Determining how effective a dry ice based modified atmosphere treatment will be at suppressing avocado respiration in pack-house cold rooms and refrigerated trucks

FJ Kruger, GO Volschenk and L Volschenk

Lowveld Postharvest Services
PO Box 4001, Mbombela 1200, SOUTH AFRICA

E-mail: fjkruger58@gmail.com

ABSTRACT

Door-to-door controlled atmosphere is presently used in South Africa on a limited scale due to certain cost and logistical considerations. This report deals with a study being performed to establish how effective and practical it would be to establish a temporary balanced atmosphere in pack-house cold rooms and in refrigerated trucks en route from the pack-house to the harbour. The results indicated that artificial carbon dioxide applications are considerably more effective at suppressing the fruit's metabolism than similar increases brought about by the fruit's respiration. It would appear that dry ice applications in cold rooms and trucks will effectively reduce the respiration rate of avocados stored in pack-house cold rooms and refrigerated trucks. This finding will be tested under commercial conditions during the 2020 season.

INTRODUCTION

During storage, the respiration rate of avocado fruit is influenced by a range of factors such as pre-harvest quality, maturity, storage temperature, storage atmosphere and the application of ethylene inhibitors. An example of the individual and combined effects of the various factors is shown in Figure 1. From the figure it is evident that controlled atmosphere (CA) at a 6% CO_2 : 4% O_2 ratio is effective at suppressing the respiration rate of 'Hass' avocado fruit stored at various temperature settings (Lemmer *et al*., 2009).

During the last two seasons, a balanced atmosphere (BA) consisting of 8% CO_2 and ± 13% O_2 has been introduced to the industry. As a degree of scepticism existed regarding the effectiveness of this combination, a laboratory-based study was performed by Kruger *et al*. (2020) to test the technology. The results indicated that, taking the natural ripening variability within avocado fruit into account, CA and BA have comparable ripening inhibition effects. Feedback received from back-to-back commercial trials performed by industry members supported these observations.

Due to the high costs involved in door-to-door shipments, most CA containers are stored at Cape Town harbour. The present progress report

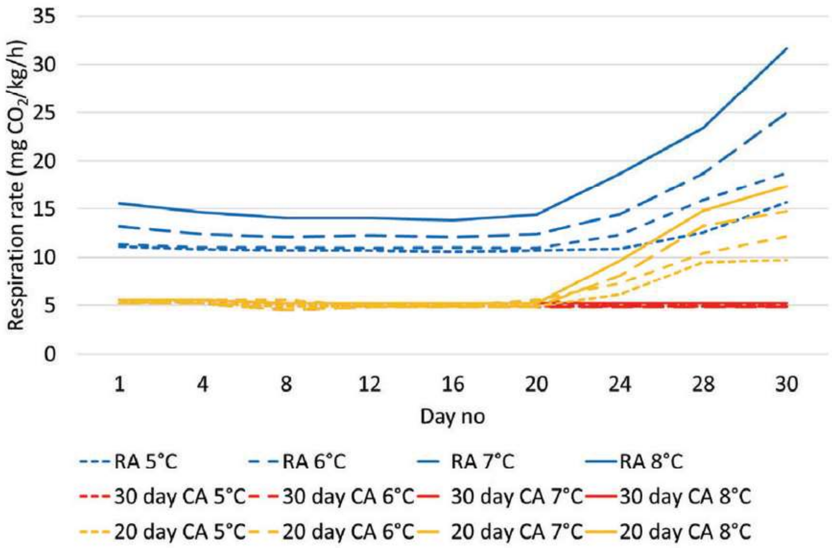


Figure 1: Respiration rates of 'Hass' fruit stored under regular atmosphere (RA) and controlled atmosphere (CA) conditions. Half of the CA replicates were opened after 20 days to demonstrate the effects that exposure to RA conditions has on the respiration rates of fruit that were stored under CA conditions

deals with a study we are currently conducting aimed at establishing what effects the artificial raising of the CO_2 contents inside pack-house cold rooms and refrigerated trucks will have on the respiration rate and, ultimately, the storage potential of export avocado fruit. The aim is to reduce the need for door-to-door shipments.

