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Effect of Polyethylene Film Thickness and Exposure Time of Ethylene on the Ripening Behavior and Quality of Banana

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ABSTRACT

The objectives of this study were carried out to test the ethylene effect, its time of exposure, polyethylene packaging, its thickness and the interaction between both on the ripening and quality of ripe banana fruit. The experiment was laid out according to Factorial Design with four replications. It is observed that exposure of 1000 ppm ethylene for one day is enough to attain early ripening. The combination of CO_2 and O_2 (CO_2 less than 5% & O_2 above than 14%) in polyethylene bags did not reduce the ripening effect of exogenous ethylene. Ethylene treated bananas (one & two days) packed in 100 and 150 gauge of polyethylene bags ripened at the same time (after 9 days) but significantly earlier than those, which were packed in 200 gauge polyethylene bags. Packaging of bananas in 200 gauge polyethylene bags extended the storage life of banana but these received lower scores by panelists for their acceptability than those, which were packed in 100 and 150 gauge polyethylene bags. The softener of fruits packed in polyethylene bags was directly proportional to weight loss. Packaging of fruit in polyethylene bags did not affect the total soluble content of banana fruit during ripening. Bananas packed in 100 and 150 gauge polyethylene bags showed less weight loss percentage. Bananas packed in 100 and 150 gauge polyethylene and exposed of one day ethylene received maximum score (4.0) by the panelist for acceptability. Packaging of bananas in 100 and 150 gauge polyethylene bags was effective in achieving a more attractive appearance, freshness and good flavour of ripe fruit than un-packed fruit and those packed in 200 gauge polyethylene bags.

Key Words: Effect of polyethylene; Thickness; Exposure; Time of ethylene

INTRODUCTION

Loss of moisture with consequent wilting is one of the ways in which freshness of fruits and vegetables is lost (Zomorodi, 1990). Moisture losses of 3 - 6% are usually enough to cause marked deterioration of quality for many kinds of produce so it is important to reduce such moisture losses by lowering temperature, raising relative humidity and reducing air movement. All these methods for reducing moisture losses of fresh produce could be accomplished by modified atmospheric storage (Day, 1993). He further claimed that packaging of banana fruit in a suitable thickness of polyethylene film extend the storage life. Packaging of fruits in impermeable film reduces the level of oxygen that can cause the onset of anaerobic respiration. Reduced oxygen level cause un-desirable odors, flavor and market deterioration in product quality. Fully permeable film cannot create a modified atmosphere within the package, so fully permeable films are un-suitable for fresh produce packaging. The selection of intermediate permeable film is necessary to provide the most appropriate gas concentration at the appropriate temperature, for the storage life of the particular fruits. On the other hand ethylene is natural plant hormones, which bring about the onset of climacteric peak with a characteristic rise in respiration. The treatment of exogenous ethylene in climacteric fruits advances the onset of the irreversible rise in respiration and rapid ripening (Zagory & Kadar, 1988). Therefore this study was undertaken to investigate the effect of polyethylene thickness and exposure time of ethylene treatment on the ripening and quality of ripe banana fruit.

Marriott *et al.* (1981) in a review stated that trace amounts of ethylene shortened the pre-climacteric period, and high concentrations induced a rapid initiation of the climacteric period. Thompson and Seymour (1982) observed that the treatment of bananas with 10, 100 or 1000 ppm ethylene for 24 h all initiated ripening. Ethylene induced ripening of banana fruits, which is dependent on the duration of ethylene treatments (Whitehead & Bosse, 1991). Scott *et al.* (1971) found the storage life of green bananas could be extended by at least two weeks by packaging the fruit in sealed polyethylene bags wit an ethylene absorbent. Ali Azizan (1988) reported that the total soluble solids did not change during storage in MA at ambient temperature. Agillon *et al.* (1987) claimed that effect of MA on the quality parameter varied according to variety of banana fruit. He also found that TSS and TTA did not change in Latundan bananas but were increased in Lakatan bananas.

The objective of this study was to investigate the effect of polyethylene film and ethylene exposure time on the ripening and quality of banana fruit.

