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Preliminary Studies on Modified Air Storage of the Fuerte Avocado Fruit

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Observations on the respiratory trend of Fuerte avocados at the storage temperature of 4 to 5 degrees C and at the ripening temperature of 15 degrees C have been reported (1). A definite relationship was found between carbon dioxide evolution and softening. The maximum in the rate of respiration invariably preceded softening when the fruit was stored in ordinary air. This behavior did not occur in an atmosphere of nitrogen. Under anaerobic conditions a sharply declining carbon dioxide output took place with no characteristic climacteric and no softening. Apparently the respiratory system of the avocado is highly sensitive to complete lack of oxygen. On the other hand, a 20 per cent oxygen content, as normally found in air brought about rapid oxidation and softening. These differences between aerobic and anaerobic carbon dioxide production suggested the advisability of investigating the effects of modified atmospheres, with a view to prolonging the storage life of this fruit.

EFFECTS OF MODIFIED ATMOSPHERE NO. 1

The first modified atmosphere to which the fruit was subjected in these studies consisted of 10 per cent oxygen, 10 per cent carbon dioxide, and 80 per cent nitrogen. This gas mixture, supplied in cylinders by a commercial concern, was checked in the laboratory and the composition found to be reasonably close to specifications.

The avocados for the first experiment came from Escondido, San Diego County, and were placed in storage February 15, 1941, at a temperature of 4 to 5 degrees C. In this particular case only 12 fruits were used for each treatment. The total fresh weight of the treated sample was 2,425 grams as compared with 2,415 for the control. For several days prior to differential treatment all containers were stored under a continuous air stream, and carbon dioxide evolution determined daily by methods described previously (1). All respiration measurements were made in air. On February 24, two of the four containers were placed under modified atmosphere No. 1 which was supplied at a rate of 100 cc/minute for a period of 2 weeks. On March 10 all the fruit was transferred to air at 15 degrees C. At that time the control avocados as well as those exposed to the modified atmosphere showed no signs of softening. The effects of controlled air storage on subsequent respiration rates under air in a ripening room maintained at 15 degrees C are presented in Table I.

TABLE I—Respiration of Fuerte Avocados in Air at 15 Degrees C, After Preliminary Treatment at 4 to 5 Degrees C (In Milligrams Carbon Dioxide per Kilogram of Fruit per Hour)

Preliminary Treatment	March					
	11	12	13	14	15	17
Air	87.6	98.1	101.9	104.6	96.8	82.7
Modified Air No. 1	66.9	79.8	91.3	98.0	94.0	83.2
	18	19	20	21	22	
Air	70.0	58.0	48.7	42.1	37.9	
Modified Air No. 1	65.3	51.9	52.8	37.1	37.2	

As may be seen from this table, the initial rate of carbon dioxide evolution was about 24 percent lower in avocados under the modified atmosphere than in control fruit. This divergence was rapidly diminished, and the climacteric took place in both cases on March 14. Similarly, the rate of softening was not materially delayed by an exposure to the modified atmosphere for 14 days.

The period of treatment with modified atmosphere No. 1 was lengthened in a second experiment, for which avocados were obtained on March 12, 1941 from the orchard of the Division of Horticulture at Los Angeles. The fruit was divided into three equal samples. Sample A was exposed for 2 weeks, sample B for 4 weeks, and sample C for 6 weeks to gas storage at 5 degrees C. Fifteen fruits were used in each treatment and control. At the end of each storage period the respective sample and its control were transferred to air at IS degrees C, and carbon dioxide evolution determined. In Fig. 1 the readings obtained immediately following this transfer as well as the climacteric values are presented.