During the 2018 season, the respiration-dependent CO_2 accumulation rates of six refrigerated trucks were measured en route from Tzaneen to Cape Town (Kruger *et al.*, 2019a) (Fig. 2). The maximum CO_2 level achieved during the two-day period was around 4%. The CO_2 build-up rate was further not increased by fitting a curtain to the back of the trucks. What was, however, important to note is that in all six cases, the CO_2 build-up was linear. No tapering-off of the CO_2 accumulation rate took place towards the end of the journey. This indicates that no respiratory inhibition took place due to the increased CO_2 levels.

During the 2019 season, the effects that artificial CO_2 applications have on the fruit's respiration rate was studied by applying CO_2 in the form of dry ice to pack-house cold rooms and refrigerated trucks. The project consisted of five studies, each with its own aim.

Trial set 1: Determining the diffusion pattern of artificially applied CO_2 inside an empty space

The first goal was to determine how dry ice-derived CO_2 diffuses through an empty sealed space. To do this, calculations were made to determine the mass

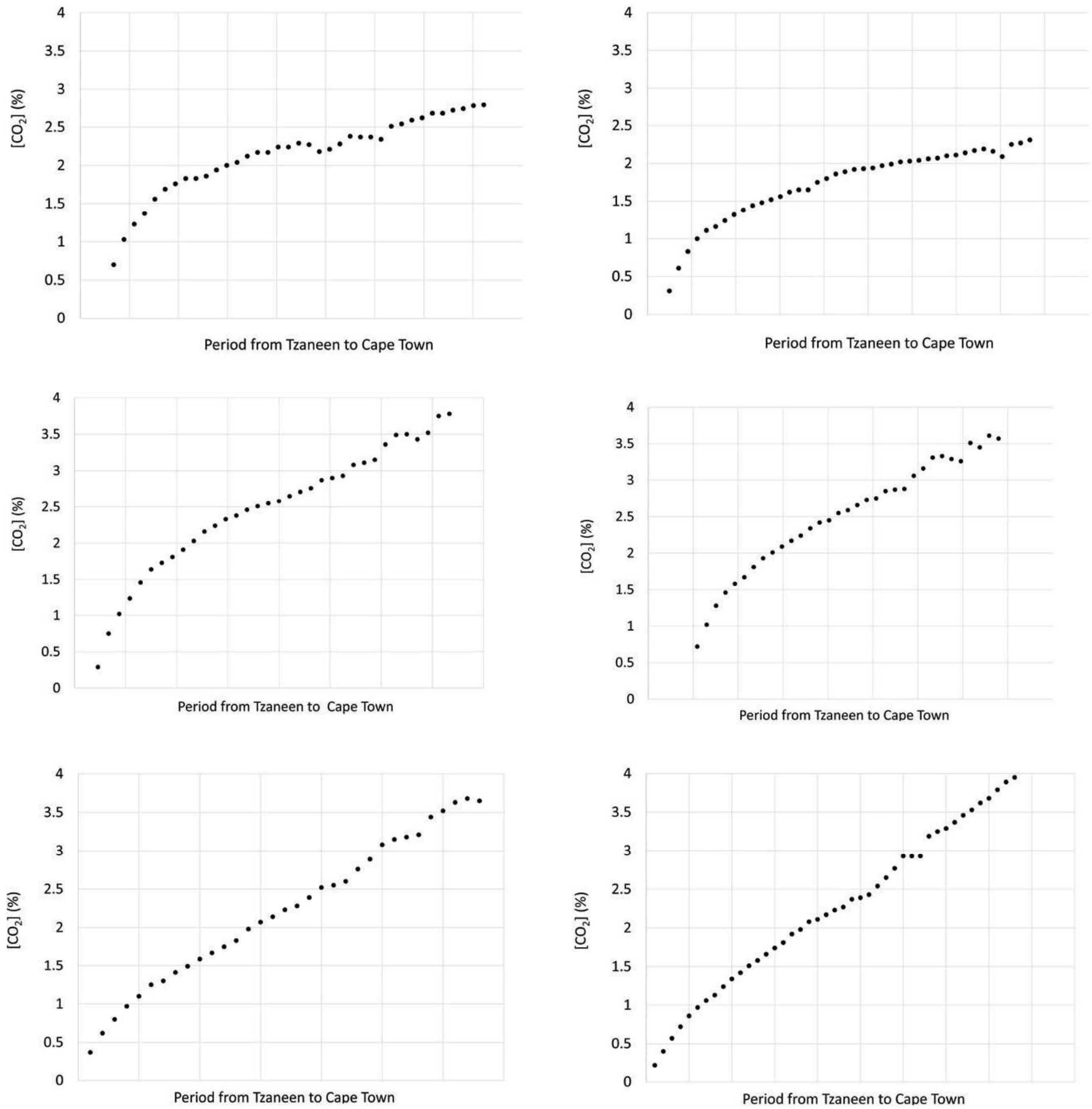


Figure 2: Carbon dioxide contents inside refrigerated trucks transporting avocado fruit from Tzaneen to Cape Town harbour

of dry ice required to attain a specific CO_2 concentration inside an airtight tent of known volume. The dry ice was then placed inside a bucket of water and the CO_2 content inside the tent measured under low and high air circulation conditions.

The CO_2 concentration measurements inside the sealed tents with and without circulation are shown in Figure 3. As may be deduced from the results, in the tent with poor circulation, the CO_2 concentration in the vicinity of the meter (which was placed on the floor) initially increased to around 10% and then decreased and stabilised at around 6% as the gas dispersed. In contrast, in the tent with good circulation the initial peak did not occur and the CO_2 gas dispersed throughout the tent right from the start.

