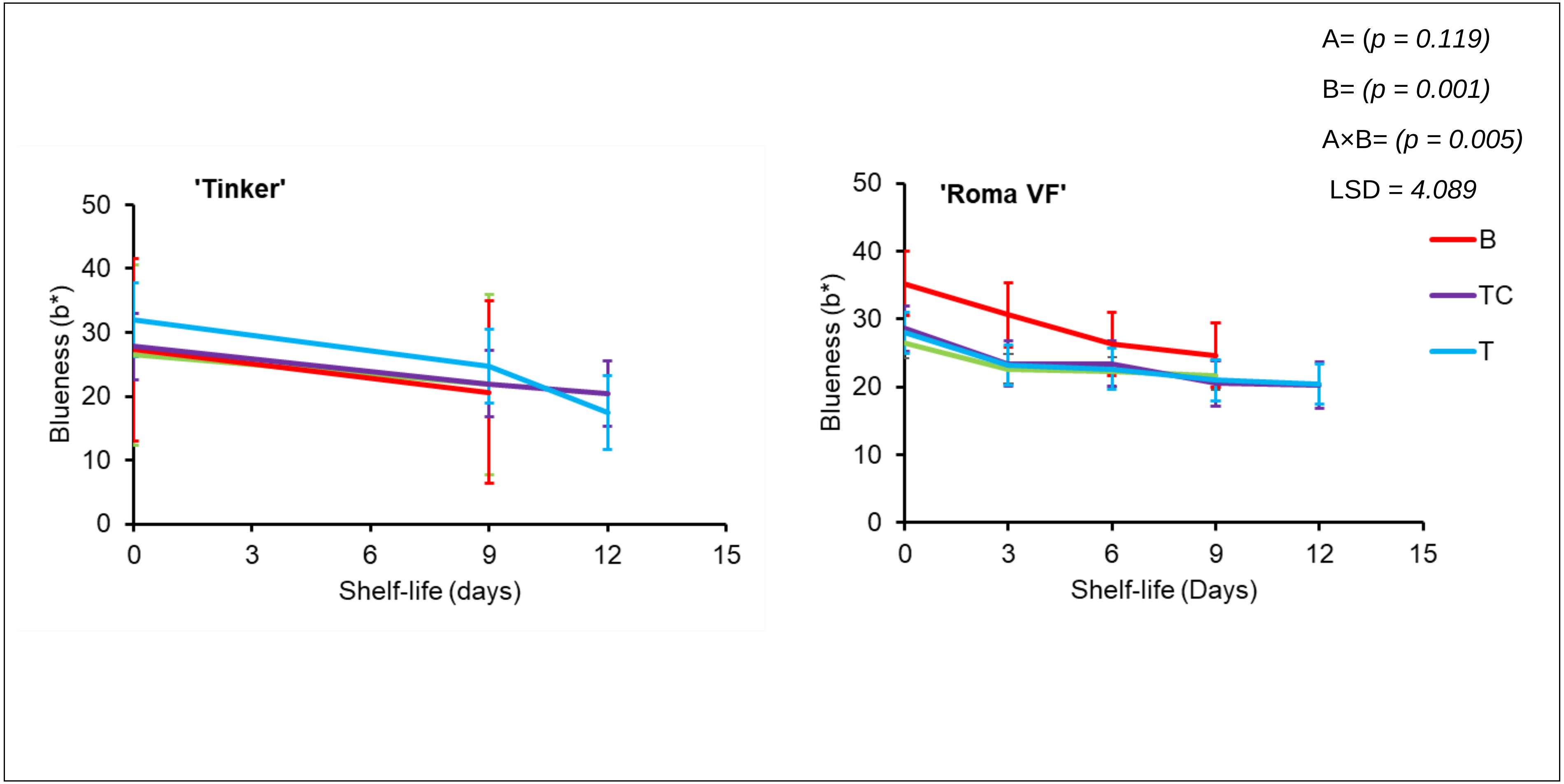

Figure 4.1: Effect of pre-harvest bagging on fruit blueness (b*) for 10 days. Fruit were stored for 12 days at post-harvest. Values are means of 5 fruit, and error bars indicate ± SE of means at $P \leq 0.05$. Mean separation was done using LSD, least significant difference. A = cultivar, B = Treatment and A×B = interaction of cultivar and treatment. BC = blue plastic bag control, B = blue plastic bag, TC = transparent plastic bag control and T = transparent plastic bag.

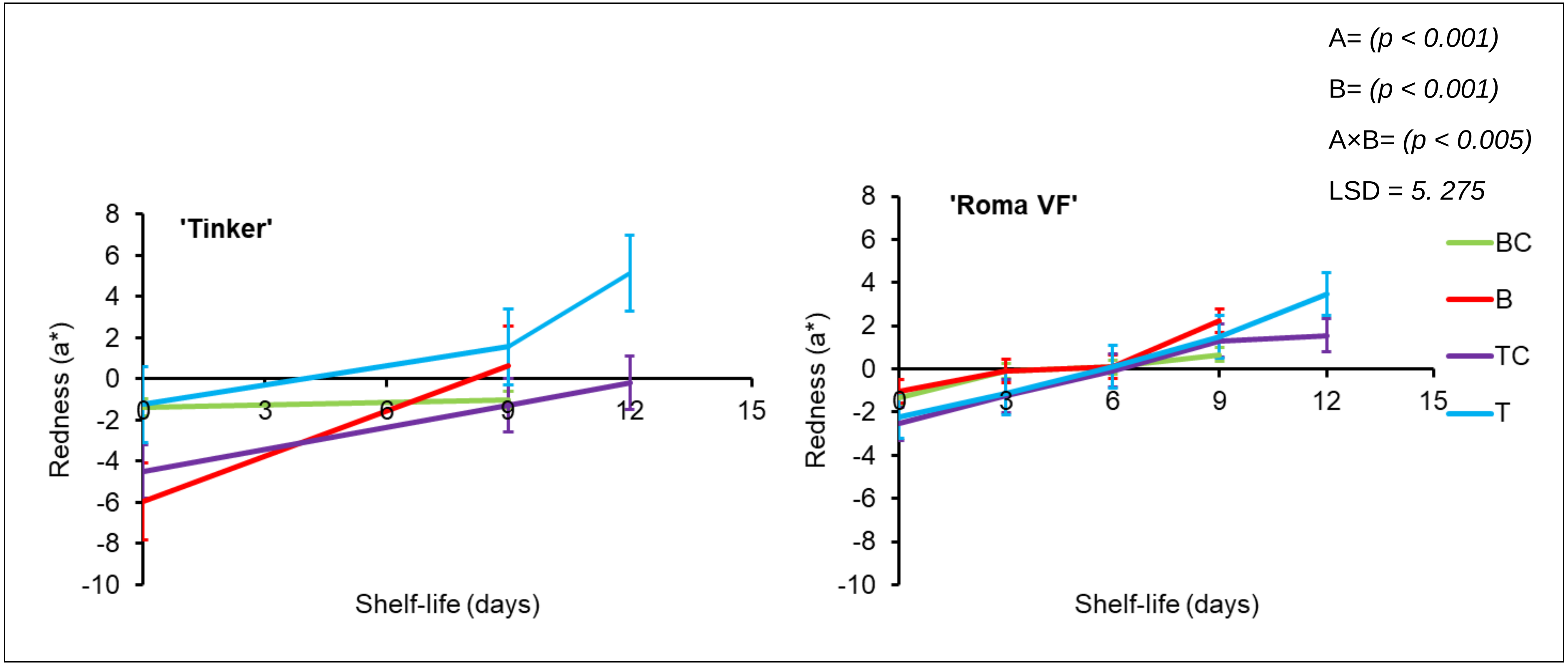

Figure 4.2: Effect of pre-harvest bagging on fruit redness (a*) for 10 days. Fruit were stored for 12 days at post-harvest Values are means of 5 fruit (n=5), and error bars indicate ± SE of means at $P \leq 0.05$. Mean separation was done using LSD, least significant difference. A = cultivar, B = Treatment and A×B = interaction of cultivar and treatment. BC = blue plastic bag control, B = blue plastic bag, TC = transparent plastic bag control and T = transparent plastic bag.

Chroma (C*)

Both the cultivar and cultivar and treatment interaction were not significant on fruit exocarp chroma (Figure 4.3). However, the treatment had a significant effect ($p < 0.001$) on chroma values for both cultivars during shelf-life days. Interestingly, fruit bagged with blue plastic showed higher chroma (26.94 to 37.48) when compared with transparent plastic (22.94 to 31.88) and non-bagged fruit (23.77 to 27.86) for 'Roma VF' during shelf-life days. Conversely, results showed higher Chroma (22.88 to 40.73) in 'Tinker' fruit bagged with transparent plastic when compared with blue plastic (23.81 to 29.54) and non-bagged fruit (18.66 to 33.02) at 12-day shelf-life.