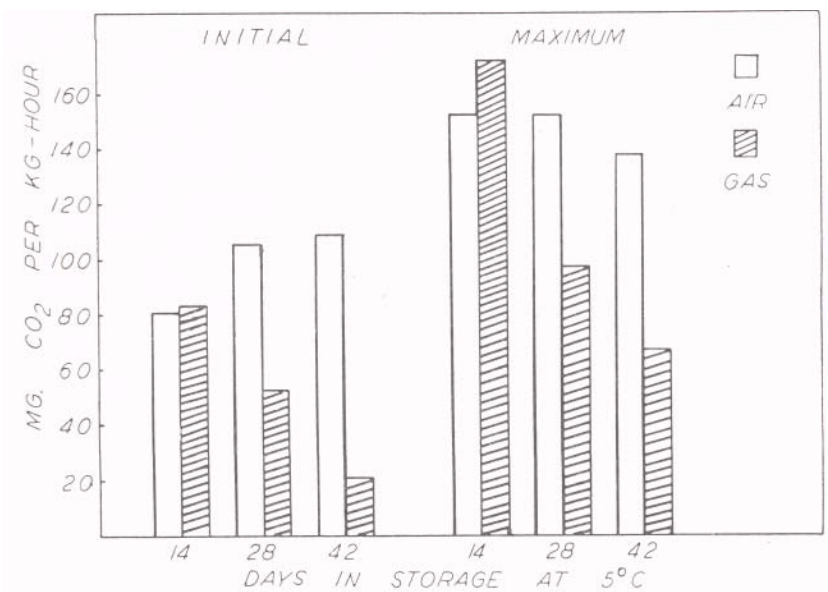

Fig. 1. Respiration of Fuerte avocados in air at 15 degrees C, after exposure to air and modified atmosphere No. 1 at 5 degrees C.

The time elapsed between the initial and maximum respiration varied with the different samples. The longer the fruit was kept in storage the shorter appeared to be this time interval. Here, as in the first experiment, a 2-week treatment with modified air did not result in any reduction in carbon dioxide evolution. On the other hand, samples B and C, which were two and three times longer under the modified atmosphere than sample A, showed a retarded rate of respiration. However, so far as ripening was concerned this treatment did not bring about any appreciable delay in softening nor did it prevent darkening of the skin. There were some indications that the carbon dioxide concentration in modified air mixture No. 1 lowered the keeping quality of the fruit.

From the results of the experiments conducted in the spring of 1941, it was considered advisable to lower both the oxygen and the carbon dioxide contents of the modified air mixture. Specifications were, therefore, issued for cylinders containing 2.5 per cent oxygen, 5 per cent carbon dioxide and 92.5 per cent nitrogen. The mixture actually supplied deviated considerably from this specification. The oxygen content varied from 3.6 to 5.6 per cent, and the carbon dioxide content from 2.9 to 4.9 per cent, nitrogen making up the difference. This gaseous composition will be referred to as "modified atmosphere No. 2". The results obtained with this mixture are believed to justify a report at this time. Thus far two experiments have been carried out with this modified atmosphere, one on early and the other on midseason Fuerte avocados.

EFFECTS OF MODIFIED ATMOSPHERE NO. 2

Effects of Modified Atmosphere No. 2 on Early Fruit:—For this experiment avocados picked at Escondido December 15, 1941 were placed at 7 degrees C on December 19 under a constant stream of air. Twenty fruits were included in each treatment. On December 24 one of the jars (No. 20) was placed under the modified air mixture at a rate of 100 cc/minute, while jar No. 19 was left under air at the same rate. During respiration measurements the rate was increased to the standardized flow of 350 cc/minute. The response of the fruit to modified air storage as compared with ordinary air is shown in Fig. 2.

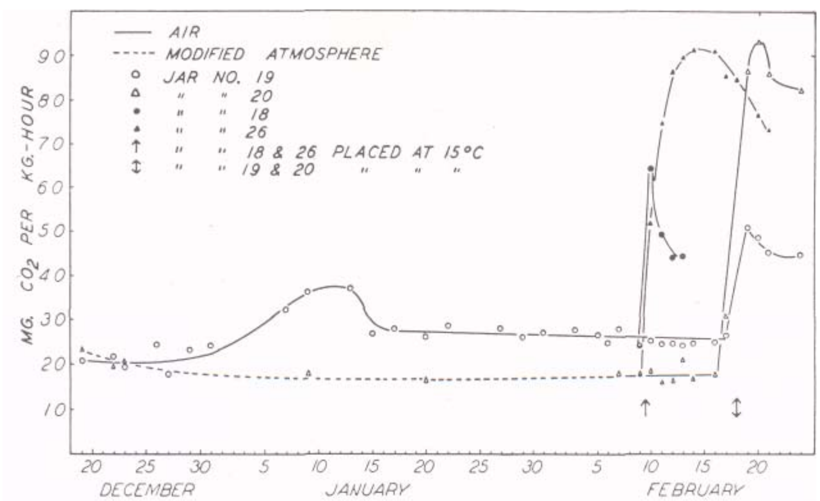

Fig. 2. Carbon dioxide production by early season Fuerte avocados in relation to controlled air storage (Modified atmosphere No. 2).