Trial set 2: Determining the carbon dioxide contents of slightly leaking tents with good circulation containing cooled fruit that received a dry ice dosage calculated so as to obtain a CO_2 concentration of 8%

The first aim of this trial was to determine how CO_2 will disperse when applied to cooled fruit in slightly leaking tents that emulate commercial cold rooms and refrigerated trucks. The second aim was to determine what effect an artificial 8% CO_2 application will have on the fruit's respiration rate.

Two trials were performed in tents containing fruit to air volumes that were roughly similar to that of refrigerated trucks. The tents had good circulation and the fruit were cooled in a cold room set at 6°C for four days before the dry ice was administered. The dry ice dosage was calculated to establish a CO_2 concentration of approximately 8% in the tents.

The results are shown in Figure 4. The CO_2 reached the desired level of 8% in due time, after which the concentration gradually reduced due to slow leakage from the tent. The results demonstrated that the artificial 8% CO_2 application effectively suppressed the fruit's respiration rate, as no further increases in CO_2 occurred after sublimation of the dry ice.

Trial set 3: Determining the carbon dioxide contents of tents containing non/semi-cooled fruit and <8% CO_2 applications

The aim of this trial was to emulate the effects that suboptimal dosages of CO_2 will have when applied to partially cooled fruit in cold rooms or refrigerated trucks with different levels of airtightness.

The respiration rate patterns of two batches of fruit that were at room temperature upon loading into the tent, and then received suboptimum doses of dry ice, are shown in Figure 5. In both cases, the CO_2 content readings showed the above dispersal

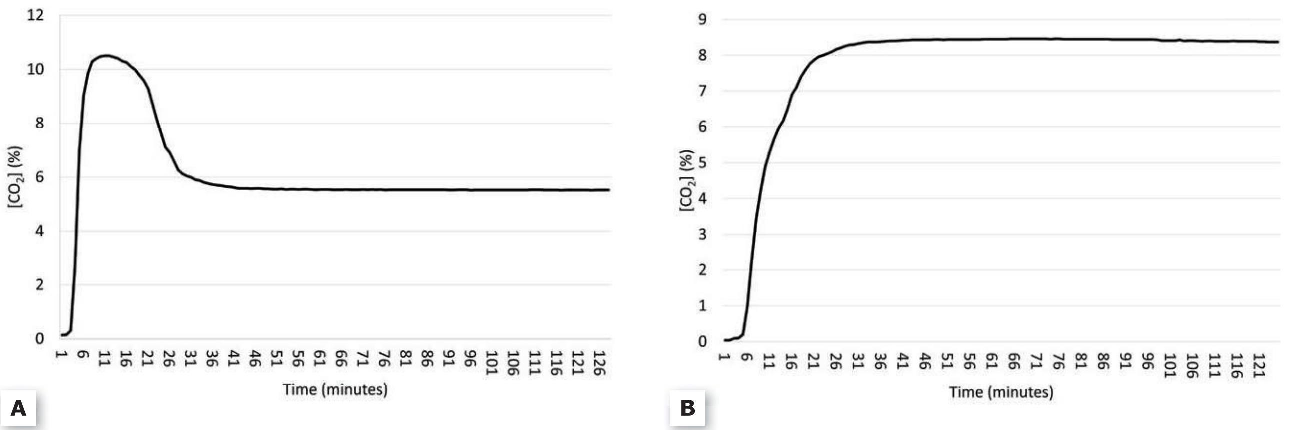


Figure 3: Carbon dioxide dispersal rate in two empty tents; the first without air circulation (A) and the second with circulation inside the tent (B)

