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THE EXTENSION OF STORAGE LIFE OF AVOCADOS BY MEANS OF MODIFIED ATMOSPHERE STORAGE CONTROL

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OPSOMMING

1. *Beheerde en Gemodifiseerde Atmosfeer (BA en GA) verminder verkoelde vrugte se respiraste deur die O_2 te beperk. 'n Verhoging in CO_2 help ook om die respirasie te verminder.*
2. *GA verskil van BA deurdat by GA die atmosfeer uit gassilinders voorsien word. Die gasse word in gasdigte houers of plastieksakke geblaas, waarin die vrugte gehou word. By BA word die O_2 verlaag deur die respiraste van die vrug of deur beheerde verbranding van O_2 totdat die verlangde konsentrasie bereik is. CO_2 word verwyder deur 'n absorpsieproses.*
3. *Die aanwending van BA op die bootreis was sover nie moontlik nie weens die gebrek aan betroubare outomatisasie van O_2 en CO_2 toevloei.*
4. *Die NIW het gevind dat CO_2-skok pulpvlek by avokados in koue opberging verminder, maar die praktiese aanwending van hierdie tegniek lewer nog probleme.*
5. *BA verleng gewoonlik die raklewe van avokados maar veroorsaak weer 'n verhoging in na-oesbederf.*
6. *Die inwerkingstelling van BAof GA sal nie oornag kan geskied nie. Navorsingsresultate is belowend en regverdig verdere ondersoek in samewerking met oorsese navorsers.*
7. *Die huidige bevindings dui aan dat verskeping in gewone atmosfeer houers nie vir lank aan die orde sal wees nie maar verbeterings kan bewerkstellig word deur die koue Retting te verbeter en 'n temperatuur van 5,5 °C na te street vanaf die produksiegebiede tot by die punt van ontskeping.*
8. *Ondersoek het getoon dat die koue ketting bale swak in stand gehou word vanaf die produksie gebiede tot in Kaapstad. Slegs 15,8% van die vrugte het by die vereiste temperatuur gearriveer en 39% van die besendings se temperatuur was 3,0 °C tot 7,0 °C bokant die korrekte verskepingstemperatuur.*

SUMMARY

1. *Controlled and Modified Atmosphere storage (CA and MA) depend on further slowing down the cold stored fruits' respiration process by means of restricting the O_2 concentration available to the stored fruit. An increase in the Co_2 concentration also*

aids the lowering of the rate of respiration for those fruits able to tolerate relatively high CO_2 concentrations.

2. *MA storage differs from CA storage due to the atmosphere being used in MA storage being provided from cylinders. It is fed into gas-tight containers or large plastic bags holding the fruit. CA depends on lowering the O_2 concentration either by the fruit's respiration process or by means of controlled combustion of the O_2 until the correct level is reached. The CO_2 is removed by means of one appropriate absorption process.*
3. *CA storage application during sea voyage has to date not been possible. This is due to the inability to reliably automate the O_2 and CO_2 contents so that they remain at the set optimum storage limits.*
4. *The FFTRI has found that CO_2 shock successfully reduces pulp spot injury in cold stored avocados. The practical application of this technique during the land transport phase is presenting some difficulty,*
5. *Most of the CA techniques investigated for avocado storage tend to lengthen the storage life but results in the development of a high incidence of anthracnose rot ie for storage periods exceeding 3 to 4 weeks.*
6. *The rapid introduction of CA or MA storage for the export of avocados is not expected to occur overnight. The research results are promising enough to warrant looking at integrated MA reefer containers.*
7. *Present findings tend to suggest that shipment in regular atmosphere reefer containers will have to be used for some time to come for sea shipment of avocados. Improvements in this technique appear possible if greater attention is paid to maintenance of the cold chain at 5,5 °C from the point of production to the port of discharge.*
8. *Fruit temperatures taken at Cape Town revealed that the cold chain was poorly maintained during the transport of avocados from the production area to Cape Town. Only 15,8% of the fruit arrived at the correct shipping temperature at Cape Town. Thirty nine percent of the consignments were found to have avocados that were 3,0 °C to 7,0 °C above the correct shipping temperatures.*

REGULAR ATMOSPHERE STORAGE

The extension of the storage life of fruit and vegetables is principally dependant on slowing the rate of respiration of the product down. This is generally achieved by reducing the temperature, for the lower the temperature the slower the rate of respiration. The utilization of mechanical refrigeration during transport of perishable products at low temperatures was the dominant factor responsible for the great success met with in exporting highly perishable fruit from South Africa to the important United Kingdom and other overseas markets.