MATERIALS AND METHODS

This research was conducted in post harvest laboratory of Canfield University at Silsoe College, UK. Cavendish bananas were taken from Bedford market. After the fungicide treatment, fingers were put in to plastic boxes of 27 x 19 x 10 cm sizes. These boxes were placed in one of three thick nesses of polyethylene film bags, i.e. 100 gauge, 150 gauge and 200 gauge. These bags were tied with an elastic band. These boxes were put in airtight plastic boxes of 60 liters marked as zero, one, two, three and four days exposure to ethylene and sealed, except the zero ethylene one, which remained opened. The experiment was carried out with four replications. Thereafter 1000 ppm ethylene was injected into these boxes except, which were marked as zero ethylene. These boxes were kept at 16^{o}C with 80 - 85% relative humidity. The main ethylene boxes were opened one, two, three and four days after ethylene injection. CO_2, O_2 and C_2H_4 (Ethylene) gases were measured from the packaging when the main boxes were opened and when banana had reached colour stage 6. All quality parameters were measured using the procedure described below when bananas reached colour stage 6.

Assessment of fruit ripening (Assessment of fruit colour stage). The ripening process has been divided into seven stages by colour changes (Stover & Simmonds, 1987). These are as follows: 1, green; 2, green with a trace of yellow; 3, more green than yellow; 4, more yellow than green; 5, only green tips remaining; 6, all yellow; 7, yellow flecked with brown. The quality of ripe fruit was assessed by two methods.

1. Objective methods. The peel color was measured by colorimeter A positive (a*) values corresponding to the degree of redness, while a* negative value corresponding to the degree of greenness. The positive values (b*) represents the degree of yellowness and negative one represents the blueness. Peel and pulp firmness was measured using an instron universal testing machine (model 2211) with an 8 mm cylindrical probe. Pulp and peel were separated and weighed individually and expressed as pulp peel ratio as follows:

$$\text{Pulp/peel ratio} = \frac{\text{Pulp weight}}{\text{Peel weight}}$$

Total soluble solids were measured using refractometer. Starch percentage was measured by using the technique recommended by Blankenship *et al.* (1993).

Individual fruit was weighed using a digital balance (precise 60000) just before the start of experiment and re-weighed at score 6 (fully ripe) and then cumulative weight loss percentages and weight loss percentage per day was calculated as follows.

$$\text{Weight loss\%} = \frac{\text{Wo - Wi}}{\text{Wo}} \times 100$$

Where

Wo. = original weight.

Wi. = Weight at sampling (when Banana reached at color score 6).

Weight loss percentage per day was calculated as follows:

$$\text{Weight loss percentage per day} = \frac{\text{TWP}}{\text{SC}}$$

Where

TWP = Total weight loss percentage at color stage 6.

SC = Storage life (total days when Banana reached color store 6 from pre-climacteric stage).

2. Subjective assessments (Sensory evaluation). The fruits were removed from storage when they were at color score 6. Panel of eight assessors was selected and asked to assess pulp flavor, sweetness and acceptance on life point's sale as follows: 1, Low; 2, Moderate; 3, Moderate high; 4, Good/high; 5, Very good/high. An average was calculated for each parameter and sub parameter. There averages were used for statistical analysis. Means of treatments were calculated and presented in the form of Tables.

Statistical analysis. Data were processed and analysis of variance (ANOVA) was carried out based on Factorial Design using MSTATC, a P.C based programming with four replications. LSD at P = 0.05 was used to test for significant difference of results.

RESULTS AND DISCUSSION

Storage life. The results are shown in Table I. Analyses of variance showed significant differences for different polyethylene thickness, ethylene exposure time and interaction between the two at the P = 0.001 level. Bananas packed in 200 gauge polyethylene film took a longer time (17 days) to reach colour stage 6 than those in 100 and 150 gauges polyethylene film (13 & 14 days). A significant difference was found in the ripening periods of bananas, which were packed in 100 and 150 gauges polyethylene film. As would be expected all ethylene treated bananas ripened earlier than un-treated bananas. Bananas exposed to one and two days to ethylene ripened significantly earlier than those, which were exposed for three and four days to ethylene but no significant difference was found between the first two treatments. The interaction between ethylene treatment and polyethylene thickness showed that fruit, which were packed in thicker polyethylene bags without exogenous ethylene treatment took longer time to ripen than those packed in thinner polyethylene bags.

