RESEARCH TO VERIFY IF A HEAT SHOCK TREATMENT PRIOR TO A COLD TREATMENT (RANGING BETWEEN 1.1 ºC AND 2.2 ºC) WILL AFFECT SOUTH AFRICAN 'HASS' AVOCADO FRUIT QUALITY

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ABSTRACT

The objective of this study is to verify if a heat shock treatment (38 °C, 10-12 hours) prior to cold storage (1.1 °C for a duration of 12 days) will affect the fruit quality of South African 'Hass' avocado fruit. Hawaiian 'Sharwil' avocados are exported to the USA using this cold storage treatment and the question is whether the same treatment could be applied to South African 'Hass' avocados. 'Hass' avocados are sensitive to cold damage and are usually not shipped at 1.1 °C. The cold treatment involves a 38 °C heat shock for 10-12 hours prior to the implementation of the 12-day 1.1 °C sterilisation period. This method makes Hawaiian 'Sharwil' avocados more resistant to cold damage. This trial consisted of three treatments:

- the temperature treatment as mentioned above, with the remainder at 5.5 °C,
- similar to the first treatment, but without the heat shock,
- storage at 5.5 °C for the full duration of the trial.

Fruit were stored for a total of 35 days in regular atmosphere and evaluated at multiple times during this storage duration.

The heat shock treatment did not reduce the incidence of black cold damage. After 18 days of cold storage, fruit exposed to the 12-day sterilisation period at 1.1 °C (both with and without the heat shock) and placed in 5.5 °C storage had similar incidence of black cold damage. In contrast, after 25 and 35 days of storage at 5.5 °C only, significantly lower black cold damage on fruit was noted. The results suggest that 'Hass' is more sensitive towards freezing damage when stored at 1.1 °C compared to 'Sharwil' avocados.

The cold treatment with heat shock resulted in a higher moisture loss of 2.5% compared to the cold treatment without the heat shock (1.9% moisture loss). Moisture loss increased progressively as storage duration increased.

The cold treatments, with and without a heat shock, resulted in higher grey pulp incidence with values of 10.4% and 8.9% respectively, which was significantly higher compared to the 5.5 °C treatment (1.6%). There was no evidence that the heat shock affected the DTR, fruit firmness, anthracnose, stem-end rot, and vascular browning in a negative or positive way.

INTRODUCTION

A Hawaiian research article (Jang *et al*., 2001) demonstrated that 'Sharwil' fruit quality was not affected when stored up to 12 and 22 days at quarantine cold temperatures ranging between 1.1 ºC and 2.2 ºC, by applying a heat shock treatment (38 ºC, 10-12 hours) prior to the quarantine cold treatment. Besides controlling chilling injury, the heat shock reduced the incidence of grey pulp. This needs to be tested on South African 'Hass' avocados as it is not known if the heat shock will provide effective protection against cold damage.

Cold treatments are used for disinfestation of phytosanitary insects in a number of commodities including citrus, carambola, lychee, and kiwifruit (Gould, 1994). The United States Department of Agriculture, Animal Plant Health Inspection Service (USDA - APHIS) requires that avocados (*Persea americana*) from Hawaii, which are hosts of fruit flies, be free of such live pests prior to their entry into the US. The treatment requires that fruit be exposed to a minimum fruit core temperature (FCT) of 12 days at < 1.1 ºC, 14 days at < 1.67 ºC or 16 days at < 2.2 ºC. In March 1996, use of the cold treatment, T107 (a), was approved for Hawaiian grown 'Sharwil' avocados by USDA-APHIS (APHIS, 1998). To export at these low temperatures, the Hawaiian export protocol includes a heat shock treatment (38 ºC, 10-12 hours) prior to the quarantine period (Jang *et al*., 2001).

In recent years there has been growing interest in heat shock treatments as a method of reducing chilling injury in horticultural crops, thus permitting extended storage times and storage at lower temperatures (Hatton, 1990; Wang, 1990). The effects of postharvest heat treatments on different fruit kinds varied. Elevated temperatures alter the firmness of fruits such as plums, tomatoes, and avocados (Eaks, 1978; Biggs *et al*., 1988), their chemical composition (Klein and Lurie, 1992; Klein *et al*., 1990), colour (Klein *et al*., 1990; Klein and Lurie, 1992), respiration (Kerbel *et al*., 1985; Lurie and Klein, 1990, 1992), and ethylene production (Biggs *et al*., 1988). To date, most of the work regarding the effects of postharvest heat treatments of fruit has concentrated on long periods at elevated temperatures, typically from 12 h to four days (Klein and Lurie, 1992). Among the changes caused by heat treatments is the induction of heat shock proteins (HSP) which protect plants from heat injury.

