COMMERCIALISATION OF THE INTERMITTENT CARBON DIOXIDE TRUCK TREATMENT DEVELOPED DURING RECENT SEASONS

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ABSTRACT
The artificial CO_2 enrichment procedures that were developed during recent seasons were commercialised during the 2021 season. The first commercial applications took place in refrigerated trucks during March 2021 with the Maluma Hass cultivar. This is an early season cultivar with a high respiration rate and substantial soft landing/grey pulp risk. During 2021 there was a shortage of controlled atmosphere (CA) containers during the above period, which allowed us to generate information that would not have been possible under normal conditions. Fruit from two producers were tracked. Producer A exported 1 675 'Maluma Hass' pallets during February and March 2021. Of these, 735 pallets were exported during February. Of these, 460 pallets were exported under door-to-door CA conditions (the container was transported to the packhouse and the fruit placed into CA within a couple of days after packing). Of these, 3.7% were found to contain fruit that developed grey pulp symptoms (primarily in dead seed fruit) upon arrival in Europe or shortly thereafter. Also during February, another 275 pallets were trucked under regular atmosphere (RA) conditions to Cape Town before being placed into CA. Of these, 16.7% contained fruit that developed grey pulp symptoms during storage. During March, 940 pallets from Producer A were exported. Of these, 237 pallets were shipped under door-to-door CA conditions. From February to March the incidence of grey pulp in these door-to-door consignments increased from 3.7% to 11.8%. Also, during March, 703 pallets were transported to Cape Town in refrigerated trucks of which the atmosphere was artificially enriched with CO_2. This resulted in the incidence of grey pulp being similar to that of the door-to-door consignments. From Producer B's export quality results we recommend that when applying dry ice derived CO_2 enrichment to 'Maluma Hass' fruit in refrigerated trucks, the period between harvest and CA-containerisation must preferably not exceed one week. However, based on our laboratory results, these strict measures do not apply to 'Hass' and the currently developed techniques will provide considerably more flexibility to 'Hass' exporters.

INTRODUCTION
During the last three seasons, Lowveld Postharvest Services (LPS) has developed a supplementary postharvest procedure involving a pre-shipping carbon dioxide treatment (Kruger *et al*., 2019; 2020a; 2020b; 2021). The most important conclusion derived at was that an artificial CO_2 treatment is more effective at slowing down the respiration rate of avocado fruit than is passively built-up CO_2.

The present report deals with the initial commercialisation phase that took place during the 2021 season.

MATERIALS AND METHODS
The Maluma Hass cultivar was selected for the study. 'Maluma Hass' is an early season cultivar with an elevated respiration rate and a high incidence of dead seeds that tend to further reduce the storage potential of the fruit. It was therefore an ideal candidate for testing the newly developed CO_2 enriching technology.

A total of 1 864 export pallets were tracked during the study. Of these, 1 675 were from one producer (Producer A) while another 189 pallets were from a second producer (Producer B). Of these, 697 pallets were exported under door-to-door controlled atmosphere (CA) conditions. A further 275 were exported under regular atmosphere (RA) in refrigerated trucks (thus without dry ice CO_2 enrichment) to Cape Town harbour. A third batch of 892 pallets were treated with dry ice-derived CO_2 in refrigerated trucks *en route* from the packhouse to the harbour.

A CO_2 meter was placed into eight of the trucks to record the atmospheric carbon dioxide levels while in transit.

The feedback received from the European clients was used to assess the efficacy of the treatments. The number of pallets that contained fruit with quality problems (primarily soft landings and grey pulp, especially in fruit with dead seeds) was recorded for each consignment.

RESULTS AND DISCUSSION

The CO_2 readings that were taken inside the trucks are shown in Figures 1 and 2. Figure 1 represents the first two applications that were made. Due to teething problems, approximately half an hour went by from inserting the dry ice into the truck until the doors were closed. As may deduced from the graphs, the CO_2 content in especially the first truck showed a linear increase in concentration, which indicates that the respiration rate of the fruit was not reduced during the transport period.

The CO_2 contents in the six experimental trucks of which the doors were closed directly after the dry ice applications are shown in Figure 2. In this case, all the applications exhibited an initial increase in CO_2 levels followed by a decrease and then levelling-off. This indicates that the respiration rates of the fruit were effectively reduced by the CO_2 applications.

At the beginning of the 2021 season, a shortage of CA containers prevailed. This was unfortunate for 'Maluma Hass' producers as it created quality problems due to the long periods from packing to CA containerisation. However, it was beneficial in the context of our research, since the efficiency of the artificial CO_2 applications could be thoroughly tested under commercial conditions. The results from Producer A are shown in Table 1.