Early ripening of ethylene treated bananas confirms the results of Strydom and Whitehead (1990). The interaction could be due to the increased amount of CO_2. The CO_2 and O_2 percentages from the packaging were measured when banana packaging was removed from the ethylene boxes. It was concluded that the combination of CO_2 and O_2 (CO_2 less than 5% & O_2 above than 14%) did not reduce the effect of ethylene but when the concentration of CO_2 increased above 5% and O_2 remained the same, it reduced the ripening effect of exogenous ethylene. Therefore the differences between thinner polyethylene (100 & 150 gauge) and thicker

Table I. Effect of polyethylene film thickness and ethylene concentration on the storage

Quality Parameter and polyethylene thickness	Duration of ethylene treatment 0 ethylene	One day	two days	three days	four days	Mean	LSD	CV%	FR
Storage life (days)									
100 gauge	22	9	9	10	13	13	Polyeth. = 0.4	3.7	
150 gauge	24	9	9	11	15	14	Ethy. = 0.3		
200 gauge	27	13	13	15	18	17	PolyxEth.= 0.8		
Mean of ethylene	24	10	10	12	16				
Weight loss%									
100 gauge	1.10	0.90	0.91	0.79	0.78	0.89	Polyeth. = 0.05	6.9	
150 gauge	10.5	0.88	0.84	0.8	0.75	0.86	Ethy. = 0.04		
200 gauge	1.13	1.00	0.91	0.81	0.73	0.92	PolyxEth.= NS		
Mean of ethylene	1.10	0.93	0.88	0.8	0.75				
Weight loss% per day									
100 gauge	0.05	0.10	0.10	0.07	0.05	0.07	Polyeth= 0.003	8.3	
150 gauge	0.04	0.09	0.09	0.07	0.05	0.07	Ethy. = 0.002		
200 gauge	0.04	0.07	0.06	0.05	0.04	0.05	Poly.xEth0.006		
Mean of ethylene	0.04	0.09	0.08	0.06	0.05				
Peel colour a* values									
100 gauge	-4.42	-2.30	-3.43	-3.27	-3.86	-3.46	Polyeth. = 0.27	9.2	-17.29
150 gauge	-4.81	-2.40	-3.34	-3.57	-3.56	-3.54	Ethy. = 0.21		
200 gauge	-4.50	-3.04	-3.47	-3.97	-4.04	-3.81	Poly.xEt.= NS		
Mean of ethylene	-4.50	2.58	3.41	-3.61	-3.82				
Peelcolour b*values									+15.93
100 gauge							Polyeth. = NS	8.8	
150 gauge	+45.01	49.76	49.41	48.30	46.09	47.71	Ethy. = NS		
200 gauge	45.28	48.96	47.17	48.61	46.73	47.35	Poly.xEth.= NS		
Mean of ethylene	44.73	47.09	48.10	46.04	45.25	46.24			
	45.0	48.60	48.23	47.66	46.02				
Peelfirmness(Nmm-1									15.03
100 gauge	4.62	3.29	3.18	2.98	3.35	3.41	Polyeth. = 0.22	7.3	
150 gauge	4.69	3.30	3.31	3.76	4.31	3.87	Ethy. = 0.17		
200 gauge	5.32	3.55	3.40	3.67	3.90	3.97	Poly.xEth= 0.38		
Mean of ethylene	4.88	3.26	3.30	3.47	3.85				
Total Soluble Solids%									
100 gauge	22.4	24.2	23.5	23.6	23.2	23.4	Polyeth. = NS	2.4	9.0
150 gauge	22.3	23.3	23.0	23.4	23.3	23.1	Ethy. = 0.45		
200 gauge	22.2	23.9	23.0	23.2	23.6	23.2	Poly.xEth= NS		
Mean of ethylene	22.3	23.8	23.2	23.4	23.4				
Starch %									95%
100 gauge	20	15	15	18	20	18	Polyeth. = 1.42	8.4	
150 gauge	258	16	17	19	25	20	Ethy. = 1.10		
200 gauge	258	23	25	25	24	23	Poly.xEth= 2.46		
Mean of ethylene	22	18	19	26	23				

polyethylene bags (200 gauge) were greater (4 days delay) when the bananas were exposed for one and two days to ethylene. In contrast, bananas packed in 150 gauge or 200 gauges when greater amounts of CO_2 (24.98 or 30.36%, respectively) with lower levels of O_2 (6.94 to 6.49%) but the differences between their ripening times was smaller. It might be possible that the differences between lower levels of CO_2 with combination of higher O_2 might be more effective in delaying the ripening. In contrast, lower amounts of O_2 might reduce this characteristic of CO_2 and become dominant in delaying ripening. Salunkhe *et al.* (1991) reported that higher concentration of CO_2 postponed the effects of ethylene in banana fruit but they did not mention the concentrations of O_2 or at which combination these effects are more effective.