Florissen and his research team (1995) studied the ripening of 'Hass' avocado fruit and the development of chilling injury in relation to short heat treatments. These researchers found that a minimal heat shock exposure of 38 ºC for 4 h was sufficient to induce maximal production of heat shock proteins (HSP) in the mesocarp tissue. Heat treatment also hastened the occurrence of the climacteric in fruit treated in the early pre-climacteric period. A similar regime applied to fruit immediately prior to this event delayed the onset of the climacteric. Furthermore, the use of short heat treatments to overcome the effects of chilling injury was investigated by subjecting the fruit to 38 ºC for 0, 6, 12, 24, 36, or 48 h prior to transferring fruit to 0 ºC for 7, 14, or 21 days. Heating for 6-12 h provided a significant degree of protection from chilling injury and therefore may have potential for extending the period of cold storage.

OBJECTIVE

To verify if a heat shock treatment (38 ºC, 10-12 hours) prior to a cold storage regime (1.1 ºC for a duration of 12 days) will affect the fruit quality of South African 'Hass' avocado fruit.

DESIGN

Trials were done at the ExperiCo postharvest research facility in the Western Cape of South Africa. A cold room was used for the treatment.

Temperature logging of fruit pulp

Squirrel SQ2020 Wi-Fi series sensors and data loggers were used to measure and log pulp and air temperatures. A minimum of ten fruit flesh sensors and four air sensors were used whenever temperature logging was required, and treatment intervals were judged to have begun when half of all sensors read at or below the target temperature. Sensors were calibrated to 0 ºC before use. Temperatures of avocado fruit pulp were maintained in order to prevent fluctuations above 0.39 ºC between two consecutive hourly readings. The lowest recorded fruit pulp temperature was no lower than 0.1 ºC below the target temperature. The fruit treatment replicates were kept inside a polystyrene enclosed chamber, to ensure that fluctuations within the cold room did not influence the pulp temperature.

This desired cold treatment is specified as T107-a by the USDA as follows:

"The treatment requires that fruit be exposed to a minimum fruit centre temperature (FCT) of 12 days at < 1.1 ºC, followed by 16 days at < 2.2 ºC."

IMPORTANT

The treatment commenced when all sensors were reading 1.1 ºC or below, to adhere to the USDA protocol.

Storage temperatures and duration

The setpoint of the cold room used for this phytosanitary cold sterilisation trial can be closely managed and adjustments as small as 0.1 ºC can be made. Therefore, the required set points of 1.1 ºC could be achieved. The exact temperature of the fruit pulp is dependent on fruit respiration rate. Furthermore, to obtain fruit temperatures with less deviation within the USDA protocol, the effect of the cold room defrost cycle needed to be controlled, and so the fruit treatment cartons were placed on shelves enclosed with polystyrene to minimise the temperature differential effect of the defrost cycles on fruit pulp temperatures. This was compared to the commercial shipping at 5.5 ºC in a second cold room.

Second grade local Count 16 'Hass' fruit were sourced from Westfalia as export quality fruit were too expensive and not within the budget constraints of the trial. Initially it was planned to store the fruit under CA but due to limited space (two other avocado trials were also stored under CA) and the fact that fruit from this trial was evaluated more frequently, it was decided to rather store fruit under regular atmosphere (RA). Furthermore, CA could not be applied in the cold sterilisation cold room, it was decided to use 1-MCP treated fruit (300 ppb SmartFresh™) which could mask or exacerbate freeze damage in any way. Fruit sourced from Tzaneen (harvested and packed on 30 May) arrived in Stellenbosch four days postharvest at export temperature of ± 5.5 ºC. The heat shock treatment needs to be applied to fruit with a pulp temperature of 25 ºC. Therefore, the fruit temperature was gradually increased from 5.5 ºC to 25 ºC in a cold room in a step-up manner, to prevent condensation.