During February, 16.7% of the pallets that were transported under RA conditions (without dry ice CO_2 enrichment) contained fruit that exhibited postharvest quality problems (primarily grey pulp in fruit with dead seeds). In contrast, only 3.7% of the pallets that were exported under door-to-door CA conditions had fruit with postharvest defects. However, from February to March the incidence of grey pulp in

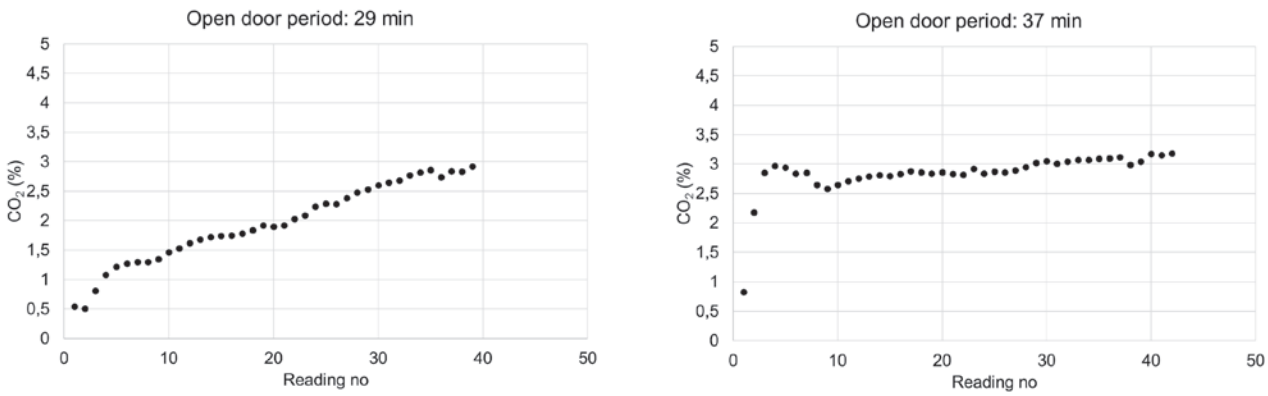

Figure 1: Carbon dioxide contents during transport of the first two refrigerated trucks where delays occurred between inserting the dry ice and closing the doors

Table 1: Incidence of postharvest problems as well as the packing to controlled atmosphere (CA) periods of 'Maluma Hass' fruit from Producer A that were exported under either door-to-door conditions, or in refrigerated trucks, under either regular atmosphere (RA) conditions from Tzaneen to Cape Town harbour or under artificial CO_2 enrichment conditions from Tzaneen to Cape Town harbour

Month	Treatment	Number of pallets		Incidence of postharvest problems (%)	Mean period from harvest to CA containerisation (days)	
		Without postharvest problems	With postharvest problems		Pallets without postharvest problems	Pallets with postharvest problems
February	Door to door CA	443	17	3.7 a*	3,56 e**	3,67 e
	RA trucks	229	46	16.7 b	7.8 p	8.05 p
March	Door to door CA	209	28	11.8 j	2,01 u	1,68 u
	CO_2 enriched trucks	620	83	11.8 j	8.08 x	8.8 x

*Chi Square Test ($p \leq 0.05$)
**Student's T-Test ($p \leq 0.05$)

the door-to-door consignments increased from 3.7% to 11.8%. This was due to 'Maluma Hass' fruit from orchards with a high nitrogen content being extremely sensitive to maturity increases.

In the case of non-door-to-door consignments, the incidence of postharvest problems decreased from 16.7% under RA trucking conditions in February to 11.8% under CO_2-enrichedment conditions during March. It was thus similar to that of the door-to-door consignments. This reduction happened despite the fruit being physiologically older/more mature, thus confirming that the CO_2 treatments were effective.

In the case of Producer A, the mean period from harvest to CA containerisation of the door-to-door consignments that were exported during February, was 3.6 days for the problem-free pallets and 3.7 days for pallets with grey pulp. In the case of the pallets that were trucked to Cape Town without CO_2 enrichment, the mean time periods that elapsed between harvest and CA containerisation in Cape Town were 7.8 days for unaffected fruit and 8.1 days for affected fruit. During March, the mean periods from harvest to CA containerisation of the door-to-door consignments decreased to 2 days for unaffected fruit and 1.7 days for affected fruit. During this month, the same periods for the consignments that received CO_2 enriching increased to 8.1 days for the unaffected fruit and 8.8 days for affected fruit.