Weight loss %. The statistical analysis showed significant differences for polyethylene film thickness and exposure time of ethylene the P = 0.001 and P = 0.05 level, respectively (Table I). Bananas packed in 200 gauge polyethylene bags showed significantly greater weight loss than those packed in 100 and 150 gauge polyethylene bags. Weight loss in ethylene treated bananas followed a pattern, in that as exposure time of ethylene treatment increased the weight loss decreased.

The greater weight losses in 200 gauge of polyethylene bags and un-treated bananas could be due to the period required for the ripening. This is because that total weight loss increases with the length of storage, as shown by many research workers including Risse *et al.* (1985). In this investigation, fruits packed in 200 gauge and un-treated ripened after 17 days and 24 days but fruits packed in 100 and 150 gauge polyethylene bags with ethylene ripened after 13 and 14 days. The second reason could be reduced rate of respiration and transpiration because Modified atmosphere decreased (Day, 1988) and applied ethylene increased the respiration rate (Salunkhe *et al.*, 1991). The greater weight loss in fruits at short ethylene exposure periods could be due to the reduced amount of CO_2. This because weight loss has been shown to decrease with CO_2 increases and O_2 decreases in the storage environment due to reduced respiration (Zagory, 1990).

Peel colour. No significant differences were found regarding b* values (yellowness) (Table I). The effect of polyethylene thickness and exposure time of ethylene treatment was significant differences for a* values at the P = 000.1 level (Table I). Bananas exposed to ethylene treatment were significantly less green than those were not treated with ethylene. Bananas exposed to ethylene treatment for one and two days showed reduced significantly reduced green values than those, which were exposed for four days. Bananas packed in thicker (200 gauge) polyethylene bas showed greater greenness values than those packed on thinner polyethylene bags (100 & 150 gauge).

In terms of peel colour development no differences in peel colour development indicated that destruction of chlorophyll was normal and probably equal in fruit in all thinness of polyethylene because the colour development was previously shown to be dependent on chlorophyll destruction (Seymour & Thompson., 1987).

Peel firmness. The statistical analysis showed significant differences for polyethylene thickness and exposure of ethylene treatment at the P = 00.1 level. The interaction between the two was also statistically significant at the P = 0.005 level. Bananas packed in 100 gauge polyethylene bags were significant softer than those packed in 150 and 200 gauge polyethylene bags but the later two treatments did not different statistically from each other. Ethylene treated bananas showed significantly reduced firmness (3.26 to 3.85 Nmm^{-1}) values (softer) than un-treated bananas (4.88 Nmm^{-1}). Bananas exposed to one day ethylene were significantly softer than those exposed for three and four days but similar those exposed for two days. The interaction between polyethylene film thickness and ethylene exposure time showed that differences in peel firmness between 150 and 200 gauge polyethylene packed bananas were greater (0.78 & 0.96) at three and four days exposure to ethylene.

The interaction between polyethylene and ethylene exposure time was due to higher concentration of CO_2. the gases were extracted from the bags just after their removal from the main ethylene boxes. Their measurement indicated that the amount of CO_2 and O_2 percentages were greater and lower, respectively in 150 gauge of polyethylene bags than 100 gauge of polyethylene bags. This situation might have remained constant due to differences in their probability and this increased amount of CO_2 did not allow the completion of processes relating to break-down of cellulose in 150 gauge polyethylene packaging. In contrast processes relating to the break-down of peptic substances might be continued normally in the 100 gauge polyethylene packing, so these bananas had softened faster than those in 150 gauge polyethylene packaging. Therefore the differences became greater in 100 gauge and 150 gauge of polyethylene when they were exposed to ethylene for three and four days. In earlier work, Salunkhe and Desai (1984) reported that high CO_2 inhibited the break-down of peptic substances and retained fruit their textural firmer for e long time.