Treatment 1

- No heat shock treatment and no cold sterilisation treatment were applied and fruit were stored at the normal export temperature of 5.5 ºC for a period of 35 days to simulate the maximum export period to an export market, including packing and transport to the Western Cape prior to export.

Treatment 2

- No heat shock treatment applied. During the heat shock treatment of treatment 3, the cartons of treatment 2 were kept at room temperature for a similar period.
- Thereafter the cartons were moved to the cold room to start the cold sterilisation period of 12 days at 1.1 ºC.
- Assuming a minimum storage period of 35 days during the sea voyage to reach a destination market, the storage temperature was increased gradually in a step-up regime from 1.1 to 5.5 ºC to complete the remainder of the 35-day storage period.

Treatment 3

- A heat shock treatment (38 ºC, 75% RH, 12 hours) was conducted prior to the cold storage period.
- The cartons were removed from the heat shock chamber and kept at 25 ºC until a fruit pulp temperature of 28 ºC was reached. Thereafter the fruit was moved to the cold room to start the cold treatment of 12 days at 1.1 ºC. This was done in a step-down manner (to ensure an acclimation period):
  28 ºC (5 h) → 5 ºC (5 h) → 3 ºC (10 h) → 2 ºC (10 h) → 1.1 ºC (10 h).
- This was followed by storage at 5.5 ºC for the remainder of the 35-day storage period.

Fruit storage, ripening and evaluation

- Taking 35 days as the maximum storage period during the sea voyage to reach an export market, the storage temperature was gradually increased in a step-up regime (to ensure an acclimation period from 1.1 ºC to 5.5 ºC to include the 14 days that remained, when the 12 days quarantine period was completed:
  1.1 ºC (5 h) → 2 ºC (5 h) → 3 ºC (10 h) → 4 ºC (10 h) → 5 ºC (10 h) → 5.5 ºC.
- The fruit from treatments 2 and 3 (T2 and T3) were removed from cold storage at day 18 after harvest and placed in 5.5 ºC storage, and then removed at day 26 and day 35 to be ripened at 20 ºC. This was to give an indication of the chilling injury development. At each evaluation day, 8 cartons of 'Hass' (Count 16) fruit were evaluated for each treatment. This equated to a total of 72 x 4 kg cartons of 'Hass' avocado fruit (8 replicates x 3 treatments x 3 evaluation dates).
- Evaluation was done upon ripening and included a full set of fruit quality parameters: number of days to ripen (DTR), % moisture loss, Total Soluble Solids (TSS), firmness, physiological disorders (grey pulp, black cold damage, lenticel damage, vascular browning), and pathological disorders (anthracnose and stem-end-rot).

Site

'Hass' fruit (Count 16, 30% dry matter) were sourced from Tzaneen (Westfalia). Care was taken to choose an orchard with high nitrogen mineral levels, and iron, calcium, boron, silica, and phosphate within the correct norms. According to literature, these nutrients are linked to reduced freeze damage incidence and it would be advantageous for the fruit to be inherently more resistant when exposed to low temperature storage.

Statistical analysis

Statistical analysis was conducted on 8 carton replicates ('Hass', Count 16, 30% dry matter) per treatment. The data was subjected to a factorial analysis of variance (ANOVA), using Statistica (statistical software). Temperature treatment (A) and storage duration (B) were the main factors.

RESULTS

Fruit quality parameters

- Black cold damage (Table 1a)

The heat shock treatment (T3) did not reduce the incidence of black cold damage.

After 18 days of cold storage, fruit from treatments 2 and 3 (T2 and T3) had no significant differences in incidence of black cold damage. However, fruit stored at 5.5 ºC with no cold regime, still had 5.47% incidence of this disorder.

After 25 and 35 days of storage at 5.5 ºC only (T1), significantly lower black cold damage (8.7% and 11.8%, respectively) was noted, compared to the two treatments (T2 and T3) which included the cold storage regime (30.50-31.63% incidence). Incidence of black cold damage was similar between T2 and T3, and the inclusion of the heat shock (T3) did not reduce the incidence of black cold damage.

The results suggest that 'Hass' is more sensitive towards freezing damage when stored at 1.1 ºC compared to 'Sharwil' avocados.

It is suggested to test the efficacy of a 38 ºC heat shock prior to the other cold treatment of 22 days at 2.2 ºC in the second year of the study.