In the case of Producer B (Table 2), 46% of the pallets contained fruit showing grey pulp symptoms

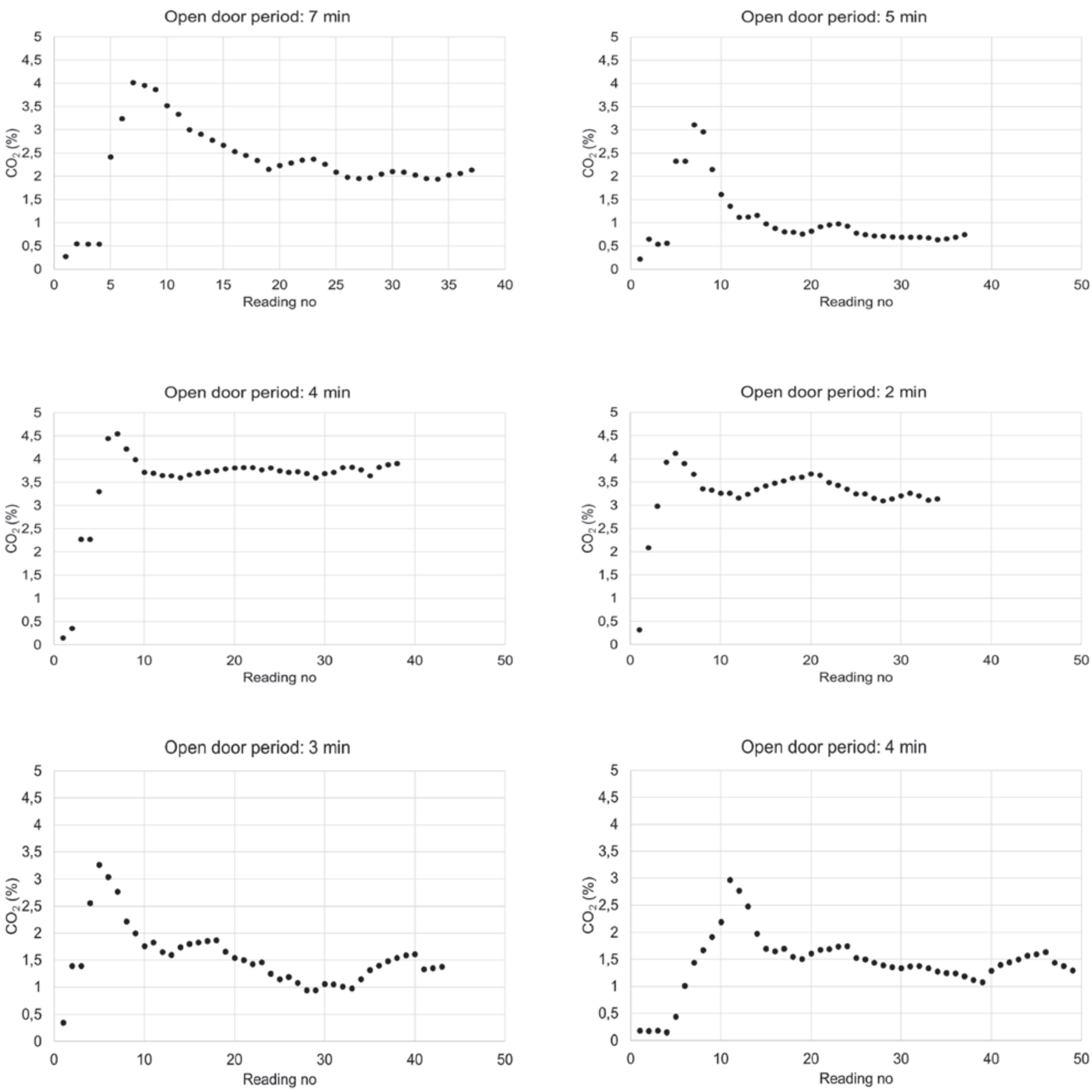

Figure 2: Carbon dioxide contents during transport of six refrigerated trucks where there were no delays between inserting the dry ice and closing the doors.

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Table 2: Incidence of postharvest problems and the packing to controlled atmosphere (CA) periods of 'Maluma Hass' fruit from Producer B that were exported under CO_2 enrichment conditions from Tzaneen to Cape Town harbour

Month	Treatment	Number of pallets		Pallets with postharvest problems (%)	Mean period from harvest to CA containerisation (days)	
		Without postharvest problems	With postharvest problems		Pallets without postharvest problems	Pallets with postharvest problems
March	CO_2 enriched trucks	102	87	46	9.8 a*	12.2 b

*Student's T-Test ($p \leq 0.05$)

during March and April. Most importantly, the period from harvest to CA containerisation was 9.8 days for the unaffected pallets and 12.2 days for the affected fruit, which is an inappropriately long RA period for the Maluma Hass cultivar (our recommendation is 4 days). It would thus appear that the extended period from harvest to CA containerisation played a major role in the development of grey pulp in these fruit.

From the results we recommend that, when using dry ice derived CO_2 enrichment on 'Maluma Hass' fruit in refrigerated trucks, the period between harvest and CA containerisation must preferably not exceed one week. However, based on our laboratory results, these strict measures do not apply to 'Hass' and the current techniques will provide considerably more flexibility to exporters. The use of the technology will significantly reduce the need for door-to-door carting of shipping containers and will facilitate the assembling of orders in Cape Town harbour. It will further contribute towards a reduction in soft landings and grey pulp in late season 'Hass'. There is a further possibility that only CO_2 enrichment and no CA may be applied to 'Hass', should empty market conditions prevail during the early- or mid-season.

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