Table II. Measurement of gases from the polyethylene packaging when these were removed from main ethylene box

Gas measurement and polyethylene thickness	0 ethylene	Duration of ethylene treatment One day	two days	three days	four days	Mean
Ethylene ppm						
100 gaug	0.1	780.7	717.3	585.2	76.3	568.9
150 gauge	0.3	830.9	727.9	614.9	805.5	595.9
200 gauge	0.8	834.7	757.7	647.4	880.7	624.3
Mean of ethylene	0.4	815.4	734.3	615.8	815.8	
CO_2 %						
100 gauge	0.5	2.8	3.8	12.9	21.1	8.2
150 gauge	0.6	4.1	3.8	18.3	25.0	10.4
200 gauge	1.0	5.3	5.5	25.0	30.4	13.4
Mean of ethylene	0.7	4.1	4.3	18.7	25.5	
O_2 %						
100 gauge	19.3	17.2	16.4	12.8	10.9	15.3
150 gauge	19.8	16.8	14.8	9.7	6.9	13.9
200 gauge	18.3	16.0	15.2	7.8	6.5	13.0
Mean of ethylene	19.1	16.7	15.5	10.1	9.0	

Table III. Measurement of gases from the polyethylene packaging at the colur stage 6

Gas measurement and polyethylene thickness	0 ethylene	Duration of ethylene treatment One day	two days	three days	four days	Mean
Ethylene ppm						
100 gauge	0.9	1.4	1.2	1.5	3.4	3.5
150 gauge	0.8	2.5	3.1	4.5	12.5	4.9
200 gauge	1.0	4.9	4.6	5.0	13.3	4.6
Mean of ethylene	0.9	2.9	3.0	3.7	11.1	
CO_2 %						
100 gauge	0.5	1.0	1.3	0.8	1.3	1.0
150 gauge	0.3	2.5	1.5	1.3	2.1	1.6
200 gauge	0.8	2.5	3.1	2.7	3.1	2.4
Mean of ethylene	0.5	2.0	2.0	1.6	2.2	
O_2 %						
100 gauge	19.6	19.3	19.0	19.8	19.0	19.3
150 gauge	19.3	17.6	17.0	17.6	17.8	17.9
200 gauge	18.0	18.0	18.5	17.2	17.1	17.7
Mean of ethylene	19.0	18.3	18.2	18.2	18.0	

Total soluble solids % and starch percentage. The statistical analysis showed significant differences for ethylene treatment at the P = 0.001 level. The results regarding polyethylene film thickness and interaction between ethylene exposure and polyethylene film thickness were non-significant. Ethylene treated bananas showed significantly greater total soluble solids than un-treated bananas. Bananas exposed one and two days ethylene showed greater TSS% (23.8%) than those exposed of two days (23.2%). However, no significant differences could be found between exposure times. The percentage of total soluble solids was also statistically equal in all bananas, which were packed in different thickness of polyethylene bags. No interaction was found between polyethylene film

Table IV. Effect of polyethylene film thickness and ethylene concentration on the storage

Quality Parameter and polyethylene thickness	Duration of ethylene treatment							
	0 ethylene	One day	two days	three days	four days	Mean	LSD	CV%
Flavour								
100 gauge	1.5	3.5	3.5	2.5	2.0	2.6	Polyeth. = NS	14.3
150 gauge	1.5	3.5	3.0	2.0	2.0	2.4	Ethy. = 0.22	
200 gauge	1.7	3.0	3.0	2.0	1.7	2.	PolyxEth.= NS	
Mean of ethylene	1.6	3.3	3.0	2.2	1.9			
Sweetness								
100 gauge	2.5	4.0	4.0	3.5	3.0	3.4	Polyeth. = NS	13.0
150 gauge	2.0	4.0	3.5	3.8	3.0	3.3	Ethy. = 0.27	
200 gauge	2.5	3.5	3.5	3.5	2.8	3.2	PolyxEth.= NS	
Mean of ethylene	2.3	3.8	3.7	3.6	2.9			
Off-odour								
100 gauge	2.5	1.0	1.5	1.8	2.0	1.8	Polyeth. = NS	22.3
150 gauge	2.5	1.0	1.0	2.0	2.8	1.9	Ethy. = 0.27	
200 gauge	2.5	1.3	2.0	2.5	3.0	2.3	PolyxEth.= NS	
Mean of ethylene	2.5	1.1	1.5	2.1	2.6			
Astringency								
100 gauge	2.8	1.3	1.0	2.0	2.5	1.9	Polyeth. = 0.39	25.6
150 gauge	2.3	1.0	1.5	2.5	3.0	2.1	Ethy. = 0.30	
200 gauge	2.8	1.0	2.0	2.5	3.0	2.3	Poly.xEt.=0.67	
Mean of ethylene	2.6	11	1.5	2.3	2.8			
Acceptability								
100 gauge	2.5	4.0	4.0	3.5	3.0	3.4	Polyeth. = 0.39	18.9
150 gauge	25	4.0	3.5	3.0	2.5	3.1	Ethy. = 0.39	
200 gauge	2.3	3.0	3.0	3.0	2.5	2.7	Poly.xEth.= NS	
Mean of ethylene	2.4	3.7	3.5	3.0	2.7			