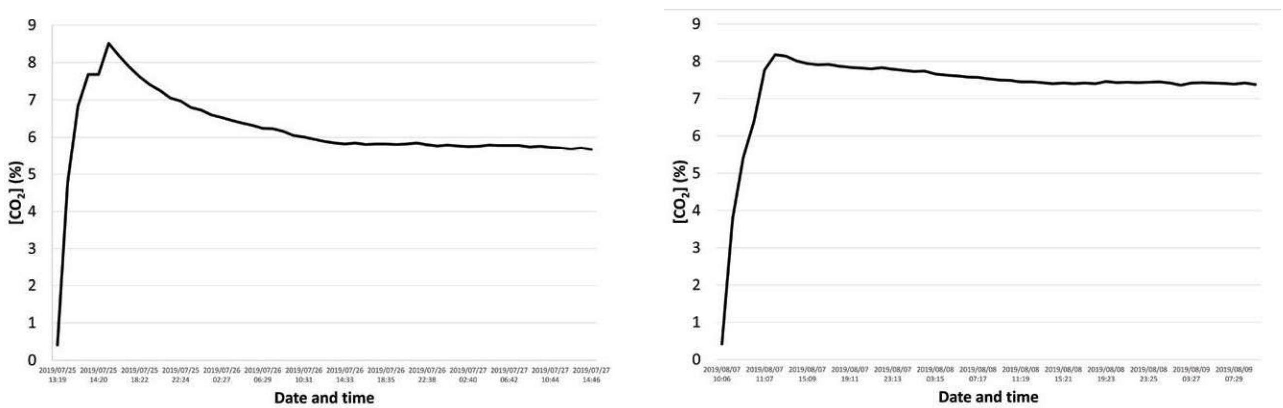
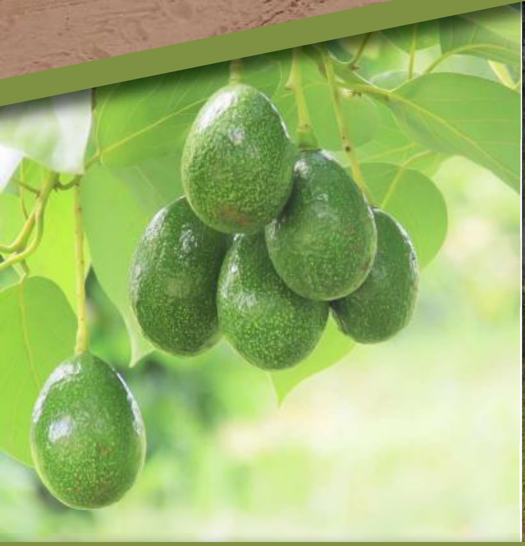
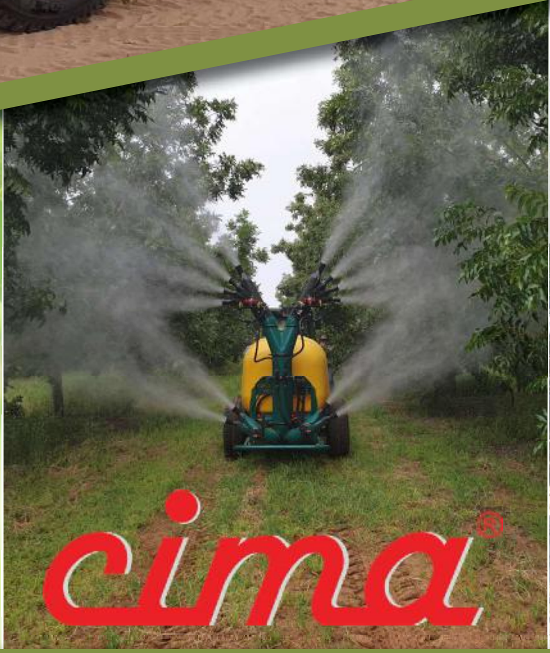