Hue angle (h^0)

The treatment and cultivar and treatment interaction had a highly significant effect ($p < 0.001$) on fruit hue angle. In general, hue angle progressively decreased throughout shelf-life duration. With respect to treatment, the lowest hue angle value was observed in fruit bagged with blue plastic bag (113.87 to 83.05) compared with transparent plastic bag (116.4 to 91.49) and non-bagged (115.3 to 113.43) for 'Roma VF' at 9-days shelf life. However, 'Tinker' cherry tomato fruit exhibited the lowest exocarp hue angle value (115.67 to 61.27) when bagged with transparent plastic bag compared with blue plastic bags (117.10 to 100.76) and non-bagged treatment (116.87 to 108.09) at 12-day shelf-life.

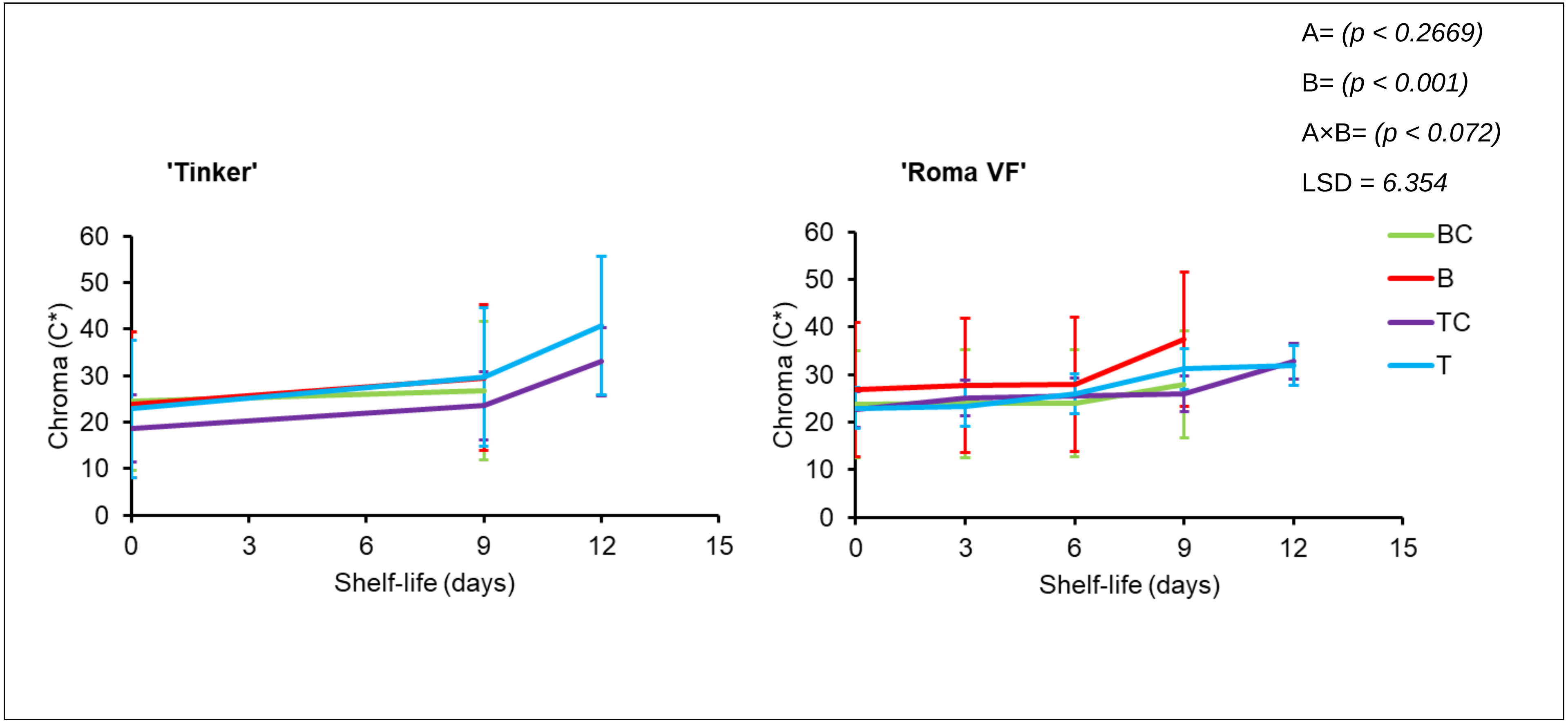

Figure 4.3: Effect of pre-harvest bagging on fruit exocarp Chroma (C*) for 10 days. Fruit were stored for 12 days at post-harvest. Values are means of 5 fruit (n=5), and error bars indicate ± SE of means at P ≤ 0.05. Mean separation was done using LSD, least significant difference. A = cultivar, B = Treatment and A×B = interaction of cultivar and treatment. BC = blue plastic bag control, B = blue plastic bag, TC = transparent plastic bag control and T = transparent plastic bag.

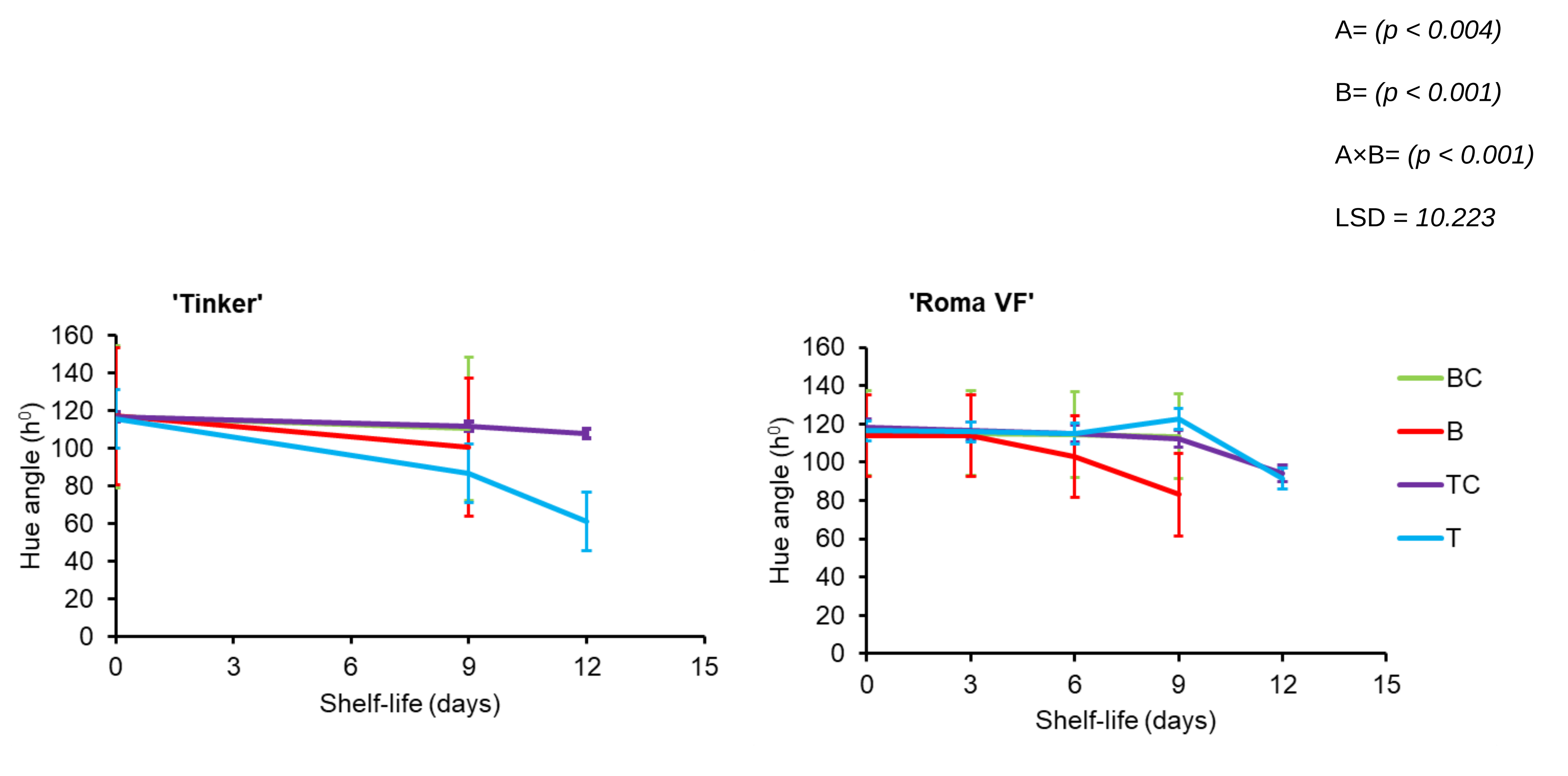

Figure 4.4: Effect of pre-harvest bagging on fruit hue angle for 10 days. Fruit were stored for 12 days at post-harvest Values are means of 5 fruits, and error bars indicate ± SE of means at P ≤ 0.05. Mean separation was done using LSD, least significant difference. A = cultivar, B = Treatment and A×B = interaction of cultivar and treatment. BC = blue plastic bag control, B = blue plastic bag, TC = transparent plastic bag control and T = transparent plastic bag.