CONTROLLED AND MODIFIED ATMOSPHERE STORAGE

It is possible to further reduce the rate of respiration by means of restricting the amount of the oxygen made available to the product stored at a low temperature. An increased level of CO_2 does also aid the lowering of the rate of respiration of many products. The use of low O_2 alone or in combination with relatively high CO_2 levels is referred to as Controlled Atmosphere Storage and/or Modified Atmosphere Storage. Low O_2 high CO_2 during storage definitely also requires the use of low storage temperatures for the success of this storage system. The low O_2 and raised CO_2 levels must therefore strictly speaking be looked on as a supplement to refrigeration.

MODIFIED AND CONTROLLED ATMOSPHERE

A distinct difference is claimed in the USA between Modified Atmosphere and Controlled Atmosphere storage. Modified Atmosphere involves the displacement of the regular atmosphere in the storage space with a specially created modified atmosphere which is known to suit the product being stored. The gasses are injected from cylinders of liquid or compressed cylinders and are generally O_2, CO_2, N_2 and in certain specific cases CO gas is added for rot control.

Controlled Atmosphere like Modified Atmosphere can only be applied in a gass-tight room or container. Controlled Atmosphere was originally dependant on the respiration process of the stored product altering the gass composition. The O_2 is reduced and CO_2 is accumulated. The CO_2 is, however, kept to within safe limits by means of absorption of the CO_2 gass.

The latter process is achieved by various means and is termed scrubbing. Modern Controlled Atmosphere is initially achieved by means of controlled rapid combustion of the atmosphere. The CO_2 is absorbed and the correct O_2 and CO_2 composition can be created within 24 to 48 hours.

CONTROLLED ATMOSPHERE (CA) AND SEA TRANSPORT

The Sea Land Service Inc in USA has great practical experience re the introduction and use of CA per sea. In the late 1960's to early 70's they converted a few hundred of their containers with Oxytrol Controlled Atmosphere equipment. The O_2 content was controlled by means of flushing with Nitrogen (N_2). Sea Land found this system unreliable as the control system often flushed too much N_2 into the containers which resulted in the O_2 dropping too low which resulted in anaerobic conditions which were toxic to the product. This resulted in the development of off flavors and internal breakdown disorders in certain products. Another criticism was that the large N_2 tanks which had to accompany the containers resulted in the loss of cargo space.

MODIFIED ATMOSPHERE—A SUPPLEMENT FOR TRANSPORT REFRIGERATION

Sea Land Service did not abandon the idea of manipulating the gas environment in the container as a means of improving the keeping quality of the product during transport.

The Oxytrol Controlled Atmosphere system was replaced with the Tectrol Modified Atmosphere technique. This was in the early 70's and it is still being largely used in most of Sea Land's trade lanes. It is estimated that 50% of the entire Sea Land fleet of good refrigerated containers is equipped to take modified atmosphere. Since the mid-1970 all their new refrigerated containers have been factory equipped for Tectrol Modified Atmosphere.

The Modified Atmosphere system is extensively used in the trans-Atlantic and trans-Pacific routes with transit times ranging from ten to twenty-five days.

It is extensively being used for the transport of green and leafy vegetables, cherries and meats. Fresh asparagus are claimed to benefit greatly when held under Modified Atmosphere conditions. Based on results obtained by the FFTRI this system could lend itself to transport of avocados.

METHODS OF APPLYING THE TECTROL MA SYSTEM

The MA system can be applied in. two ways for use during transport.

1. Containers:

   The container must be airtight and have the facilities provided for placing a plastic seal curtain in the rear doorway. Certain valve control inlets are provided for injecting the required gas mixtures for the specific product.

2. Pallet Bag System:

   The commodity generally in cartons is palletized and enclosed in a plastic pallet bag. The gas is injected into the bag which is then sealed. This system is used with much success to local and export of shipments from California.