Figure 4: Carbon dioxide concentration inside slightly leaking tents (emulating refrigerated trucks and pack-house cold rooms) containing cooled fruit that received a dry ice application aimed at establishing an 8% CO_2 content





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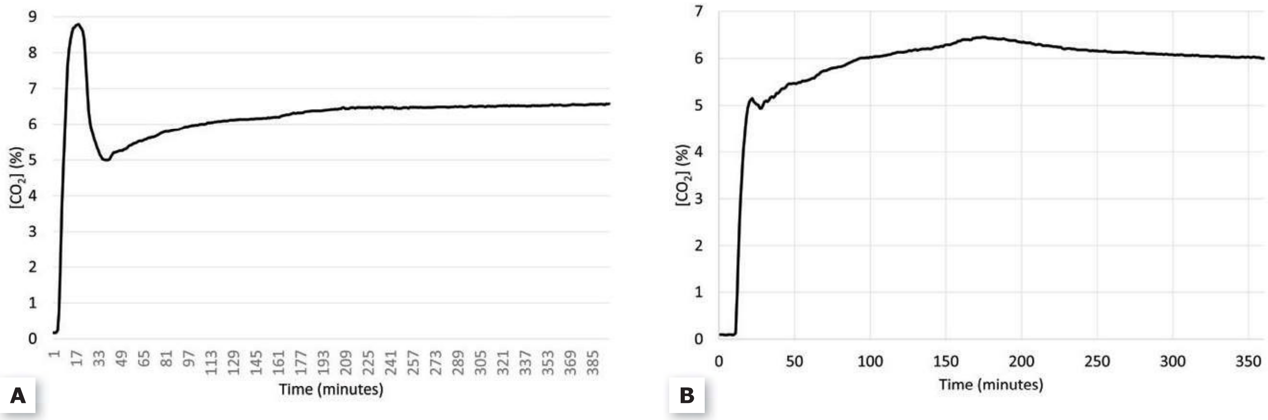

Figure 5: Carbon dioxide concentration inside air tight (A) and slightly leaking (B) tents containing room temperature fruit that received a suboptimal dry ice application

peak, albeit that it was higher in the first trial than the second. However, what is important to note, is that in both cases, the CO_2 stabilised at 5% and then gradually increased due to fruit respiration to approximately six and a half percent. The CO_2 content then remained constant (sealed tent) or slowly decreased (slightly leaking tent), indicating that the fruit's respiration rate drastically decreased after reaching ± 6.5% under room temperature conditions.

The same trial performed with fruit that were cooled to approximately 12°C are shown in Figure 6. After the initial dispersal peak, the respiration-driven CO_2 content again increased due to fruit respiration. However, in this case it peaked one percentage point lower than the above at five and a half percent.

The results suggest that the prescribed CO_2 content of balanced atmospheres are temperature dependent. The threshold CO_2 values, where respiration rate reductions took place, were around 6.5% for fruit that were at room temperature, while it was about 5.5% for fruit that were cooled to approximately 12°C before the CO_2 was applied. This implies that even lower CO_2 rates than the above should affect the respiration rate when the fruit's temperature is further decreased.

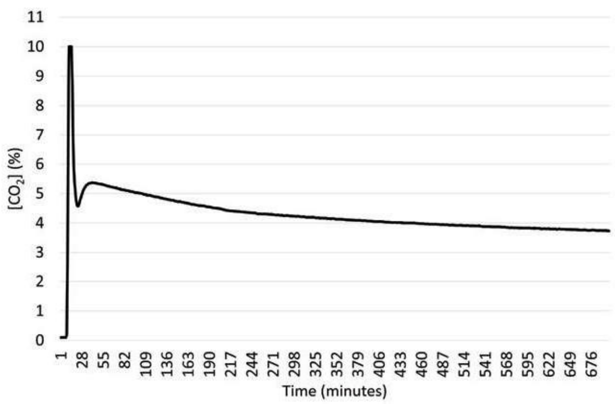

Figure 6: Carbon dioxide concentration inside a slightly leaking tent containing avocado fruit cooled to 12°C that received a suboptimal dry ice application

Trials set 4: Carbon dioxide content trends of refrigerated trucks in which dry ice applications were made

Three trials were performed in refrigerated trucks with fruit that were cooled to approximately 6°C during the 2019 season. In each case, a specific mass of dry ice was weighed out and placed inside four 20 litre drums that were placed in the back of the truck after loading. The CO_2 concentration of the air was then measured during the trip from Tzaneen to Cape Town.