- DTR (Table1b)

The heat shock treatment (T3) did not affect the DTR, either negatively or positively.

The two-way analyses did not show a significant interaction ($P = 0.9710$) in DTR values, between the factor A (treatment of storage temperature) and factor B (storage duration).

However, the storage duration (factor B) showed that the DTR was significantly higher (11.2 days) after 18 days of storage ($P = 0.00001$), compared to 25 days and 35 days of storage (10.34 and 10.18 days, respectively).

Table 1: Quality of Count 16 'Hass' fruit that were subjected to a heat shock treatment or not (38 ºC, 12 hours) prior to the cold storage regime (1.1 ºC for a duration of 12 days) followed by cold storage at 5.5 ºC for a total storage period of 35 days

HEATSHOCK TREATMENT – 'HASS'								
a) FRUIT QUALITY PARAMETER – Black cold damage (%)								
Factor A (Temperature treatment) x Factor B (Storage duration)				**Factor A (Temperature treatment)**		**Factor B (Storage duration)**		
Storage duration:	**18 days**	**25 days**	**35 days**			**18 days**	**25 days**	**35 days**
1. T1 Storage 5.5 °C only	5.5 a	8.7 a	11.8 a	**1. T1** Storage 5.5 °C only	8.6 a	9.4 a	23.5 b	24.9 b
2. T2 Storage @ 1.1 °C and 5.5 °C No heat shock applied	14.2 a	31.3 b	31.6 b	**2. T1** Storage @ 1.1 °C and 5.5 °C No heat shock applied	25.7 b	–		
3. T3 Storage @ 1.1 °C and 5.5 °C Heat shock applied	8.6 a	30.5 b	31.2 b	**3. T3** Storage @ 1.1 °C and 5.5 °C Heat shock applied	23.4 b			
P = 0.0342					**P = 0.0000**	**P = 0.0185**		
b) FRUIT QUALITY PARAMETER – DTR (days)								
1. T1 Storage 5.5 °C only	11.19	10.50	10.22	**1. T1** Storage 5.5 °C only	10.63	11.22 a	10.34 b	10.18 b
2. T2 Storage @ 1.1 °C and 5.5 °C No heat shock applied	11.25	10.36	10.17	**2. T1** Storage @ 1.1 °C and 5.5 °C No heat shock applied	10.59	–		
3. T3 Storage @ 1.1 °C and 5.5 °C Heat shock applied	11.21	10.32	10.15	**3. T3** Storage @ 1.1 °C and 5.5 °C Heat shock applied	10.57			
P = 0.9710					P = 0.8610	**P = 0.0000**		
c) FRUIT QUALITY PARAMETER – % Moisture loss								
1. T1 Storage 5.5 °C only	1.6	1.7	2.3	**1. T1** Storage 5.5 °C only	1.9 a	1.7 a	2.0 b	2.5 c
2. T2 Storage @ 1.1 °C and 5.5 °C No heat shock applied	1.6	1.8	2.4	**2. T2** Storage @ 1.1 °C and 5.5 °C No heat shock applied	1.9 a	–		
3. T3 Storage @ 1.1 °C and 5.5 °C Heat shock applied	2.1	2.4	2.9	**3. T3** Storage @ 1.1 °C and 5.5 °C Heat shock applied	2.5 b			
P = 0.7562					**P = 0.0000**	**P = 0.0185**		
d) FRUIT QUALITY PARAMETER – Firmness (iQ)								
1. T1 Storage 5.5 °C only	55.6	54.5	53.3	**1. T1** Storage 5.5 °C only	54.5	55.5 a	54.3 b	53.05 c
2. T2 Storage @ 1.1 °C and 5.5 °C No heat shock applied	55.4	54.3	52.9	**2. T1** Storage @ 1.1 °C and 5.5 °C No heat shock applied	54.2	–		
3. T3 Storage @ 1.1 °C and 5.5 °C Heat shock applied	55.4	54.2	52.9	**3. T3** Storage @ 1.1 °C and 5.5 °C Heat shock applied	54.1			
P = 0.9988					P = 0.5214	**P = 0.0000**		

• Moisture loss (Table 1c)
The factorial ANOVA did not show a significant interaction in moisture loss (P = 0.7564) between factor A (storage temperature treatment) and factor B (storage duration).