Lightness (L*)

Individually, treatment, cultivar, and their interaction significantly ($p < 0.001$) affected fruit exocarp lightness (Figure 4.6). In 'Tinker' cherry tomato, fruit bagged with transparent plastic bag showed lower lightness (51.54 to 47.76) when compared with fruits bagged with blue plastic bag (56.70 to 55.67) and non-bagged fruit (57.92 to 57.11) at 12-day shelf-life. However, 'Roma VF' tomatoes showed lower exocarp lightness (61.26 to 52.36) when bagged with blue plastic bag compared with a transparent plastic bag (60.33 to 55.87) and non-bagged fruit (61.92 to 59.75) at 9-day shelf-life.

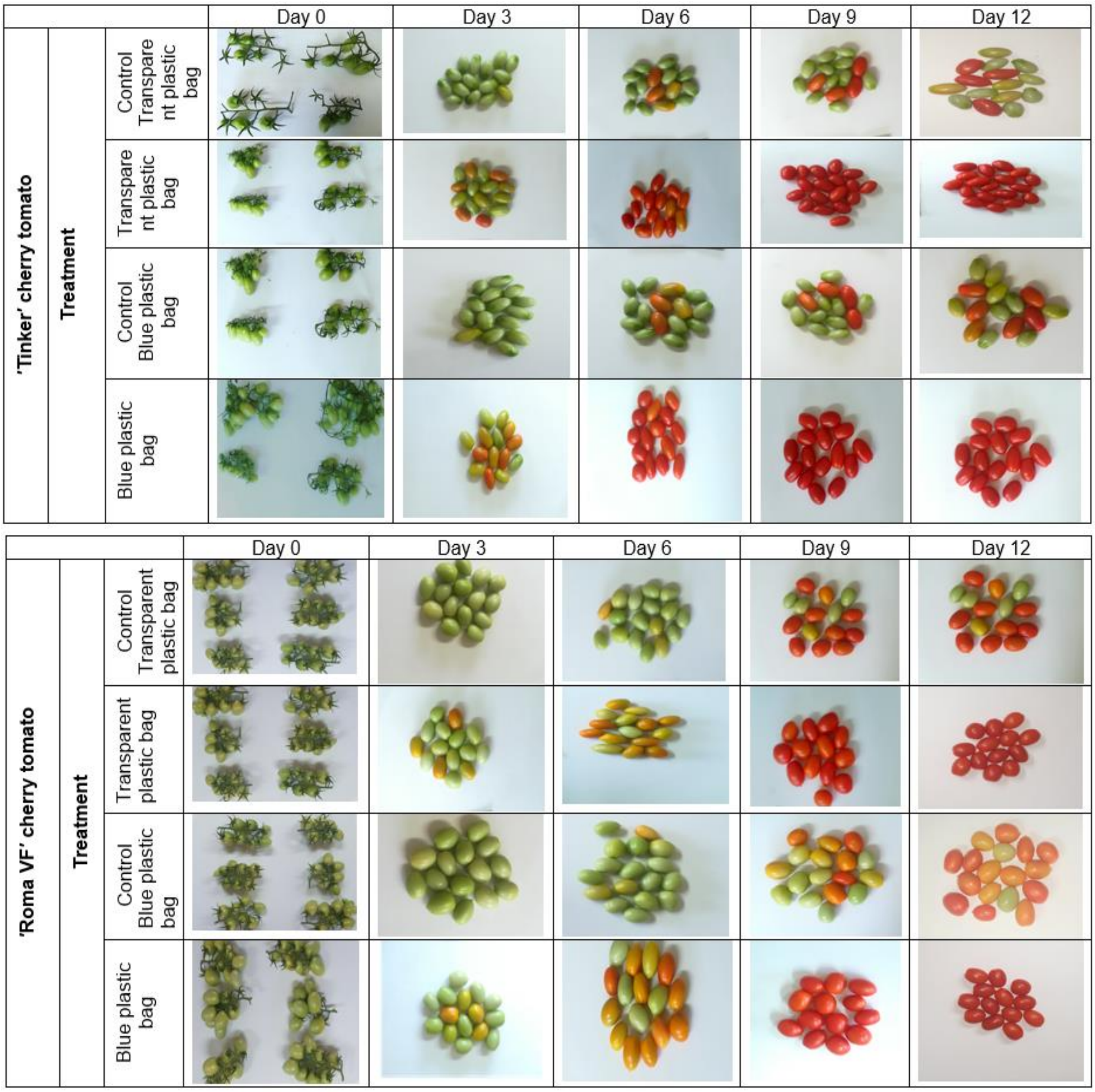

Figure 4.5: Colour change for each treatment/cultivar during shelf-life days.

4.1.2. Weight loss

The results showed that pre-harvest bagging had an effect on weight loss of cherry tomato cultivar, as demonstrated in Figure 4.7. The findings showed that the cultivar, treatment, and their interaction had a significant effect ($p < 0.001$) on fruit weight loss during shelf-life (Figure 4.8). Lower weight loss (3.7%) was observed in fruit bagged with transparent plastic bag compared with blue plastic bag (18.87%) and control treatment (16.27%) in 'Tinker' at 12-day shelf-life. However, 'Roma VF' cherry tomatoes exhibited lower weight loss with blue plastic bag (6.48%) compared to a transparent plastic bag (16.08%) and control treatment (12.11%) at 9-day shelf-life.