thickness and exposure time to ethylene. Statistical analysis showed significant differences for polyethylene film thickness, exposure of ethylene and the interaction between the two at the P= 0.001 level. Banana treated ethylene showed significant reduced (18% to 23%) starch percentage than un-treated bananas (22%). Fruits treated for long period of ethylene with showed a significantly greater (26 & 23%) starch percentage than those, which were treated for short period (22%, 18% & 19%).

The conversion of starch into sugar no variation in total soluble solids in fruit packed in all polyethylene thickness and exposure time indicated that a modified atmosphere did not affect the starch hydrolysis. This has previously been found by Agillon *et al.* (1987), who reported that no significant changes in total soluble solids were observed during MA storage. The greater total soluble solids in ethylene treated bananas were due to the increased starch hydrolysis because ethylene treatment accelerates the ripening and starch is hydrolyzed during ripening. The greater TSS in one day exposure time of ethylene was due to higher CO_2 concentrations. This is because the fruit exposed for one day had higher concentration of CO_2 and this period was not long enough to reduce the starch hydrolysis processes. Therefore these bananas ripened with greater total soluble solids than those, which were exposed for long period to ethylene. It had previously been reported (Zagory, 1990) that higher concentrations of CO_2 slowed down the de-compositional changes associated with ripening processes.

Gases measurement. The results are given in (Table II & III). Data were not analyzed statistically because only duplicate sample were measured when packaging was removed from ethylene boxes and when fruits reached colour stage 6. The results were clear without statistical analysis and are presented in the results and discussion section of this study.

Sensory evaluation. Results are shown in Table IV. Ethylene treaded bananas had significantly better flavor than un-treated bananas. Bananas exposed of ethylene for one and two days significantly received higher score (3.3 & 3.2) for flavour than bananas of other treatments. All bananas ripened in different polyethylene thickness showed statistically similar flavors. Significant differences, was found between those, which were exposed of ethylene for different period with regard to their sweetness, but they were significantly sweeter than un-treated bananas. Bananas packed different polyethylene thickness did not show any significant difference from each other. Off-odour showed the same tend as other parameters, in that it was significantly reduced the ethylene treated bananas but there was no significant effect regarding polyethylene thickness. Panelist could not make statistically significant distinction between bananas packed in different thickness of polyethylene. Panelist gave significantly higher score to ethylene treated bananas especially to those, which were exposed for one and two days to ethylene.

The sensory evaluation showed the superiority of ethylene treated bananas over non-treated bananas as regards their flavour, sweetness and acceptability. This was assumed to be because ripeness of banana fruits has a very influential effect on flavour due to a higher formation of volatile compounds, reduced astringency and off odour (Esguerra *et al.,* 1992). It was observed by Abdullah and Tirtosoekotjo (1989) that critical limits of CO_2 and O_2 levels were 10 - 15%

and 1 - 3%, respectively for banana fruits. In the current research bananas packed in polyethylene bags and exposed to three and four days ethylene treatments showed a higher percentages of CO_2 than mentioned above but they ripened with acceptable quality. This could be due to the permeability of polyethylene bags. When these were removed from the ethylene boxes, CO_2 might have been decreased so the quality was not affected but it reduced the score slightly for acceptability.

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