There was a significant difference between the treatments (storage temperatures, factor A): the heat shock (T3) resulted in a higher moisture loss of 2.5% compared to the cold treatment without the heat shock (T2) and the 5.5 ºC treatment (T1) (both had a lower 1.9% moisture loss).

There was a significant difference between storage durations (factor B): after 18 days of storage the average moisture loss of all treatments was 1.7%, followed by a significant increase in moisture loss of 2% and 2.5% on day 25 and day 35, respectively. This suggests an increase in moisture loss as the storage duration increased with all treatments, although it could also be attributed to sampling error.

• Firmness (Table 1d)
The factorial two-way analyses did not show a significant variance in fruit firmness (P = 0.9980) between factor A (storage temperature treatment) and factor B (storage duration).

After 18 days of storage the average fruit firmness of all treatments was 55.5 iQ, followed by significantly lower fruit firmness of 54.3 iQ and 53.05 iQ on day 25 and day 35, respectively. This suggests lower firmness as the storage duration increased.

• Anthracnose (Table 2a)
The heat shock treatment (T3) did not affect the incidence of anthracnose, negatively or positively.

The two-way analyses did not show a significant difference in the incidence of anthracnose (P = 0.9990) between factor A (storage temperature treatments) and factor B (storage duration).

However, there was a significant difference in the incidence of anthracnose (P = 0.00001) between storage durations (factor B): after 18 days of storage the average incidence of anthracnose of all treatments was 0.0%, followed by significantly higher incidence on day 25 and day 35 (6.8% and 8.3%, respectively).

• Stem-end rot (Table 2b)
The heat shock treatment (T3) did not affect the incidence of stem-end rot, negatively or positively.

The two-way analyses did not show a significant interaction in the incidence of stem-end rot (P = 0.9391), between factor A (storage temperature treatments) and factor B (storage duration).

However, there was a significant difference in the incidence of stem-end rot (P = 0.00001) between storage durations (factor B): after 18 days of storage the average incidence of stem-end rot of all treatments was 0.0%, followed by significantly higher incidence on day 25 and day 35 (7.0% and 9.4%, respectively).

• Grey pulp (Table 2c)
The ANOVA factorial two-way analysis did not show a significant interaction in grey pulp incidence (P = 0.7172) between factor A (storage temperature treatments) and factor B (storage duration).

There was a significant difference between the treatments (storage temperature treatments, factor A): the cold treatment with heat shock (T3) and the cold treatment without a heat shock (T2) had significantly higher grey pulp incidence with values of 10.4% and 8.9%, respectively, compared to the 5.5 ºC treatment (T1, 1.6%).

• Vascular browning (Table 2d)
The heat shock treatment (T3) did not affect the incidence of vascular browning negatively.

The two-way analyses did not show a significant interaction in the incidence of vascular browning (P = 0.9953), between factor A (storage temperature treatments) and factor B (storage duration).

However, there was a significant difference in the incidence of vascular browning (P = 0.0032) between storage durations (factor B): after 18 days of storage the average incidence of vascular browning of all treatments was 0.0%, followed by significantly higher values on day 25 and day 35 (1.1% and 3.1%, respectively). Vascular browning was associated with stem-end rot which increased with evaluations after 25 and 35 days of storage. There was no physiological vascular browning present in any of the treatments.

SUMMARY

The heat shock treatment did not reduce the incidence of black cold damage. After 18 days of cold storage, fruit exposed to the 12-day sterilisation period at 1.1 ºC (both with and without the heat shock) had no significant differences in black cold damage incidence (5.5-14.2%). However, fruit stored at 5.5 ºC had only 5.47% incidence of this disorder. After 25 and 35 days of storage at 5.5 ºC only, significantly lower black cold damage (8.7% and 11.8%, respectively) was noted, compared to the two treatments which included cold storage (30.50-31.63%). Incidence of black cold damage was similar between the two treatments which were subjected to cold storage and the inclusion of the heat shock did not reduce the incidence of black cold damage. The results suggest that 'Hass' is more sensitive towards freezing damage when stored at 1.1 ºC compared to 'Sharwil'.