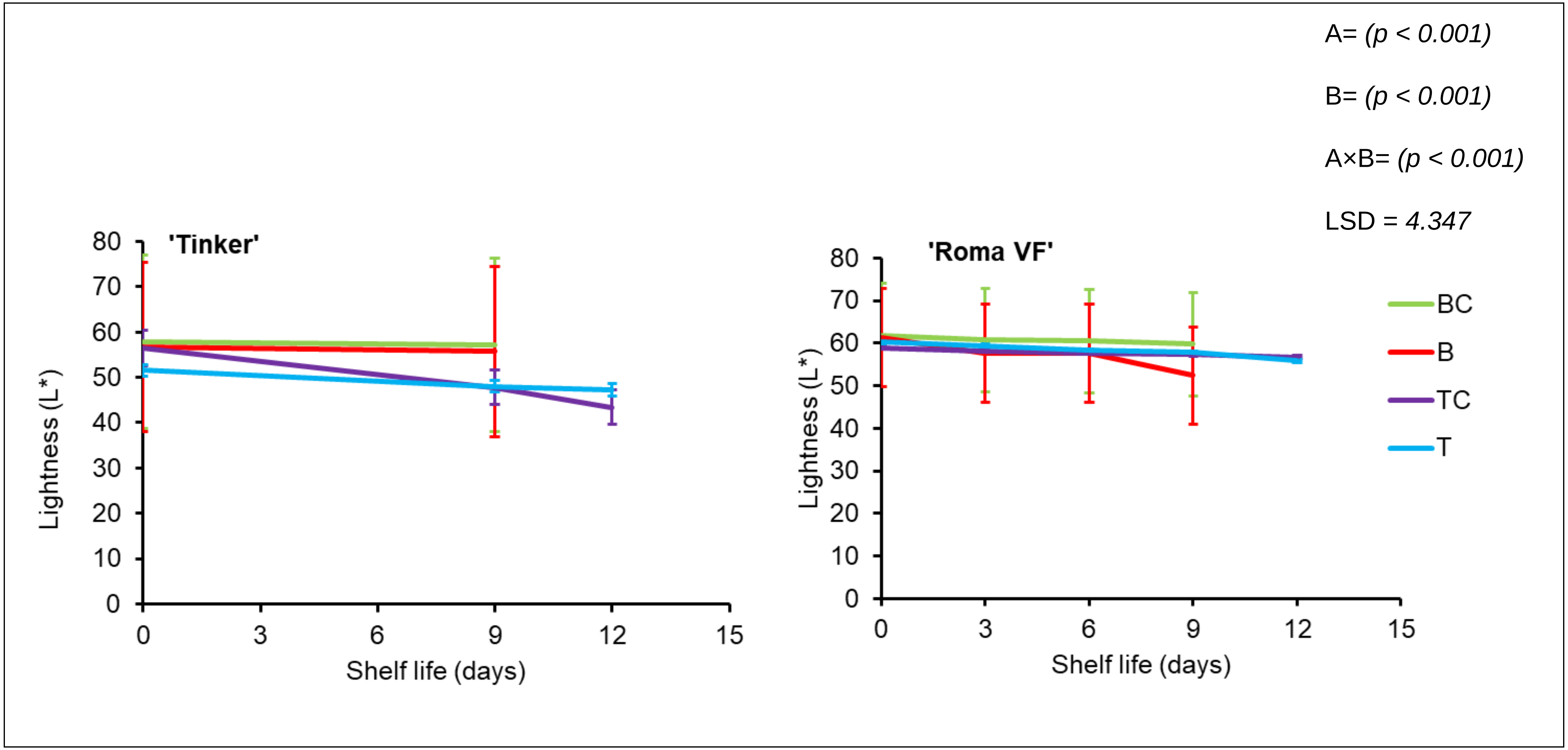

Figure 4.6: Effect of pre-harvest bagging on fruit lightness (L*) for 10 days. Fruit were stored for 12 days at post-harvest. Values are means of 5 fruits, and error bars indicate ± SE of means at $P \leq 0.05$. Mean separation was done using LSD, least significant difference. A = cultivar, B = Treatment and A×B = interaction of cultivar and treatment. BC = blue plastic bag control, B = blue plastic bag, TC = transparent plastic bag control and T = transparent plastic bag.

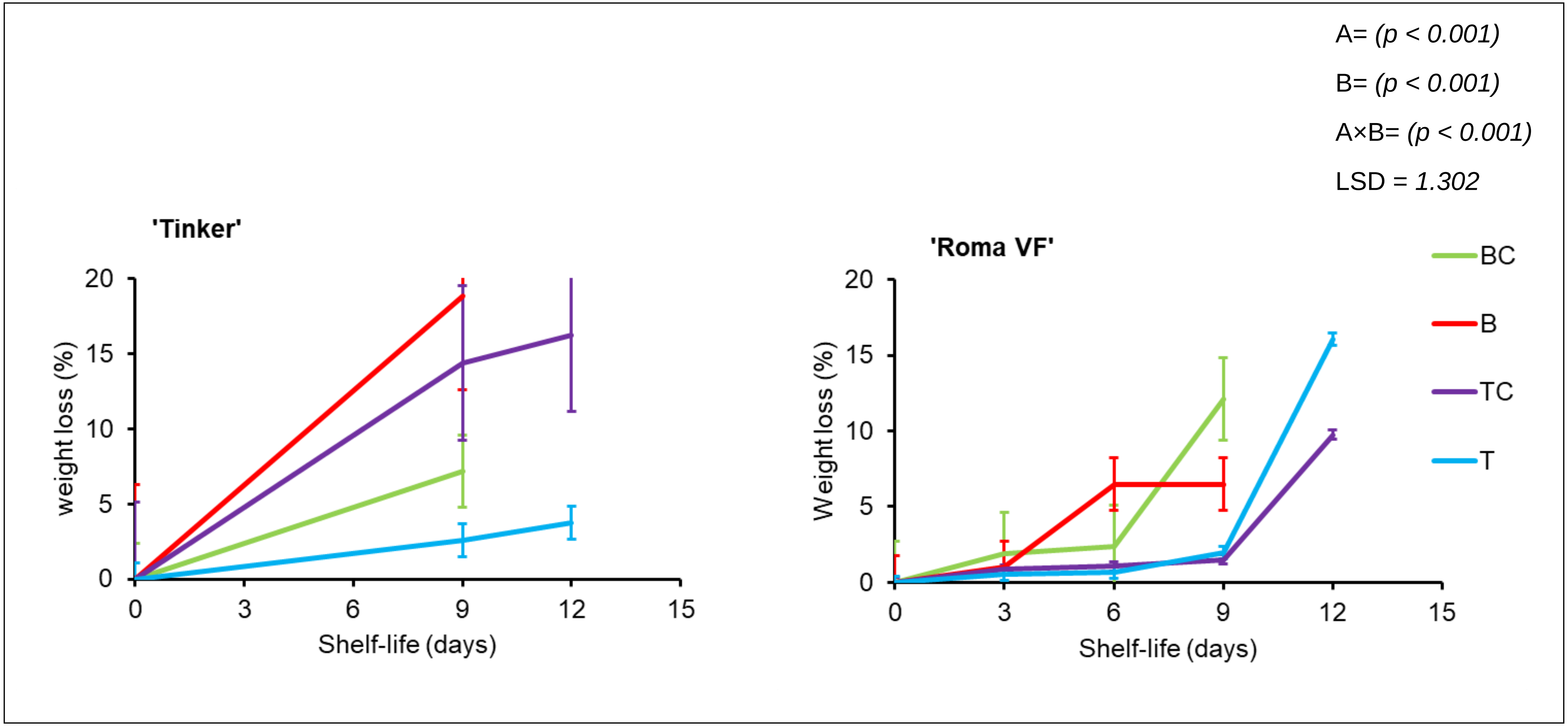

Figure 4.7. Effect of pre-harvest bagging on fruit weight loss for 10 days. Fruit were stored for 12 days at post-harvest. Values are means of 5 fruit (n=5), and error bars indicate ± SE of means at $P \leq 0.05$. Mean separation was done using LSD, least significant difference. A = cultivar, B = Treatment and A×B = interaction of cultivar and treatment. BC = blue plastic bag control, B = blue plastic bag, TC = transparent plastic bag control and T = transparent plastic bag.

4.1.3. Size

The interaction between cultivar and treatment had no significant effect ($p = 0.013$) on fruit size during shelf-life days. However, cultivar and treatment as individual factors had a significant effect ($p < 0.001$) on fruit size (Figure 4.8). Fruit bagged with transparent plastic bag had a decrease in fruit size in both 'Tinker' (20.90 to 19.08) and 'Roma VF' (22.97 to 19.4) cherry tomatoes throughout 12-day shelf-life. Similarly, bagging 'Tinker' tomatoes with blue plastic bag sharply decreased fruit size (17.39 to 11.62) when compared with a transparent plastic bag (20.90 to 19.08) and non-bagged fruit (17.41 to 16.89) at 9-day shelf-life.

4.1.4. Firmness

The interaction between cultivar and treatment had no significant effect ($p = 0.370$) on fruit firmness. In contrast, individually, cultivar and treatment had a significant effect ($p < 0.001$) on fruit firmness during the shelf-life days (Figure 4.9). Bagging with transparent plastic bag in 'Roma VF' showed the lowest firmness (7.09 to 6.01) when compared with transparent plastic bag (6.87 to 6.20) and non-bagged fruit (7.08 to 6.38) at 12-day shelf-life. Similarly, transparent plastic bag in 'Tinker' resulted in lower firmness (6.48 to 5.82) when compared with blue plastic bag (6.47 to 6.00) and non-bagged fruit (6.54 to 5.91) at day 12-day shelf-life.