The respiration curve of the control fruit seemed to rise to the characteristic climacteric, which was not observed previously at a storage temperature of 2 to 3 degrees lower. The largest quantity of .carbon dioxide evolved at 7 degrees C was one-third to one-fourth that of avocados during the peak of respiration at 15 degrees C. The fruit in control jar No. 19 were firm on January 14, 1942, but appeared to soften on February 7. The time interval between the climacteric and onset of softening was much longer at 7 degrees C than at 15 degrees *C.* This observation is in conformity with the high Qio for avocado respiration reported previously (1). The fruit in jar No. 20 which was stored in the modified atmosphere was found to be firm on February 7. On that day the contents in each jar were split into two equal samples. Ten avocados from jar No. 19 were transferred to jar No. 18, and 10 from jar No. 20 to jar No. 26, leaving 10 fruits in each of the original containers. All jars were placed under air at 350 cc/minute.

On February 9, jars No. 18 and No. 26 were moved to the ripening room which was maintained at 15 degrees C. In both cases a sharp rise in carbon dioxide evolution took place, but the trend of the respiration curves is strikingly different for the two samples. Jar No. 18 which had passed the climacteric at the low temperature exhibited a declining rate of carbon dioxide output. On the other hand, the fruit in jar No. 26, which was in the pre-climacteric stage when transferred to the ripening room, showed the typical increase to a maximum followed by a decrease in the rate of respiration. A similar difference in behavior was observed between jars No. 19 and No. 20 which were transferred to 15 degrees C on February 18. The effect of modified air storage for 6 weeks was also observed in the manner of ripening. The treated fruit kept firm longer and softened more gradually than that exposed to air. The former had also a more desirable appearance of the skin. In general, there seemed to be a definite improvement in the keeping quality of the fruit under the modified atmosphere.

Effects of Modified Atmosphere No. 2 on Midseason Fruit:—The avocados for this experiment were obtained from the Divisional orchard on January 21, 1942 and placed the same day at 7 degrees C under air at 350 cc/minute. Twenty fruits were included in each respiration jar. The fresh weights of the fruit were 3,855, 3,985, and 4,150 grams for jars No. 7, 9, and 11, respectively. On January 27, two jars (No. 7 and No. 9) were put under the modified air mixture at 100 cc/minute, while jar No. 11 was left as control under air at the same rate of flow as the treated fruit. Jar. No. 7 was kept under controlled atmosphere storage for 5 weeks and No. 9 for approximately 3 weeks. The effects of this treatment on carbon dioxide evolution are presented in Figs. 3 and 4.

In this experiment, as in the previous one, the respiration of the control fruit reached the climacteric at 7 degrees C. However, the time interval between the initial reading and the maximum was shorter by one week here than in the early season fruit. On February 10, all the avocados in jar No. 11 were very firm, but on March 5 some had started softening. At that time the treated fruit was still firm. On February 20 jar No. 9 was transferred to air. On March 5 half of the fruit from each jar were transferred to separate containers and placed at 15 degrees *C.* The following transfers were made: from jar No. 7 to No. 17, from No. 9 to No. 18, and from No. 11 to No. 19. The remainder of the fruit in the original jars was left at 7 degrees C until March 12 at which time transfers to a ripening temperature of 17.5 degrees C were made.

It is of particular interest to note the respiration curves after the changes in temperature. The avocados in jar No. 19 which were in the post climacteric stage, behaved like those of No. 18 in the early season fruit. The treated fruit (Fig. 3) which had been in air since February 20 and was at the peak of respiration at the time of transfer, followed essentially the same respiratory course as the control. On the other hand, a climacteric occurred in the avocados of jar No. 7 and No. 17 (Fig. 4), because they were under the modified air mixture until March 5, and presumably had no climacteric previously.