The ANOVA factorial two-way analyses did not show a significant interaction in moisture loss (P = 0.7564) between factor A (storage temperature treatments) and factor B (storage duration). However, there was a significant difference between the treatments (storage temperatures, factor A): the cold treatment with heat shock resulted in a higher moisture loss compared to the other two treatments. There was also a significant difference between storage durations (factor B): moisture loss increased progressively as storage duration increased.

The cold treatments, with and without a heat shock, resulted in fruit with higher grey pulp incidence with values of 10.4% and 8.9%, respectively, which were significantly higher compared to the 5.5 ºC treatment

Table 2: Quality of Count 16 'Hass' fruit that were subjected to a heat shock treatment (38 ºC, 12 hours) or not (T3 and T2), prior to the cold storage regime (1.1 ºC for a duration of 12 days) followed by cold storage at 5.5 ºC for a total storage period of 35 days

HEATSHOCK TREATMENT – 'HASS'								
d) FRUIT QUALITY PARAMETER – Anthracnose (%)								
Factor A (Temperature treatment) x Factor B (Storage duration)				**Factor A (Temperature treatment)**		**Factor B (Storage duration)**		
Storage duration:	**18 days**	**25 days**	**35 days**			**18 days**	**25 days**	**35 days**
1. T1 Storage 5.5 °C only	0.0	6.3	7.8	**1. T1** Storage 5.5 °C only	4.7	**0.0 a**	**6.8 b**	**8.3 b**
2. T2 Storage @ 1.1 °C and 5.5 °C No heat shock applied	0.0	7.0	8.6	**2. T1** Storage @ 1.1 °C and 5.5 °C No heat shock applied	5.2		–	
3. T3 Storage @ 1.1 °C and 5.5 °C Heat shock applied	0.0	7.0	8.6	**3. T3** Storage @ 1.1 °C and 5.5 °C Heat shock applied	5.2			
		P = 0.9990			P = 0.9182		**P = 0.0000**	
f) FRUIT QUALITY PARAMETER – Stem-end rot (%)								
1. T1 Storage 5.5 °C only	0.0	6.3	10.2	**1. T1** Storage 5.5 °C only	5.5	**0.0 a**	**7.0 b**	**9.4 b**
2. T2 Storage @ 1.1 °C and 5.5 °C No heat shock applied	0.0	7.8	10.2	**2. T1** Storage @ 1.1 °C and 5.5 °C No heat shock applied	6.0		–	
3. T3 Storage @ 1.1 °C and 5.5 °C Heat shock applied	0.0	7	7.8	**3. T3** Storage @ 1.1 °C and 5.5 °C Heat shock applied	4.9			
		P = 0.9391			P = 0.8913		**P = 0.0000**	
g) FRUIT QUALITY PARAMETER – Grey pulp (%)								
1. T1 Storage 5.5 °C only	2.3	2.3	0.0	**1. T1** Storage 5.5 °C only	1.6 a	7.0	7.0	6.8
2. T2 Storage @ 1.1 °C and 5.5 °C No heat shock applied	7	9.4	10.2	**2. T2** Storage @ 1.1 °C and 5.5 °C No heat shock applied	8.9 b		–	
3. T3 Storage @ 1.1 °C and 5.5 °C Heat shock applied	7.0	7.0	6.8	**3. T3** Storage @ 1.1 °C and 5.5 °C Heat shock applied	10.4 b			
		P = 0.7172			**P = 0.0000**		P = 9877	
h) FRUIT QUALITY PARAMETER – Vascular browning (iQ)								
1. T1 Storage 5.5 °C only	0	0.78	3.1	**1. T1** Storage 5.5 °C only	1.3	0.0 a	1.1 a	3.1 b
2. T2 Storage @ 1.1 °C and 5.5 °C No heat shock applied	0	1.56	3.1	**2. T1** Storage @ 1.1 °C and 5.5 °C No heat shock applied	1.6		–	
3. T3 Storage @ 1.1 °C and 5.5 °C Heat shock applied	0	0.89	3.1	**3. T3** Storage @ 1.1 °C and 5.5 °C Heat shock applied	1.4			
		P = 0.9953			P = 0.9518		**P = 0.0032**	

(1.6%). This suggests that the heat shock did not reduce the incidence of grey pulp.

There was no evidence that the heat shock affected the DTR, fruit firmness, anthracnose, stem-end rot, and vascular browning, in a negative or positive way.

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