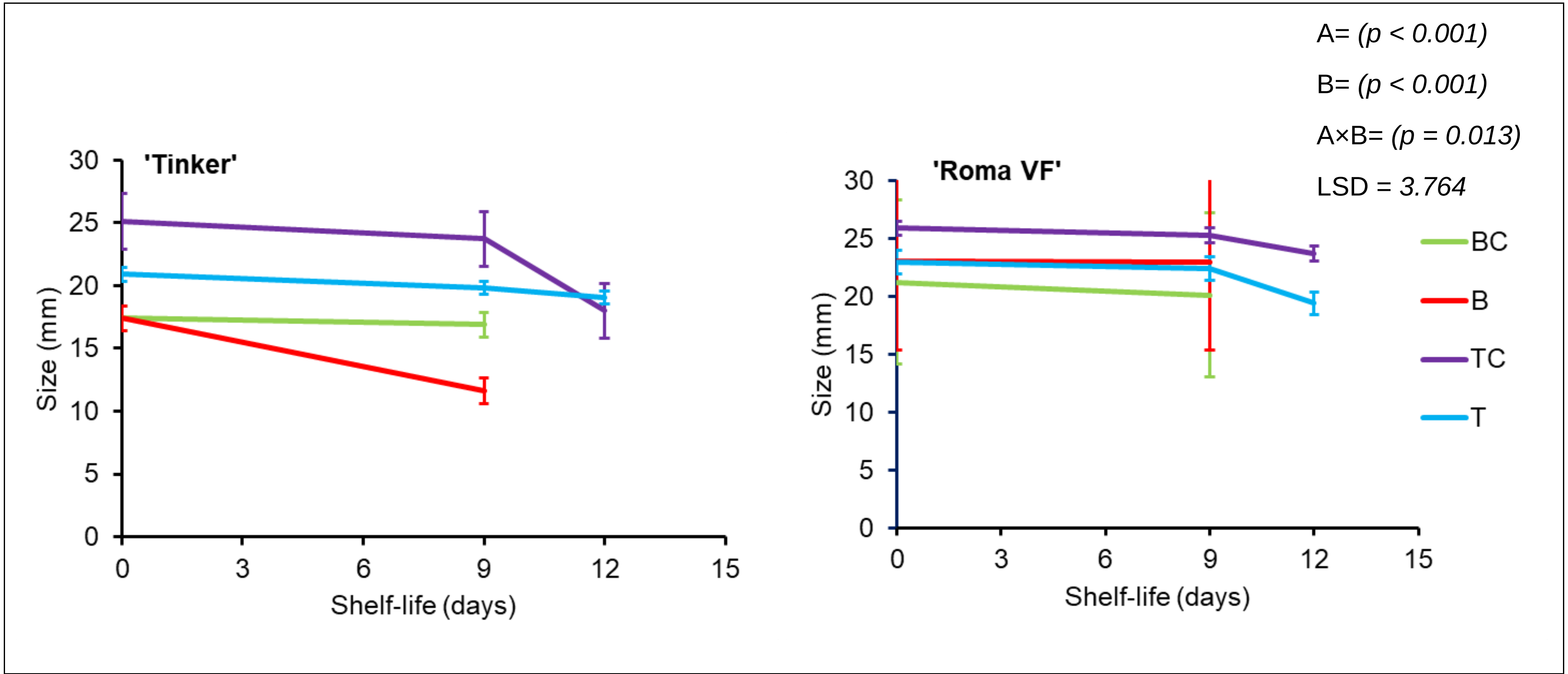

Figure 4.8: Effect of pre-harvest bagging on fruit size for 10 days. Fruit were stored for 12 days at post-harvest. Values are means of 5 fruit, and error bars indicate ± SE of means at P ≤ 0.05. Mean separation was done using LSD, least significant difference. A = cultivar, B = Treatment and A×B = interaction of cultivar and treatment. BC = blue plastic bag control, B = blue plastic bag, TC = transparent plastic bag control and T = transparent plastic bag.

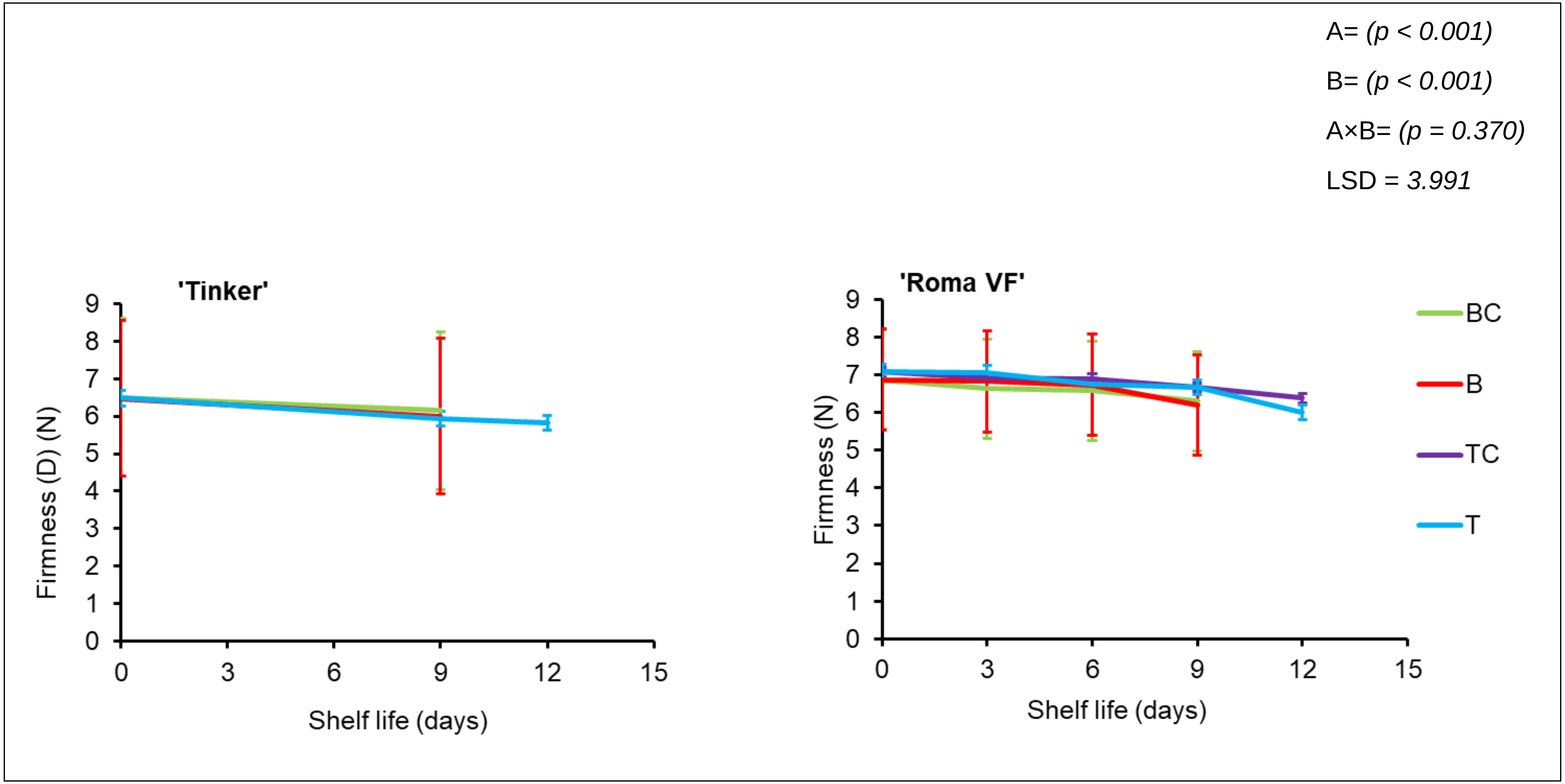

Figure 4.9: Effect of pre-harvest bagging on fruit firmness for 10 days. Fruit were stored for 12 days at post-harvest. Values are means of 5 fruit, and error bars indicate ± SE of means at $P \leq 0.05$. Mean separation was done using LSD, least significant difference. A = cultivar, B = Treatment and A×B = interaction of cultivar and treatment. BC = blue plastic bag control, B = blue plastic bag, TC = transparent plastic bag control and T = transparent plastic bag.

4.1.5. pH

The cultivar had no significant effect ($p = 0.898$), however, treatment and interaction had high significant effect ($p < 0.001$) individually on fruit pH (Figure 4.10). Fruit bagged with transparent plastic significantly increased pH (4.34 to 4.67) compared with blue plastic bag (3.87 to 4.49) in 'Tinker' cherry tomato at 12-day of shelf-life. Moreover, both blue (4.54 to 4.6) and transparent plastic bags (3.29 to 4.6) increased pH in 'Roma VF' during shelf-life days.

4.1.6. Total soluble solids (TSS)

The interaction between cultivar and treatment had no significant effect ($p = 0.020$) on fruit total soluble solids. However, individually, the cultivar and treatment had a significant effect ($p < 0.001$) on total soluble solids on both cherry tomato cultivars during shelf-life days (Figure 4.11). The total soluble solutes significantly increased with shelf-life days when compared with control treatment. However, fruits bagged with blue and transparent plastic bags had a constant increase (0.05 to 0.06 ^{0}Brix) compared to control for both treatments (0.047 to 0.06 ^{0}Brix) in 'Roma VF'. In contrast, there was a transient TSS increase in 'Tinker' tomatoes (0.05 to 0.07 Brix^{0}) in fruits bagged with transparent plastic when compared with blue plastic bags (0.05 to 0.06 ^{0}Brix) and control treatment (0.05 to 0.06 ^{0}Brix) at 9-day shelf-life.

4.1.7. Titratable acidity (TA)

The cultivar, treatment, and their interaction had a significant effect ($p < 0.001$) on fruit titratable acidity (Figure 4.12). The total titratable acidity significantly decreased in 'Roma VF' fruit bagged with blue (2.3 to 1.5%) and transparent plastic bags (2.67 to 1.5%) when compared with the non-bagged fruit which remained constant (1.5 to 1.5%) during shelf-life days. In contrast, a decrease in TA was observed in fruits bags with blue plastic bags (3.67 to 2%) when compared with control treatment (2.5 to 3.67%) and transparent plastic (2 to 2%), which remained constant at 9-day of shelf-life.