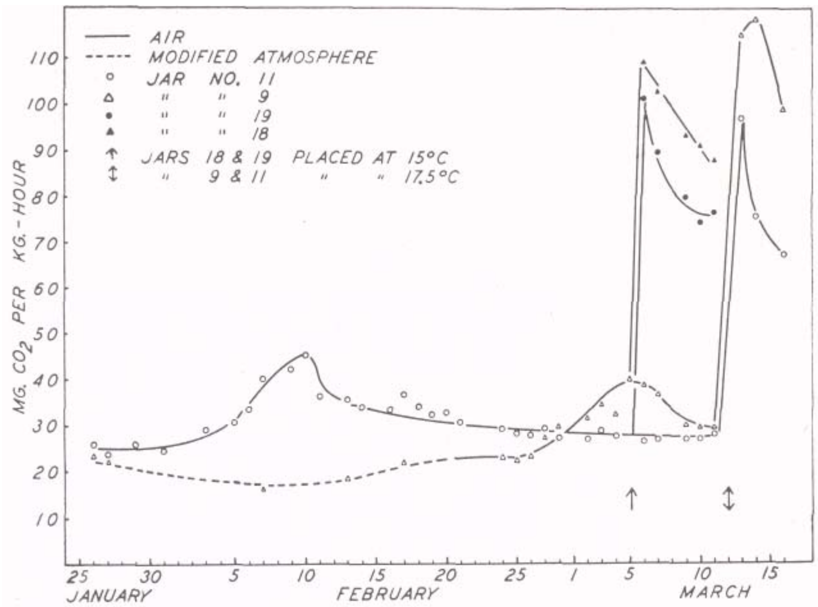

FIG. 3. Carbon dioxide evolution by Fuerte avocados as affected by controlled air storage for 3 weeks (Modified atmosphere No. 2).

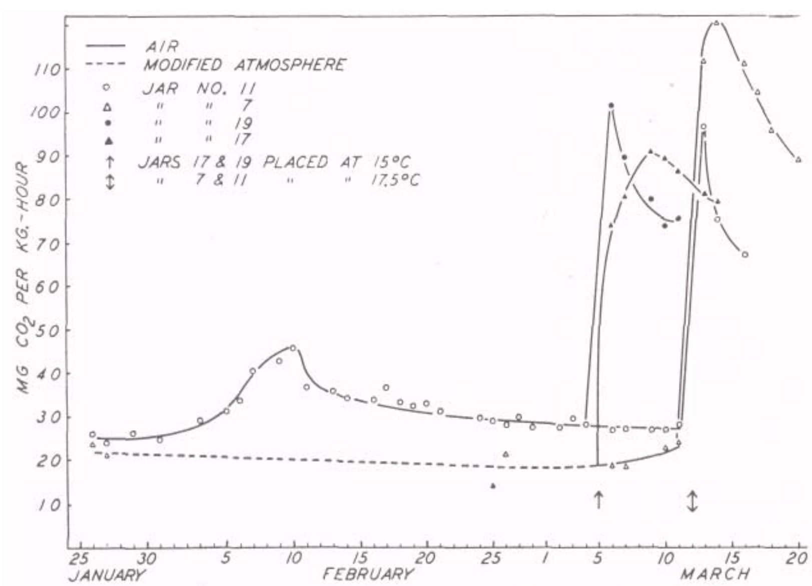

FIG. 4. Carbon dioxide evolution by Fuerte avocados as affected by controlled air storage for 5 weeks (Modified atmosphere No. 2).

The observations on the effects of modified atmosphere No. 2 on softening and keeping quality support the findings in the experiment with early season fruit. On March 11 when the avocados in jar No. 19 showed many dark spots and were in the edible stage, the fruits in No. 18 were fully green and quite firm. All the fruits in jar No. 17 retained good color and were very firm. At the end of the experiment the control avocados had passed the edible stage and showed considerable discoloration of the skin. Of the treated fruits, those in jar No. 7 kept longest and had best appearance upon ripening. Doubtless, the better keeping quality of this fruit was due to modified air storage. It would be premature, however, to conclude on the basis of available data as to which is the most desirable atmosphere to be employed. For this purpose better controlled experiments are planned for next season.

CONCLUSIONS

Fuerte avocados were subjected for different periods to controlled air storage. One of the modified air mixtures consisted of 10 per cent oxygen, 10 per cent carbon dioxide and 80 per cent nitrogen. The other mixture had about one-third to one-half as much oxygen and carbon dioxide.

Of the two modified air mixtures, the second appeared to give promising results. The rate of carbon dioxide evolution was lower in controlled atmosphere storage than in air. Apparently no climacteric rise in respiration took place under treatment. Fruit softening was definitely delayed and the fresh appearance of the skin was retained longer under the second modified atmosphere than under air.

LITERATURE CITED

1. BIALE, J. B. The climacteric rise in respiration rate of the Fuerte avocado fruit. *Proc. Amer. Soc. Hort. Sci.* 39: 137-142. 1941.