SHOCK CO_2 TREATMENTS

Work done by Dr Ken Olsen USDA and others in Washington State established that shock doses of high CO_2 in atmospheres with very low O_2 applied for several days had a very beneficial effect on Golden and Red Delicious types of apples subsequently stored under optimum CA conditions. The shock CO_2 treatment improved retention of firmness which is an important quality factor looked for in stored apples. This method has, however, not been used on a large commercial scale, as the risks for CO_2 injury are large. The injury is found to be more prevalent in certain areas and can be expected to occur if apples are wet just prior to the application of the treatment. The trend in apple storage is now to go for rapid CA which entails having the CA conditions i.e. temperature and correct gas composition established within 6 days from harvest.

SHOCK CO_2 TREATMENTS FOR AVOCADOS

The use of CO_2 shock treatment as a supplementary aid for improving the safe storage and transport time for avocados is being thoroughly researched at the FFTRI by Dr G Eksteen and Mr AB Truter. The results have proved very encouraging and no danger of

CO_2 injury has been reported. The avocados are placed in an atmosphere of 18% CO_2 and the room sealed for 6 days during which time the CO_2 built up to 33,0%. The fruit was then stored at 5,5 °C under regular atmosphere condition for a further 33 days. This treatment resulted in a very low incidence of pulp spot compared with the results for the avocados stored at 5,5 °C without the CO_2 shock treatment ie 8,3% pulp spot compared to 55,9%.

The CO_2 treated fruit did, however, develop 66% anthracnose compared to 25,2% for the control sample. The anthracnose and oil spot values were found after 4 to 7 days ripening at 20 °C (unpublished report Eksteen and Truter). The storage period was rather long i.e. 39 days from harvest which is conducive to anthracnose rot. Work in this field by Westfalia's technical team was most promising and they are contemplating overseas experimental trials. The application during transport presents quite a problem for it is difficult to maintain gas tightness in the railway refrigerated trucks. The same applies presently for the road motor transport being used. The use of the plastic bags over the pallets as used in the Tectrol system could well be the answer. The snag is to remove the bag before shipment so as to ensure effective cooling in the container.

The present line of thought is to apply the initial CO_2 shock treatment at the production point possibly using CO_2 levels well above 18% and cutting application time down to 48 or 72 hours.

CONTROLLED ATMOSPHERE STORAGE

The maintenance of Controlled Atmosphere storage conditions throughout the storage phase is also being thoroughly researched by Mr Truter of the FFTRI. The use of 2% O_2 and 10% CO_2 for 33 days storage eliminated pulp spot and the anthracnose was not much above that found for avocados held at 5,5 °C for 33 days.

Use of Controlled Atmosphere storage appears a worthwhile technique except that no reliable CA container is presently available. Trials done with avocados from Cape Town to European ports proved successful provided a technician was there to ensure adequate O_2 during the voyage. In two trials where no technicians accompanied the consignment anaerobic conditions resulted and the avocados were unsaleable upon discharge in Europe.

MODIFIED ATMOSPHERE INVESTIGATION

CA storage at present is not feasible. This means that a serious look should be taken at the Tectrol Modified Atmosphere technique as used by Sea Land Inc. Some hit-and-miss trials were done but never on a thorough organized basis. A trial programme should be considered between the Industry, the Tectrol MA Co working directly with their USA principals, the FFTRI and the PPECB. The fact that MA storage system has been used in the USA since the 70's makes it important for us to investigate its possibilities not only for avocados but for many other products.

IN PACKAGE STORAGE MODIFICATION

The use of an inner plastic bag of suitable thickness to allow for a suitable O_2 and CO_2 concentration to develop during storage and subsequent shipment is easily applicable. This technique led to big improvements in pear and Golden Delicious apples. The fact that it is readily applicable and that it comes into operation after packing has been completed are factors that make it an attractive proposition. This technique was included in the FFTRI's investigation. The results show the avocados from this treatment to have the longest shelf life. Ripening required from 7 to 10 days whereas it generally took 4 to 7 days at 20 °C. The polybags in the carton did lead to a very high incidence of anthracnose and the control of pulp spot was poor. The indications based on other fruit are that certain specially sized perforations may lessen the risk of disorders. The perforations lower the %RH. A sign of RH is possibly the factor responsible for the very high incidence of anthracnose found in this pack.