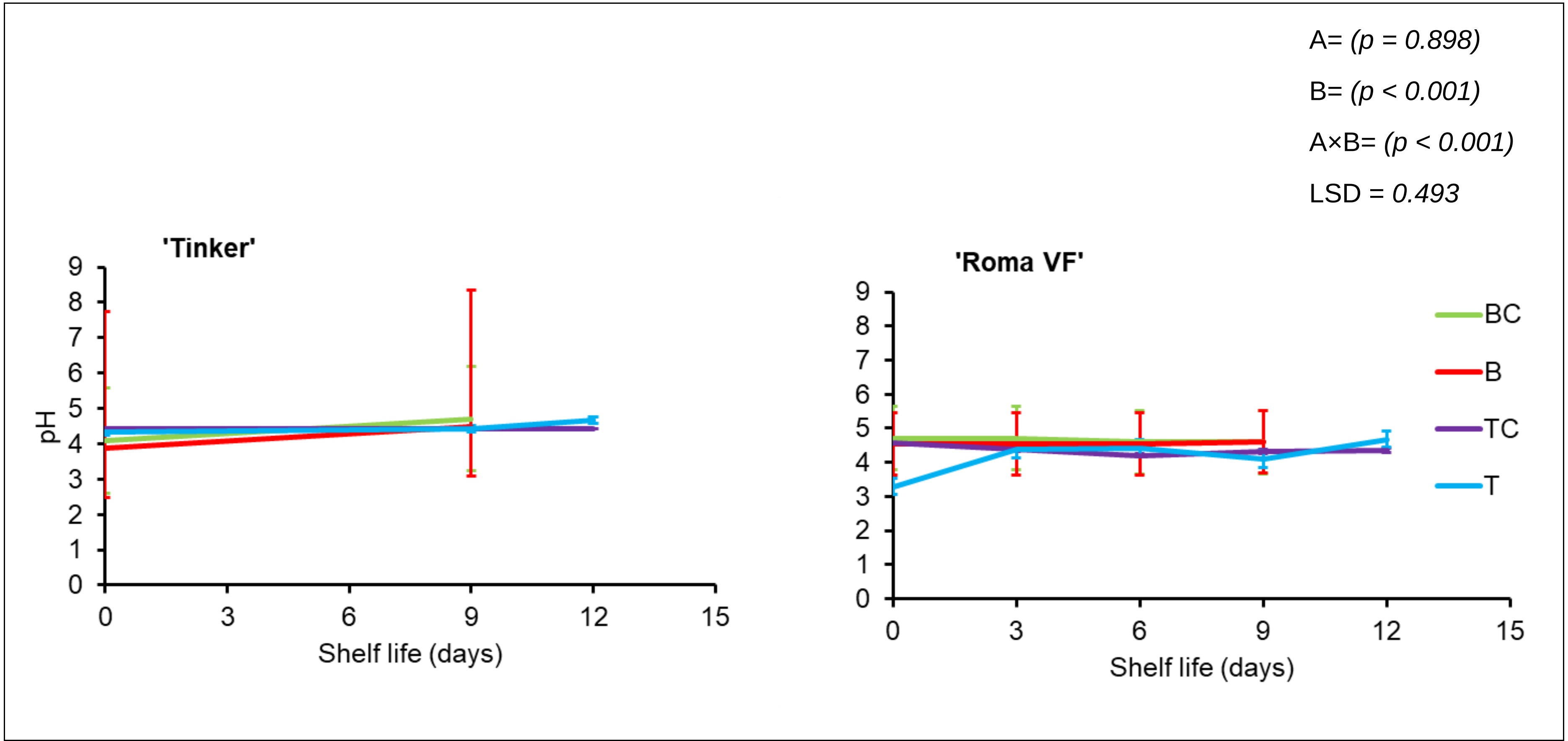

Figure 4.10: Effect of pre-harvest bagging on fruit pH for 10 days. Fruit were stored for 12 days at post-harvest. Values are means of 5 fruit (n=5), and error bars indicate ± SE of means at P ≤ 0.05. Mean separation was done using LSD, least significant difference. A = cultivar, B = Treatment and A×B = interaction of cultivar and treatment. BC = blue plastic bag control, B = blue plastic bag, TC = transparent plastic bag control and T = transparent plastic bag.

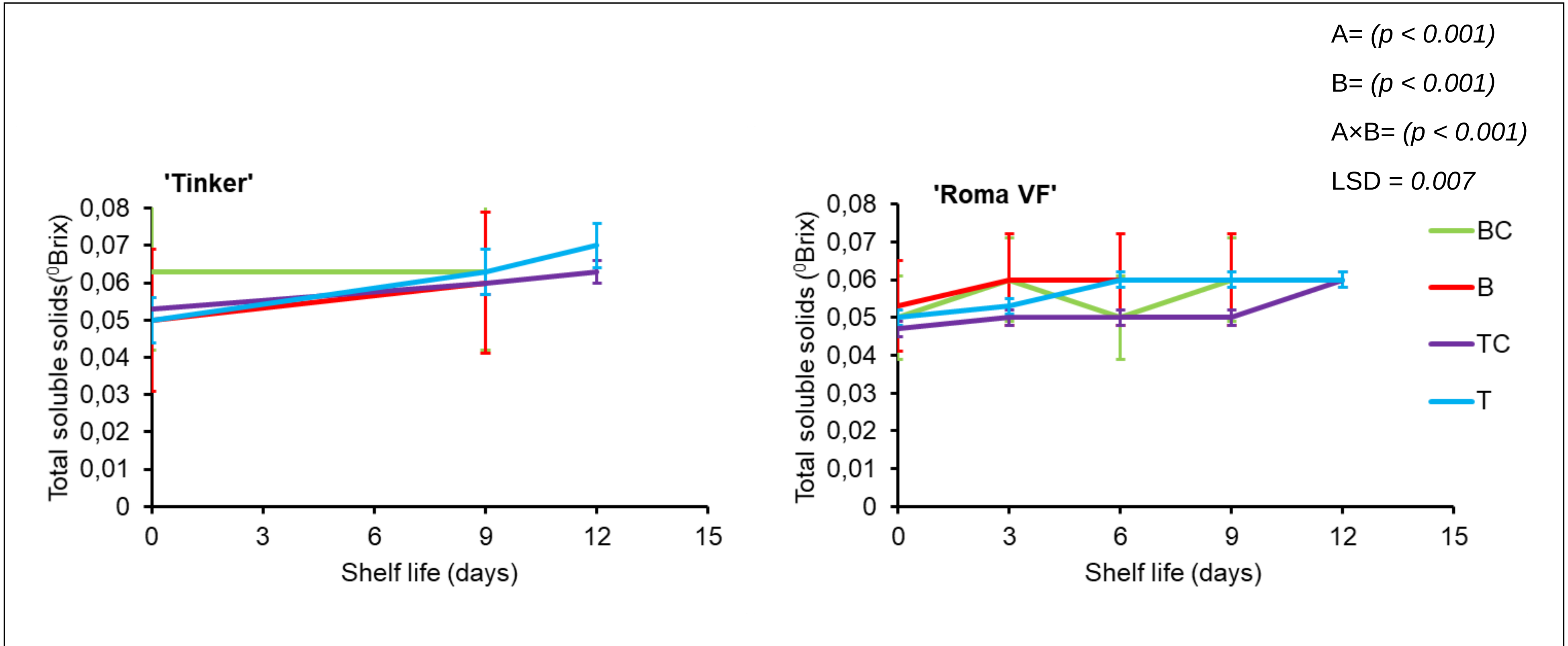

Figure 4.11: Effect of pre-harvest bagging on fruit total soluble solids for 10 days. Fruit were stored for 12 days at post-harvest. Values are means of 5 fruit (n=5) and error bars indicate ± SE of means at P ≤ 0.05. Mean separation was done using LSD, least significant difference. A = cultivar, B = Treatment and A×B = interaction of cultivar and treatment. BC = blue plastic bag control, B = blue plastic bag, TC = transparent plastic bag control and T = transparent plastic bag.