The results are shown in Figures 7A-C. In the first case, the CO_2 increased to approximately 5% after loading and then stabilised at around 4% for the duration of the trip (Fig. 7A). In the second, the CO_2 increased to approximately 4% after loading and then evened out at around 3% for the duration of the trip (Fig. 7B). In the third, the CO_2 increased to approximately 4.5% after loading and then stabilised at around 2.5% for the duration of the trip (Fig. 7C).

The results are quite positive and indicate that a substantial degree of respiration suppression can be attained when administering CO_2 artificially, even at relatively low rates. As has been shown in Figure 2, this cannot be attained under natural CO_2 build-up conditions.

Trial set 5: Ripening rates of 'Hass' avocado fruit that received artificial CO_2 applications

This part of the project was conducted in the laboratory. The aim was to quantify the ripening inhibitory effects of artificially applied CO_2 under export simulation conditions. 'Hass' fruit were first stored at 6°C under regular atmosphere (RA) conditions for 2 days to simulate the pack-house cooling phase. The control fruit then remained under RA for another 28 days. For the treated fruit, CO_2 was administered as a gas in 25 litre buckets on day 3 at, respectively, 0, 4 and 8% for a 2-day period to simulate the dry ice applications in trucks. After these two treatment days, the fruit were placed into BA after, respectively, 0, 4, 8 or 12 days at RA. This was done to simulate the current periods that commercial consignments may be kept at regular atmosphere in Cape Town harbour before being placed under CA.