INDIVIDUAL BAG PACK PER AVOCADO

The most promising FFTRI results were obtained in the trials where the avocados were placed in separate polyethylene bags (25 mm thickness). The open end of the bag was folded over and the fruit so placed that its mass sealed the end. This was the only bag closure applied. A second treatment was included where the bags were effectively heat sealed. The folded bag gave the best outturn. Pulp spot control was low (6,6%) in both treatments but anthracnose in the sealed bag resulted in twice as much anthracnose rot as the folded bag (58% compared with 29% for the folded bag). This aspect is being further studied in this year's FFTRI programme.

This is a very simple method to apply and certainly holds out no risk during sea shipment i.e. compared to the present commercial pack. It certainly appears to warrant serious industry trials.

THE PRESENT SHIPPING PRACTICE

It is accepted that a real need exists to find reliable supplementary aids to improve the keeping quality potential of avocados being shipped and under refrigeration in regular atmosphere (RA) in reefer containers at 5,5 °C. As indicated in this report much is being done in this field. The practical application of any new storage technique will not just take place overnight. Furthermore it will most likely result in increased freight rates. It is therefore important at this stage that the aim of shipment in RA reefer containers must be to ensure that optimum storage conditions be maintained throughout the transport operation from production to marketing. Time between harvesting and packing should be as short as possible. Efficient and rapid precooling must follow the completion of packing. The fruit must be reduced to the optimum shipping temperature of 5,5 °C.

This temperature must be maintained throughout the road or rail journey, while awaiting shipment and during the sea voyage. The temperature at the time of shipment must be at 5,5 °C with a permissible tolerance of ± 1 °C. This tolerance holds for the entire avocado cold chain during shipment.

ACCEPTANCE OF AVOCADOS AT 10 °C FOR EXPORT

A SAAGA ruling that avocados at 10 °C may be accepted for sea shipment is contrary to the requirements for the maintenance of the avocado sea shipment cold chain that is laid down at 5,5 °C. It does not comply with the General Loading and Carrying Temperature Instructions issued to each specific carrier. It therefore is a serious counter argument against any claims that may be made against the carrier. More important is the fact that carriage at such a high temperature even for only part of the voyage will markedly shorten both the storage and the shelf life of the avocados.

LAND TRANSPORT CARRYING TEMPERATURES FOR AVOCADOS

Temperature management for efficient sea shipment of avocados depends on the following steps being complied with —

1. Precooling as soon after harvesting and packing has been completed.
2. Rapid reduction of the avocado temperature to 5,5 °C. Preferably within 24 hours after packing has been completed.
3. Maintenance of this temperature from completion of precooling until arrival at the port of export.
4. Holding the fruit at the export harbor at 5,5 °C either on pallets or in containers i.e. until transfer to the ship.

A tolerance of ± 1,0 °C is permitted.

The land transport leg must be followed up by shipment at 5,5 °C until the fruit is discharged at the overseas port.

TEMPERATURE HISTORY OF AVOCADOS FOR 6 SHIPMENTS 1983

The temperatures taken as a routine operation by PPECB personnel for avocados on arrival at Cape Town and at the time of shipment was analyzed for 6 different shipments. This covered the period from the 22.03.83 for the Ortelius to the winter berg 27.04.83.

The fruit temperatures on arrival at Cape Town and at the time of shipment are given in Table 1. It is seen that the average arrival temperatures were from 1,5 °C to 5,2 °C above the laid down optimum shipping temperature. Much more disconcerting is the maximum temperatures that were found in the fruit received for the 6 different shipments.

Only 15,5% of the fruit was within the correct shipping temperature range. Forty two percent was from 1,0 °C to 3,0 °C above the optimum. It could be argued that the arrival temperatures of these two groups are acceptable if efficient precooling was applied soon after arrival. It is known that efficient pre-cooling is provided in some of the cold stores. There are other instances where the fruit temperature is maintained but little if any cooling is achieved. This period often extends to six days. Reference in Table 1 to the fruit temperatures at shipment shows that 3 out of the 6 shipments had an average

shipping temperature of 2,0 °C above the laid down optimum shipping temperature. The high maximum shipping temperature also seen in Table 1 is cause for concern specially in the one instance where a maximum temperature of 16,0°C was recorded at the start of the sea voyage.