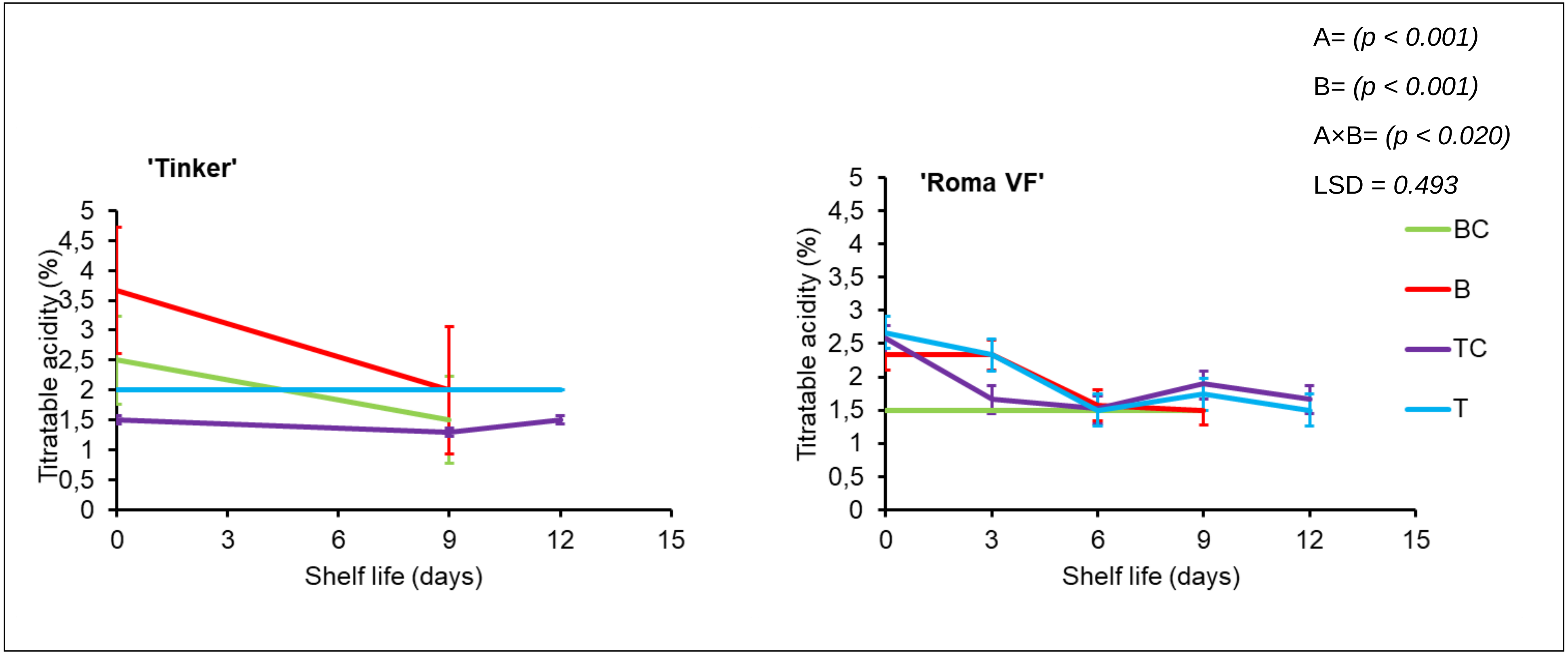

Figure 4.12: Effect of pre-harvest bagging on fruit titratable acid for 10 days. Fruit were stored for 12 days at post-harvest. Values are means of 5 fruit (n=5), and error bars indicate ± SE of means at P ≤ 0.05. Mean separation was done using LSD, least significant difference. LSD = least significant difference. A = cultivar, B = Treatment and A×B = interaction of cultivar and treatment. A = cultivar, B = Treatment and A×B = interaction of cultivar and treatment. BC = blue plastic bag control, B = blue plastic bag, TC = transparent plastic bag control and T = transparent plastic bag.

4.2. Discussion

4.2.1. Colour

Exocarp colour is an important marketable quality attribute in fresh horticultural produce (Hudina and Stampar, 2011). Attractive colour improves fruit physical appearance, for better pricing in both domestic and export market (Patel *et al*., 2020). In this study, the results showed that fruit bagging significantly influenced fruit colour development. Whereby, cherry tomato fruit bagged with transparent and blue plastic bags resulted in attractive red colour development when compared with non-bagged (Figure 4.1, 2, 3, 4 and 5). The results indicated that the colour values of L*, a*, b*, C* and h^0 in the non-bagged fruit, were lower than the bagged fruit. However, L*, h^0 and b* values decreased gradually, while a* and C* values increased sharply, indicating that the exocarp colour changed from green to red when compared with the control treatment. Moreover, it was observed that fruit bagged with transparent plastic bags developed redder colour when compared with blue plastic bags. This could be attributed to transparent plastic bags transmitting more light than blue plastic bags (Ali *et al*., 2021). Moreover, the plastic bag colour acts as a filter of photosynthetically active radiation (PAR), the wavelengths between 400 and 700 nm that are used during photosynthesis (Rajan *et al*., 2020). Additionally, blue plastic bags allowed in 73% of the wavelengths in the PAR; whereas, transparent plastic allowed in 93% in banana fruit (Rajan *et al*., 2020). Furthermore, fruit colour increase can be associated with temperature under modified micro-climate stimulating lycopene accumulation as chloroplast change to chromoplasts (Chen *et al*., 2012). These results agreed with Hudina and Stamper (2011); whereby, bagging pear fruit cv. Conference at 65 days after full bloom with 22 paper bags resulted in high fruit lightness. Also, Asrey *et al*. (2020) bagging pomegranate fruit cv. Kandari with red coloured cellulosic bag at 60 days after flowering improved fruit colour due to anthocyanin synthesis.

4.2.2. Weight loss

Weight loss is a major challenge because of high moisture loss, respiration, and shrinkage which result in reduced quality and shelf-life (Deepti*et al*., 2019, Rubel *et al*., 2019). Bagging fruit with blue and transparent plastic bags reduced weight loss when compared with the non-bagged fruit (Figure 4.6). However, the lowest fruit weight loss was observed in a transparent plastic bag as compared to blue plastic bag and non-bagged fruit. The lowest weight loss was due to reduced transpiration, respiration rate and, ethylene formation attributed to ripening and colour change (Haldankar *et al*., 2015). In addition, higher postharvest weight loss in non-bagged fruit might be due to direct exposure to high temperatures leading to high respiration and transpiration rate from fruit surface when compared to fruit bagged with transparent and blue plastic bags (Rahman *et al*., 2019). The findings of this study agreed with Gethe *et al*. (2021), who reported that bagging pomegranate fruit cvs. Phule, Bhagwa and Super with parchment bag at 9 days after fruit set reduced weight loss. Islam *et al*. (2019) recorded that bagging mango fruit cv. Langra with brown bag at 55 days after fruit set, significantly reduced weight loss percentage.

4.2.3. Size

After fruit set, the fruit grows slowly and increases in size until maturity (Sharma and Sanikommu, 2018). Pre-harvest bagging at a particular developmental stage may influence their growth and size (Sharma *et al*., 2014). In this study, bagged fruit had larger fruit size at harvest compared to the control treatment. However, a slight decrease in fruit size was recorded in both bagged and non-bagged fruit (Figure 4.7). This could be due to the increase in weight loss as a result of water vapour regulations and increased metabolic processes such as hydrolysis (Shah *et al*., 2020). Islam *et al*. (2017) also observed maximum fruit length in mango fruits cv. Amrapali bagged at 35 days after fruit set with white paper and brown paper bag. Also, another study by Yang *et al*. (2009) demonstrated that bagging longan fruit cv. Chuliang with perforated translucent plastic (TPB), white adhesive-bonded fabric bag (WAFB), and black adhesive-bonded fabric bags resulted in larger-sized fruit.

4.2.4. Firmness

According to Sharma *et al*., (2013), firmness is an important indicator for harvesting of fruit at appropriate maturity, which also determines the postharvest-life of fruit. In this study, we observed that bagging significantly affected fruit firmness. In addition, fruit bagged with the blue plastic bag were firmer than those bagged with the transparent plastic bag and control. Furthermore, fruit firmness decreased during the shelf-life days, irrespective of the treatments (Figure 4.8). In bagged fruit, firmness reduction could be due to the temperature increase inside the plastic bags, promoting an increase in carbon dioxide production and reduced oxygen; and consequently, increased hydrolytic enzyme activities; pectin methyl esterase and polygalacturonase, which act to reduce fruit firmness during softening (Hanif *et al*., 2020). According to Pastori *et al*. (2017) bagging tomato fruits cv. Valerin at 1.5 cm diameter did not alter firmness, therefore, results tended to be similar to non-bagged fruit. In addition, our findings were also in agreement with Abbasi *et al*. (2014) who reported a decrease in firmness during storage in guava fruit bagged with perforated polyethylene and newspaper bags at 30 days after fruit set. Similarly, bagging pear fruit cv. Conference with paper bags at 65 days after full bloom gradually decreased firmness during post-harvest storage (Amarante *et al*., 2002).