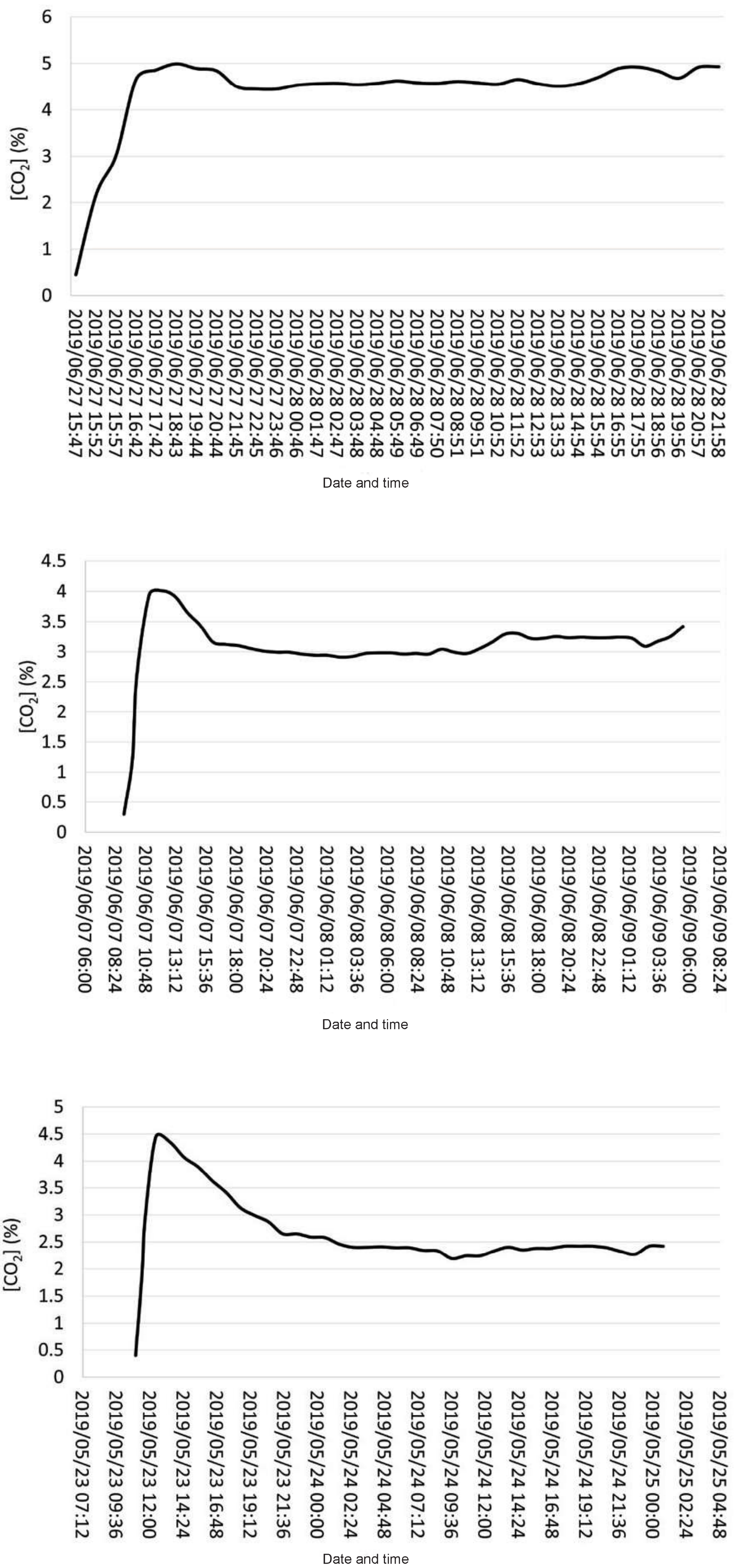

Figure 7: Carbon dioxide concentration inside three refrigerated trucks with dry ice supplementation en route from Tzaneen to Cape Town as measured during the 2019 season

Temperature was maintained at 6°C for the entire duration of the 30-day trial period, after which ripening was monitored at 20°C.

The results are shown in Table 1. The first RA control fruit reached the ready-to-eat stage by day 2. For the 0% CO_2 treatment, the first fruit of, respectively, the 14-, 18- and 22-day BA treatments reached the ready-to-eat stage by day 3 while the first fruit in the 26-day BA treatment reached the ready-to-eat stage by day 5. The fruit that received the 4% and 8% CO_2 applications started to reach the ready-to-eat stage by either day 4 or day 5.

Although a fair amount of ripening variation occurred in the above trial, the nett effect of the dry ice applications was positive, since it slowed down ripening enough to potentially decrease the risk of soft landings as proposed by Kruger *et al.* (2019b).

FURTHER RESEARCH

Although certain interesting suggestions have been made regarding the reasons why suboptimal levels of CO_2 still have an inhibitory effect on respiration rate (Allende Cruz, 2019; Hertog *et al.*, 1998; Maarten *et al.*, 2003), it is not within the current (commercially driven) project's scope to attempt to explain the physiological and biochemical reasons for the observed trends.

During the 2020 season, we will start commercialising the technique using fruit from various producers that are at different maturity stages. The dry ice applications will be done in cold rooms and refrigerated trucks. In the latter case, fruit samples will be retrieved from back-to-back control and trial consignments in Cape Town harbour. The fruit will be transported back to Tzaneen where they will be ripened and evaluated.

Acknowledgements

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Table 1: Percentage of ripe 'Hass' avocado fruit recorded after 30 days of storage at 6°C followed by ripening at 20°C (PH = pack-house; CT = Cape Town harbour; SP = the ship)

Treatment no	Periods (days)						Ripe fruit (%)											
	RA (PH)	Truck			RA (CT)	BA (SP)	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8	Day 9	Day 10	Day 11
		0% CO_2	4% CO_2	8% CO_2													
1	2	2			26			7	26	19	22	19	7				
2	2	2			0	26					33	33	15	19			
3	2	2			4	22			15	22	30	15	19				
4	2	2			8	18			7	33	26	22	11				
5	2	2			12	14			15	19	30	22	15				
6	2		2		0	26				19	30	26	26				
7	2		2		4	22				44	30	15	11				
8	2		2		8	18					37	33	15	4	4	7	
9	2		2		12	14					37	44	19				
10	2			2	0	26				11	37	33	19				
11	2			2	4	22					15	33	30	4	11	7	
12	2			2	8	18					22	44	33				
13	2			2	12	14				19	30		30	22			

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