High temperatures which prevail for several days will hasten the onset of the respiration climacteric rise. This results in an increased rate of ripening taking place which also means an increased heat of respiration being generated. This in turn plus the possible evolution of ethylene gas into the storage atmosphere may in turn stimulate other packed avocados in that container to start ripening.

SEEKING NEW AND APPLYING ESTABLISHED PRACTICES ARE BOTH IMPORTANT

The lists of pre and post harvest problems compiled by SAAGA during 1982 are accepted as being of great importance and should receive attention as soon as possible. Answers to these problems would most likely speed up solutions to pulp spot, lead discolouration, abnormal ripening etc. The programme of research work outlined is quite a formidable one and encompasses many seasons of work.

Experience with other important export fruits has shown that even when the answers to post harvest disorders become known it does not minimize the vital importance of correct temperature management and accurate maintenance of the cold chain. A good example is the disorder termed storage bitter pit, in apples. Attention to rectifying the calcium status of the apple did much to lessen bitter pit development but it was found that rapid precooling and accurate temperature maintenance of the optimum storage temperature was essential to control development of storage bitter pit.

Reference to the 1983 preshipment avocado temperatures found at Cape Town has been poor, While it certainly is not the only reason for soft and discolored fruit, there is no doubt that a big improvement in the maintenance in the South African link in the cold chain would have led to at least firmer fruit being delivered to the overseas markets.

It must also be mentioned that avocados are most likely no different from other fruit and that seasonal environmental variations influence the keeping quality greatly. Pin pointing the environmental factors that play a role must also be regarded as important. It still does not lessen the importance that must be placed on good temperature management through-out the sea export operation of avocados.

TABLE 1. The temperature of export avocados on arrival at Cape Town and the fruit temperatures at the commencement of the voyage for 6 container ships during March and April 1983.

Arrival Dates at CT	Shipping Date	Ship	Arrival fruit temps				Fruit temp at shipping			
			No of msre	Max °C	Min °C	Ave °C	No of msre	Max °C	Min °C	Ave °C
19/20 Mar	22.03.83	Ortelius	12	12,0	5,5	8,5	12	10,0	4,0	7,1
26/27/28 March 31/3;	29.03.83	Sederberg	9	10,0	4,5	7,2	8	6,5	5,0	5,8
1 & 2/4 Apr	04.04.83	Helderberg	36	19,5	5,0	10,7	24	9,5	5,0	5,2
9/10/11 Apr	12.04.83	*Waterberg	29	10,0	5,0	7,2	26	9,0	4,0	6,4
14-17 Apr	18.04.83	Transvaal	52	17,0	4,0	8,4	42	9,0	5,5	7,5
21-25 Apr	27.04.83	**Winterberg	70	17,5	2,0	8,8	40	16,0	5,5	7,6
21-25 Apr	27.04.83	Winterberg	49	17,5	2,0	7,5	40	16,0	5,5	7,6

* Waterberg — one container not shipped (arrival temps 13,0; 15,0; 16,0; 21,0).

** Winterberg — the 70 measurements include 9 containers representing 21 measurements that were for the 9 containers not shipped due to various reasons including high temperatures on arrival at Cape Town.

TABEL 2. The scatter of avocado arrival temperatures at Cape Town for the six shipments referred to in Table 1.

Departure date and ship	No of samples grouped according to different arrival temperatures					
	Below 4,5 °C	4,5 to 6,5 °C	6,6 to 8,5 °C	8,6 to 10,5 °C	10,6 to 12,5 °C	above 12,5 °C
22.03.83 Ortelius	0	2	5	3	2	0
29.03.83 Sederberg	0	3	4	2	0	0
04.04.83 Helderberg	0	2	6	12	11	5
12.04.83 Waterberg	0	6	20	3	0	0
18.04.83 Transvaal	2	10	19	16	1	4
27.04.83 Waterberg	3	9	32	16	2	3
TOTAL	5	32	86	52	16	12
	2,5%	15,8%	42,3%	25,6%	7,9%	5,9%