4.2.5 pH

Acidity is another important parameter that determines fruit quality from the consumer's perception (Hanif *et al*., 2020). Bagging significantly increased pH compared to the control treatment (Figure 4.9). This could be attributed to the enhanced metabolism, ripening, and senescence; therefore, resulting in loss of citric acid in fruit (Das *et al*., 2013). The higher metabolic rate of fruit could also be a cause for the faster rate of TA reduction and increased pH (Tigist *et al*., 2013). According to Purbey and Kumar (2015), bagging litchi fruit cv. Shahi at 40 and 50 days after bloom with polyethylene, white butter, brown paper bag and muslin cloth significantly increased pH.

4.2.6. Total soluble solids (TSS)

Total soluble solid content is an important quality indicator to measure the sweetness of fruit (Razali *et al*., 2021). In this study, it was observed that bagging fruit with transparent and blue plastic bags had a significant effect on total soluble content. Bagging increased TSS when compared with the control treatment (Figure 4.10). The increase in TSS can be caused by the breaking of long-chain carbohydrate compounds into soluble sugar compounds, which were stimulated by the increase in temperature (Astuti *et al*., 2018). In addition, blue plastic had a lower increase compared with non-bagged fruit. Similar results were observed by Abou El-Wafa (2014), in pomegranate cv. Wonderful when bagged with agril red bag at 21 days after fruit set. In tomato fruit, Patel *et al*. (2020) found that the use of newspaper bags 30 days after fruiting resulted in a significant increase in soluble solutes. Similarly, Rubel *et al*. (2019) reported that bagging banana fruit cv. Mechersagar with blue polythene bags after the bracts covering the hands had fallen when the fingers were curling upwards, and the floral remnants had hardened resulted in higher TSS content.

4.2.9. Total titratable acid

The decrease in acidity suggests a reduction in sourness with the potential of improving the sweet taste as observed in the juice solution (Aboagye-Nuamah *et al*., 2018). In the present study, bagging significantly decreased total titratable acidity when compared with non-bagged fruit. However, blue plastic bag was more effective in reducing TTA when compared with a transparent plastic bag and non-bagged fruit (Figure 4.11). The decline in acidity could be due to the utilization of acids as respiration substrates and susceptibility of citric acid to oxidative destruction as impacted by the modified environment in bagged fruit (Appiah *et al*., 2011). Additionally, the decrease in TTA can be attributed to accelerated maturity and ripening. The decline in acidity during ripening was a result of starch hydrolysis leading to an increase in TSS and a reduction in acidity (pH) (Appiah *et al*., 2011). According to Prabha *et al*. (2018) bagging pineapple fruit cv. Mauritius with paper and jute bags after flowering significantly decreased TA levels. Shah *et al*., (2020), also reported that bagging Litchi fruit cv. Rose Scented with white polypropylene bags 45 days before harvest minimized titratable acidity.

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1. Conclusion

The current study showed that cherry tomato cultivars 'Tinker' and 'Roma VF' bagged with the transparent and blue plastic bags at 1.5 cm diameter enhanced fruit quality in respect of exocarp colour (b*, a*, C*, L* and h), size, firmness, TA, TSS, with minimum weight loss and no incidence of physiological disorders. Among the treatments, it was observed that transparent plastic bags performed better for colour characteristics compared to control, which had inferior fruit quality during shelf-life days. Therefore, it can be concluded that transparent and blue plastic bags improved the maturity and post-harvest quality of cherry tomatoes.

5.2. Recommendations

Bagging 'Tinker' and 'Roma VF' cherry tomatoes with transparent and blue plastic bags significantly enhanced quality during the storage period. It is then recommended that fruit should be alternatively bagged with transparent and blue paper bags for improved maturity indices and post-harvest quality. The plastic bags can be recommended for use in the commercial production of cherry tomatoes intended for both domestic and export markets to obtain profitable prices. Future studies should include other cultivars of cherry tomato, as well as the use of post-harvest treatment such as calcium chloride, polyamines, and modified storage conditions to further prolong shelf-life produce. In addition, future studies should also evaluate the impact of pre-harvest bagging on phyto-chemical composition of the treated produce.

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APPENDICES

Appendix 1: Analysis of variance for the effect of bagging material on blueness for cherry tomato cultivars.

Source of variation	**d.f**	**s.s**	**m.s**	**F**
Replicate	2	2.013	1.006	
Cultivar	1	15.616	15.616	0.119
Treatment	17	1315.748	77.397	<.001
Cultivar*Treatment	19	172.116	19.124	0.005
Error	54	336.756	6.240	
Total	83	1664.964		

Appendix 2: Analysis of variance for the effect of bagging material on redness value in cherry tomato cultivars.

Source of variation	**d.f**	**s.s**	**m.s**	**F**
Replicate	2	8.68	4.34	
Cultivar	1	293.61	293.61	<.001
Treatment	17	3629.99	213.53	<.001
Cultivar*Treatment	19	1105.19	122.80	<.001
Error	54	560.74	10.38	
Total	83	5512.84		

Appendix 3: Analysis of variance for the effect of bagging material on Chroma value in cherry tomato cultivars.

Source of variation	**d.f**	**s.s**	**m.s**	**F**
Replicate	2	0.20	1.10	
Cultivar	1	18.80	18.80	0.2669
Treatment	17	1755.57	103.27	<.001
Cultivar*Treatment	19	257.28	28.59	0.072
Error	54	83.56	15.07	

Total	83	2699.98		

Appendix 4: Analysis of variance for the effect of bagging material on hue angle value in cherry tomato cultivars.

Source of variation	d.f	s.s	m.s	F
Replicate	2	46.81	23.40	
Cultivar	1	349.86	349.86	0.004
Treatment	17	3572.66	704.20	<.001
Cultivar*Treatment	19	11971.39	396.96	<.001
Error	54	2106.08	39.00	
Total	83			

Appendix 5: Analysis of variance for the effect of bagging material on lightness value in cherry tomato cultivars.

Source of variation	d.f	s.s	m.s	F
Replicate	2	11.874	5.937	
Cultivar	1	1062.320	1062.320	<.001
Treatment	17	726.908	42.759	<.001
Cultivar*Treatment	19	326.374	36.264	<.001
Error	54	380.741	7.051	
Total	83	2145.349		

Appendix 6: Analysis of variance for the effect of bagging material on weight loss percentage value in cherry tomato cultivars.

Source of variation	d.f	s.s	m.s	F
Replicate	2	48.99	24.50	
Cultivar	1	280.20	280.20	<.001
Treatment	17	6715.47	395.03	<.001
Cultivar*Treatment	19	3849.82	427.76	<.001

Error	54	945.67	17.51	
Total	83	11578.66		

Appendix 7: Analysis of variance for the effect of bagging material on size value in cherry tomato cultivars.

Source of variation	d.f	s.s	m.s	F
Replicate	2	29.373	14.687	
Cultivar	1	716.826	716.826	<.001
Treatment	17	410.798	45.643	<.001
Cultivar*Treatment	19	110.324	15.761	0.013
Error	54	174.951	5.146	
Total	83	863.356		

Appendix 8: Analysis of variance for the effect of bagging material on firmness value in cherry tomato cultivars.

Source of variation	d.f	s.s	m.s	F
Replicate	2	0.03009	0.01504	
Cultivar	1	5.40204	5.40204	<.001
Treatment	17	7.53647	0.06611	<.001
Cultivar*Treatment	19	0.59503	0.05943	0.370
Error	54	3.20900		
Total	83	15.08848		

Appendix 9: Analysis of variance for the effect of bagging material on pH value in cherry tomato cultivars.

Source of variation	d.f	s.s	m.s	F

Replicate	2	0.33003	0.16502	
Cultivar	1	0.00092	0.00092	0.898
Treatment	17	4.54324	0.26725	<.001
Cultivar*Treatment	19	3.23895	0.35988	<.001
Error	54	2.99597	0.05548	
Total	83	10.45910		

Appendix 10: Analysis of variance for the effect of bagging material on total soluble solids value in cherry tomato cultivars.

Source of variation	**d.f**	**s.s**	**m.s**	**F**
Replicate	2	0.00001021	0.00000510	
Cultivar	1	0.00062184	0.00062184	<.001
Treatment	17	0.00266565	0.00015680	<.001
Cultivar*Treatment	19	0.00037817	0.00004202	0.020
Error	54	0.00092619	0.0001715	
Total	83	0.00383214		

Appendix 11: Analysis of variance for the effect of bagging material on titratable acidity value in cherry tomato cultivars.

Source of variation	**d.f**	**s.s**	**m.s**	**F**
Replicate	2	115.15357	57.57679	
Cultivar	1	0.33528	0.33528	<.001
Treatment	17	17.18141	1.01067	<.001
Cultivar*Treatment	19	7.86018	0.87335	<.001
Error	54	4.89954	0.09073	
Total	83	107.96729		